Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

The Effect of STEM-Based Robotic Applications on the Creativity and Attitude of Students

Aydın Tiryaki[1]*, Sibel Adıgüzel[2]

[1]Department of Education, Istanbul University-Cerrahpaşa, İstanbul, Turkey
[2]Department of Education, Marmara University, İstanbul, Turkey

*Corresponding author: tiryaki0402@gmail.com

ABSTRACT In the present study, the effects of STEM-based robotics applications on students' creativity and scientific attitudes in the Electricity Unit of 7th grade have been investigated using the mixed method's nested pattern. Sixty students, 30 of whom are the experimental group and the other 30 constitute the control group, attending a post-school course in Istanbul in the 2018-2019 academic year, participated in two weeks of pre-applications and four weeks of applications. TOSRA measured attitude towards science, and the "Torrance Creative Thinking Test" to measure creativity was applied as pre and post-test. The data gained from the tests were analyzed with SPSS 21. In addition, semi-structured interviews' data were analyzed by using content analysis. As a result, it was observed that STEM-based robotics applications significantly increased students' creativity and attitudes towards science. Interview findings show that students enjoy using STEM applications that contain applications instead of theoretical knowledge. Using robotic and complex software materials to solve daily life problems, they felt like scientists during the practices, and the applications affected their future career choices.

Keywords STEM, Creativity, Robotic Application, Attitude, TOSRA

1. INTRODUCTION

Science, born with the need to understand the universe's phenomena, has shown rapid development from past to present. So much so that, due to the national security concerns emerging after World War II and the launch of satellite Sputnik in 1957, the role of science education became a priority among countries (DeBoer, 2000). In the 1970s, the idea of focusing on understanding the relationship between science and technology by deepening the science education provided emerged. In the following years, policies aiming to fully or partially combine these fields with engineering and mathematics were followed (Kasım & Ahmed, 2018). While providing the desired positive changes in education systems, these policies laid the philosophical foundations of STEM education in the 1990s (Adiguzel & Cakiroglu, 2019).

STEM represents a relationship where science, mathematics, technology, and engineering are intertwined and support each other. The purpose of STEM education is to raise individuals who are willing to examine STEM-related issues, use the scientific method in doing so, and recognize the cultural, contemporary, and financial environment created by each discipline in STEM, and integrate all of them by understanding the characteristics of STEM disciplines (Roostika, Setiawan, Utami, Julie, & Panuluh, 2020). For this purpose, it can be said that STEM education has a high potential to increase individuals' interests, achievements, and motivations and contribute to learning (Anikarnisia & Wilujeng, 2020). Compared to previous years, it is observed that, since the 2000s, education environments have been enriched (diversified) to gain competencies such as design, creation, and invention in new generations in the light of technology and engineering. Robotics applications enabling the integration of STEM education into classes are the most prominent of these technologies.

STEM-based robotics applications include those that require creativity in nature, such as design and problem-solving. For example, students have to design a system that includes the construction and programming of a robot to work on robotic exercises. Often, students encounter unexpected problems that they must solve during robotic applications.

Received: 24 November 2020
Revised: 28 March 2021
Published: 05 July 2021

Solving such problems also requires creativity. Within the context of robotics applications, creative design and problem-solving can also contribute to other engineering and computing activities. In this way, robotic learning makes it possible to create a more comprehensive creative application among STEM disciplines. As a result, design and problem solving that is the essence of robotic applications have a strong potential to improve student creativity (Sullivan, 2017).

Robotic applications based on STEM improve working together, problem-solving, and computational and creative thinking (Romero & Dupont, 2016). Moreover, since creativity tends to produce ideas and alternatives that can be beneficial in problem-solving and getting into with others, this education also contributes to students be more innovative and creative (Tiryaki, Çakıroğlu, & Yaman, 2019). Also, it can be seen that it allows students to acquire programming logic, engineering, and design skills and positively affect their active participation in the course (Comek & Avci, 2016).

It is thought that the desire to participate actively, that is, the student's attitude towards the course, is the determinant of future career choices (Osborne, Simon, & Collins, 2003). Developing positive attitudes towards science can motivate students' interest in science education and science-related careers because their attitudes significantly influence students' thoughts and actions (Alam, 2017). When students find a science course boring and do not understand its benefits in daily life, they tend not to take the course seriously. Therefore, innovative approaches should be adopted to increase students' attitudes towards science.

