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Arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching

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ABSTRACT

The present study aimed to determine the effects of arduino-assisted robotics coding applications integrated into the 5E learning model used in science teaching on students' scientific creativity, robotics attitude and motivation toward science. For this aim, the study was planned according to the convergent parallel mixed research method and was conducted with the 6th grade students in a STEM (Science, Technology, Engineering and Mathematics) elective course in 2018–2019 academic year. Scientific creativity scale, robotics attitude scale and