It contains many abstract and complex topics due to its scientific structure. Electricity is one of the science subjects that create confusion for students with its abstract structure. This structure, which causes the formation of many alternative concepts, makes it possible to be explained depending on models, analogies, and metaphors (Mulhall, McKittrick, & Gunstone, 2001). STEM-based robotic applications, on the other hand, allow students to gain substantial experience in electricity. Moreover, it contributes to the better learning of STEM subjects by providing constructive learning environments suitable for a better understanding of scientific and non-scientific issues (Khanlari, 2013).

When the literature is analyzed, it is seen that a wide range of studies involving the effects of robotic applications within the scope of STEM education mainly on academic success (Özdoğru, 2013; Wahab, Azahari, & Tajuddin, 2015; Yilmaz, Gulgun, & Caglar, 2017; Kozcu, Cakir, & Guven, 2019), attitude and interest towards STEM (Weinberg, Pettibone, Thomas, Stephen, & Stein, 2007; Apedoe, Reynolds, Ellefson, & Schunn, 2008; Martín-Ramos, da Silva, Lopes, & Silva, 2016; Damar, Durmaz, & Onder, 2018; Zainal et al. 2018; Yasin, Prima, & Sholihin, 2018; Prima, Oktaviani, & Sholihin, 2018), and problem-solving skills (Gaudiello, Zibetti, & Carrignon, 2010; Kabátová & Pekárová, 2010; Cankaya, Durak, & Yünkül, 2017; Apriyani, Ramalis, & Suwarma, 2019) have been carried out. On the other hand, it is remarkable that the studies within the extent of STEM education on the effects of robotics applications on attitude towards science and creativity are pretty limited. The present study, it is aimed to determine the effect of STEM-based robotics applications on 7th-grade students' creativity and science attitudes within the scope of the "Electricity" unit to overcome this shortcoming in the literature.

In the mixed method used in the research, answers to 3 research questions were sought for the predetermined purpose. The research question could be to answer quantitative and qualitative questions separately and relate these answers in the later stages of the research (Teddlie & Tashakkori, 2009).

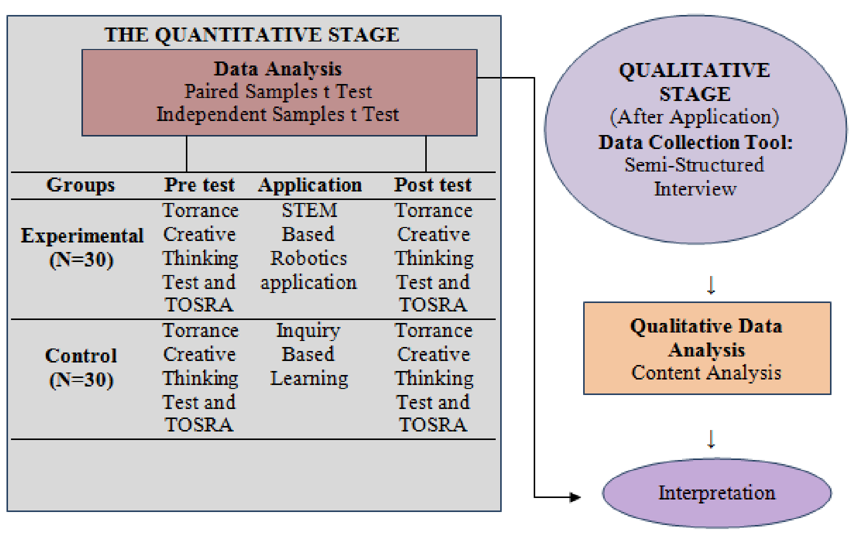

Figure 1 Research pattern

Table 1 Sub-Dimensions of robotic education interview form and questions measuring these dimensions

TOSRA sub-dimensions	Interview questions
Enjoying Science Lesson	Q1. Have you had fun doing STEM-based robotic activities? Why?
Science as Career Preference	Q2. Did STEM-based robotics applications have an impact on their thoughts on a career choice?
Science as Leisure Time Interest	Q3. Do you think that STEM-based robotics applications have brought science to an important place in daily life?
Adopting Scientific Attitude	Q4. Did you feel like a scientist during STEM-based robotics applications?

- Do STEM-based robotic applications affect students' attitudes towards science?
- What are the effects of STEM-based robotics applications on students' attitudes towards science?
- Do STEM-based robotic applications have an impact on students' creativity?

2. METHOD

2.1 Research Design

The method of the research has been determined as a mixed method. Determining the pattern, determining the priority, the level of interaction, the timing, and how and where to combine quantitative and qualitative stages were considered (Creswell, 2014). According to this; the level of interaction between quantitative and qualitative stages is "RELATED", the timing of qualitative and quantitative stages is "CONCURRENT", the priority of quantitative and qualitative data is "QUALIFIED PRIORITY," and finally, qualitative and quantitative data are combined in the "INTERPRETATION" stage. For this reason, it is decided to use the intertwined research pattern in the research. The intertwined pattern is based on collecting and analyzing the secondary dataset to support the more dominant dataset in a study. Thus, the researcher embeds qualitative research into a quantitative experiment to support the experimental elements or reveal the differences. Qualitative data can be collected before, during, or after the application. In studies in which the quantitative pattern is dominant, the reason for using the secondary qualitative pattern, which is supportive, is to determine whether the results of the experimental process is meaningful and the fact that the results obtained from the experimental process can be both related and different from it (Teddlie & Tashakkori, 2009). The research pattern is given in Figure 1.

2.2 Participants

The research participants consisted of 7th-grade students in a post-school private education course, Istanbul, in the 2018-2019 academic year. In the study, experimental and control groups were formed by using the one-to-one matching method by random-neutral assignment according to Torrance Creative Thinking Test and TOSRA scores. Sixty students, experimental (n = 30) and control groups (n = 30), participated in the study. The age of participants ranged from 12 to 13. The Control group consists of 13 girls and 17 boys, and the experimental group consists of 11 girls and 19 boys.

2.3 Data Collection Instrument

TOSRA

The TOSRA (Test of Science-Related Attitudes) scale consisting of 70 items measures science's attitude in 7 sub-dimensions of 10 items. In the study, four of the 7 sub-dimensions were used: Adopting Scientific Attitude, Enjoying Science Lesson, Science as Leisure Time Interest, and Science as Career Preference. The scale is Likert-type. Confirmatory factor analysis of the original (Fraser, 1981) and Turkish version (Telli, 2006) of the 40-item TOSRA test consisting of four sub-dimensions were performed, and the scope and construct validity were examined. The original reliability value of the test was determined as .82.

Torrance Creative Thinking Test

The Torrance Creative Thinking Test developed in 1974 by E. Paul Torrance used in the research consists of Form A and Form B. The forms consist of "verbal" and "formal" parts. Aslan (2001) used the internal consistency method for the reliability of the test translated into Turkish and found their collations with Cronbach Alpha, Guttmann, and Sperman Brown techniques for analysis. In internal consistency analyzes, correlation coefficients were obtained between (r = 0.38) and (r = 0.89). It compared the Wechsler Adults form and Wonderlic Personnel Test in the criterion validity title within the scope of validity. The scale adapted to Turkish consists of 4 sub-dimensions: flexibility, fluency, detailing, and originality as in the original (Baptista et al. 2015; Torrance, 1979).

Semi-Structured Robotic Education Interview Form

The Robotics education interview form, created after the relevant literature review and received expert opinion, consists of 4 questions and 4 sub-dimensions. The four sub-dimensions created while developing the interview form were prepared based on TOSRA's "Adopting Scientific Attitude", "Enjoying the Science Lesson", "Science as a Leisure Interest", and "Science as a Career" (Table 1).

2.4 Groups Application Steps

The application process in the experimental group consists of two parts, pre-application, and application. The application consists of 4 activities, including STEM-based robotics studies. General information about the activities and the process applied to the experimental group is in Table 2.

In the research, activities involving STEM-based robotics applications took six weeks. The preliminary application period to the experimental group was two weeks (8 lessons hours), and the application process was four weeks (16 lessons hours). In the control group, whose activities were prepared according to the inquiry-based learning model, the process lasted four weeks (16 lesson hours).

2.5 Data analysis

The analysis of quantitative data obtained from the TOSRA and Torrance Creative Thinking Test was done by the SPSS 21.00 statistical program. The Kolmogorov Smirnov test was used because the experiment and control groups were 60 people in total. As a result of the Kolmogorov Smirnov Test, it was understood that the p-value was higher than .05, and the scores were normally distributed ($p = .200$, $p>.05$ for TOSRA and $p = .058$, $p>.05$ for Torrance Creative Thinking Test). Paired Samples t-Test and Independent Samples t-Test, which are parametric tests, were used for analysis. "Torrance Creative Thinking Test", one of the quantitative data collection tools, was made by a specialist with an evaluation certificate. Qualitative data obtained from the Semi-Structured Robotic Education Interview Form were analyzed by following the content analysis. Reliability among coders was found 78.5% using Miles & Huberman (1994) reliability formula (Reliability = Consensus/(Consensus + Dissensus) x 100). The analysis of the qualitative data in this research was made based on the content analysis steps below. Organizing the data: Raw data started to be analyzed, and small notes were taken. Coding of data: The data were analyzed in detail, separated according to small information codes, and what each code represented conceptually was found. Determining the themes: To create a common idea in line with the determined purpose, themes were created by combining the codes. Arrangement of data according to codes and themes: The codes created in line with the data were arranged according to themes, and it was ensured that they were transferred to the reader as descriptively and clearly as

Table 2 Groups application process

Week	Lesson Hour	Test				
	EXPERIMENTAL GROUP					
1.	2	**As a pre-test**	TOSRA and Torrance Creative Thinking Test			
2, 3.	8	**Pre-application**	Introduction of Arduino interface program and parts and demonstration of sample codes			
		Application process	**STEM fields**			
			Science	**Mathematics**	**Engineering**	**Technology**
4, 5, 6, 7.	16	**1.** Installing serial and parallel circuits **2.** Setting up mixed circuits **3.** Current-voltage-resistance relationship and bulb brightness in electrical circuits and measurement of current and voltage values in LEDs with digital voltmeter and ammeter	S/he discovered series and parallel bonding in an electrical circuit and drew a mixed electrical circuit diagram. S/he found the difference in brightness when the bulbs are connected in series and parallel as resistance. S/he saw the relationship between the circuit element's voltage and the current flowing through it using a multimeter.	S/he calculated the different resistance values according to the voltage that the light bulbs can handle in the circuits s/he created. S/he revealed the similarities and differences between circuit elements by measuring the mathematical values of the amount of current and voltage in the circuit with a digital multimeter.	S/he built the serial, parallel, and mixed electrical circuits using essential engineering tools (instead of ordinary batteries, conductive wires, light bulbs, UNO cards, different value resistors, breadboard, and sensors like photocell on the Arduino platform). S/he made the software of the circuits using the Arduino interface program.	Before the circuit was established, s/he created her/his circuits on the digital platform using drawing programs such as Fritzing and Tinkercad.
		4. Efficient use of electricity and elimination of light pollution	S/he discussed the importance of the conscious and economic use of electrical energy in family and country economies.	S/he calculated and used the appropriate threshold value of photocell, which causes the light bulbs in the circuit to turn on or off according to the light level in the environment in Arduino.		
8.	2	**As a post-test;**	TOSRA and Torrance CreativeThinking Test			
9.	-	Robotic education semi-structured interviews				

Table 2 Groups application process (*Continued*)

Week	Lesson Hour	Test	
		CONTROL GROUP	
1.	**2**	**As a pre-test;**	TOSRA and Torrance Creative Thinking Test
		Application process	**Explanation**
2, 3, 4, 5.	**16**	**1.** Installing serial and parallel circuits **2.** Setting up mixed circuits **3.** Comparison of bulb brightness **4.** Measuring current and voltage values in bulbs via a multimeter	Structured questioning was used in the activities held every week. S/he sought an answer to the practical problem that the teacher gave for his research. S/he established series and parallel circuits with the materials (light bulbs, conductor cables, switch, battery, battery bed) given to her/him by the teacher. S/he made inferences observing the light bulbs' brightness in the cases in which the bulbs are connected in series and parallel. S/he discovered the relationships between current and voltage by making multimeter measurements.
6	**2**	**As a post-test;**	TOSRA and Torrance CreativeThinking Test

possible. Interpretation of the data: An understanding of the research has been revealed based on the codes and themes. Presenting and visualizing data: Data was presented with the help of visual tools such as tables or flowcharts.

3. RESULT AND DISCUSSION

The Paired Samples and Independent Samples t-test results on the experimental and control group's pre-test and post-test science attitude scores are given in Table 3.

In consequence of the Independent Samples t-test conducted to determine whether there is a significant difference between the science attitude scores of the students in the experimental and control groups, a statistically significant difference between the pre-test scores [t(58) = -.702, p = .475] was not reached. However, in favor of the experimental group posttest, a significant difference was achieved [t(58) = 7.301, p = .000]. As a result of Paired Samples t-test conducted to determine whether there is a significant difference between students' science attitudes pretest-posttest mean scores, both in the experimental group [t(29) = -.32.138, p = .000] and in the control group [t(29) = -.21.787, p = .000] a statistically significant difference was found on behalf of the post-test.

Results obtained from the Robotic Education Interview form on the students' attitude towards science; Results related to TOSRA's "Enjoying the Science Lesson" sub-dimension is in Table 4.

The related question (Q1) was examined under the "Yes" sub-theme within the scope of the "Enjoying the Science" theme. One hundred percent of the students stated that they had fun during the activities. They stated that they learned new and complex information about the subject, wrote the codes of the created circuits, programmed them, made applications, created circuits, and obtained theoretical information about the subject.

Results related to TOSRA's "Science as a Career Preference" sub-dimension are in Table 5.

The interview question (Q2) is gathered under two sub-themes: "Yes" and "No" within the scope of the "Science as a career" theme. 83.4 percent of the students said that STEM-based robotics applications impacted their career choice in the future. This is because they have learned that they can make different inventions in the future and realize that they can do technological studies in science, thanks to the training. On the other hand, 16.6 percent of the students stated that STEM-based robotics applications would not affect their choice of profession in the future. They stated the reason for this as having chosen the profession to do before.

Results related to TOSRA's "Science as Leisure TimeInterest" sub-dimension are in Table 6.

Table 3 *t*-test results related to the experimental and control group' pre-test and post-test science attitude scores

Groups	Application	N	Mean	Standard Deviation	t	Sd	p
Experimental	Pre-test	30	99.533	9.786	-.702	58	.475
Control	Pre-test	30	101.600	12.310			
Experi-mental	Pre-test	30	99.533	9.786	-32.138	29	.000*
	Post-test	30	184.370	8.572			
Control	Pre-test	30	101.600	12.310	-21.787	29	.000*
	Post-test	30	167.200	9.611			
Experimental	Post-test	30	184.370	8.572	7.301	58	.000*
Control	Post-test	30	167.200	9.611			

*P<0.005

Table 4 Results concerning enjoying science lesson

Theme	Sub-theme	Explained	Code	Percent
Enjoying Science Lesson	Yes	Besides making theoretical information about the subject, making applications and creating circuits Programming the circuits created by writing their codes Learning new and complex information about the subject	• Create a circuit • To practice • Light the LED • Connecting cable • Coding • Robotics • Computer • Programming • New information • Learning complex information	%100

Table 5 Results about science as a career preference

Theme	Sub-theme	Explained	Code	Percent
Science as Career Preference	Yes	To learn that make different inventions	• Making new tools • To discover • Inventing	83.4 %
		To think that work in the field of robotics and software	• Writing code • Making a robot • Software • Computer programs • Science area	
		To realize technological studies in the field of science	• Studies in the field of science • Developing science concepts • Science technology	
	No	Having previously chosen the profession to do	• Deciding the profession in advance	16.6 %

Table 6 Results concerning science as leisure time interest

Theme	Sub-theme	Explained	Code	Percent
Science as Leisure Time Interest	Yes	Having an idea about the operation of the electronic devices used Increased interest in technological developments Examining the events around more carefully	• Trying to repair • Electronic devices • Technological developments • Track new devices • Observation • Daily life • Surveying around	%100

The interview question (Q3) examined within the scope of the theme of "science as leisure time interest" is examined under the sub-theme of "Yes" 100 percent of the students state that STEM-based robotic applications have brought science to an im portant place in their daily life. Students stated that the application enables them to understand the operation of the electronic devices used, increase their interest in technological developments, and examine the events in their environment more carefully.

Results regarding TOSRA's "Adopting Scientific Attitude" sub-dimensions are given in Table 7 below.

In consequence of the content analysis of the data gained from the interview question (Q4), the results were gathered under two sub-themes: "Yes" and "No" within the scope of the "adopting scientific attitude" theme. 83.4 percent of the students stated that STEM-based robotic applications make them feel like scientists. They cited that their ability to identify, investigate and solve problems, and work in robotics made them feel this way. On the other hand, 16.6 percent stated that STEM-based robotics applications did not make them feel like scientists because they did things simpler than scientists did.

The Paired Samples and Independent Samples t-test results on the groups' pre-test and post-test creativity scores are in Table 8.

Table 7 Results regarding adopting the scientific attitude

Theme	Sub-theme	Explained	Code	Percent
Adopting Scientific Attitude	Yes	Identifying, investigating, and solving problems	• Problem-solving • Identifying the problem • Setting up circuits • Research	83.4 %
		Working in the field of robotics	• Writing code • Making a robot	
	No	Doing things simpler than what scientists do	• Simple level circuits • Less complex • Simpler materials	16.6 %

Table 8 Independent t-test results on groups pre-test creativity

Groups	Application	N	Mean	Standart Deviation	t	Sd	p
Experimental	Pre-test	30	48.100	8.297			
Control	Pre-test	30	44.500	7.560	1.757	58	.084
Experimental	Pre-test	30	48.100	8.297	-21.630	29	.000*
	Post-test	30	84.966	4.867			
Control	Pre-test	30	44.500	7.560	-15.900	29	.000*
	Post-test	30	72.833	6.000			
Experimental	Post-test	30	84.966	4.867			
Control	Post-test	30	72.833	6.000	8.602	58	.000*

*P<0.05

In consequence of the Independent, t-Test conducted to determine whether there is a significant difference between the creativity scores of the students in the experimental and control groups, no statistically significant difference was observed between the pre-test scores [t(58) = 1.757, p = .084]. However, it was found that statistically significant difference between the post-test scores in favor of the experimental group [t(58) = 8.602, p = .000]. Furthermore, in consequence of the Paired Samples t-test conducted to determine whether there is a significant difference between the creativity pretest-posttest mean scores, both in the experimental group [t(29) = -21.630, p = .000] and control group [t(29) = -15.900, p = .000] a statistically significant difference was found on behalf of the post-test. In addition, some circuits and fritzing drawings made by the students in the experimental group process activities were shown in Figure 2.

When quantitative data about attitude are analyzed, it is understood that experiment and control groups' attitudes towards science were at the same level before application. When the control group's pre and post-test attitude scores are examined, it is determined that inquiry-based learning positively affects students' attitudes towards science. When the pretest-posttest science attitude scores of the experimental group are examined, it is found that STEM-based robotic applications positively affect the students' attitudes towards science. Considering the post-test science attitude scores of the experimental and control groups, it is concluded that STEM-based robotic applications effectively increase students' attitudes towards science than the inquiry-based learning model (Table 3). Similarly, Özdoğru (2013) found that the activities carried out using robotic applications had a positive attitude towards students' science lessons and impacted their professional choices. Yilmaz et al. (2017) realized that STEM activities that include robotics positively improved students' attitudes towards science. The students stated that they were happy to obtain a product and that the activities they found intriguing made the lesson enjoyable and provided permanent learning. Acar, Korkmaz, Erdoğmuş, & Çakır (2018) found that students 'attitudes towards science were positively influenced by studying educational robot activities' effects on students' STEM skill levels and attitudes towards science. Karisan & Yurdakul (2017) reported that Microprocessor Supported STEM practices positively impact students' attitudes towards STEM fields. The studies mentioned above and the results of this study are similar.

Looking at the qualitative data on attitude, it is concluded that STEM-based robotics applications enable students to enjoy science lessons because they could make applications and create circuits related to the subject, write the circuits they created and learn complex information (Table 4). Dönmez (2017) also determined that Students found robot kits fun, functional and exciting, and their motivation and interest in scientific studies increased. Yıldız (2018), considering the opinions of students who made at least one project in robotic coding, concluded that robotic sets and computer use could increase motivation and interest in students positively. In his study, Sırakaya

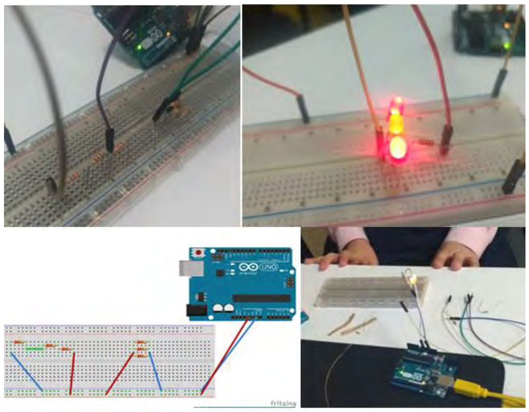

Figure 2 Students' circuit and fritzing drawing examples

(2018) stated that students are delighted to receive coding training and found education attractive and enjoyable. Yıldız (2018) reported that students generally find activities challenging in robotics and programming challenging but fun and support the activities' collaborative activities. Rubio, Hierro, & Pablo (2013) realized that students enjoyed working with Arduino and their learning motivation increased. The studies mentioned in the literature and the results obtained in this study coincide.

STEM-based robotic applications are found to impact the student's future professional selection because the students stated that they learned that they could make different inventions, do studies in the field of robotics and software, and realized that they could make technological studies in robotics science (Table 5). These results coincide with the results of the studies conducted by Weinberg et al. (2007), who concluded that robotic activities increase female students' expectations in science/mathematics and their positive attitudes towards engineering/science careers. STEM-based robotic applications have been found to bring science to an important place in students' lives because they have provided students with an idea about electronic devices' operation, increased their interest in technological developments, and positively influenced students to examine the events around them more carefully (Table 6). In the study in which Damar et al. (2018) conducted robotic projects, it was concluded that the students found the activities exciting and found themselves very popular because they made scientific research and produced projects. Moreover, the students stated that they wanted lessons to be longer and coding changed their lives a lot to be excited to participate in the activities. It has been determined that STEM-based robotic applications have made most students feel like scientists since it has enabled them to identify and solve problems and work in robotics (Table 7). When students' attitudes towards science are analyzed, it is concluded that the quantitative and qualitative data collected about their attitudes could support each other.

When quantitative data on creativity are examined, experimental and control groups' creativity is found to be at the same level as before application. When the pretest-posttest creativity scores of the control group are examined, it is seen that inquiry-based learning has a positive effect on students' creativity. When the pretest-posttest creativity scores of the experimental group are examined, it is found that STEM-based robotic applications positively affect the students' creativity. When post-test creativity scores of the experimental and control groups are analyzed, it is seen that STEM-based robotic applications are more effective in increasing students' creativity than the inquiry-based learning model (Table 8). Cavas et al. (2012) found that robotic after-school activities could positively increase students' scientific creativity and change their perception of robots, human beings, and society.

Similarly, Soophung & Seokju (2015), Masril et al. (2019), Noh & Lee (2020), Guven, Cakir, Sulun, Cetin, & Guven (2020), and Adeleh (2019) have concluded that robotic applications increase the creativity of students. Cankaya et al. (2017) found that students who program with robots have a significant relationship between their creative problem-solving skills and their performance scores. In addition, students generally have a positive attitude. It turns out that the education provided is motivating and amusing and contributes to students learning to program. The results of this research and the results of the studies mentioned above support each other.

4. CONCLUSION

As a result, it has been determined that STEM-based robotics applications positively affect students' creativity and attitudes towards science. Besides, it was stated that the students enjoyed making STEM-based robotic applications rather than theoretical lectures and using robotics and complex software materials to solve daily life problems. It was observed that they felt like scientists while making STEM applications, and STEM applications affected their future career choices. Future studies can be carried out at different educational levels (5^{th}, 6^{th}, or 8^{th} grade) and in different units (force and motion, the structure of matter). It should not be overlooked that performing robotic applications in a laboratory equipped for this area, rather than in classroom environments, is vital for the lesson's efficiency and time. Researchers are advised to keep spare parts during robotic applications to prevent the parts from working or malfunctioning.

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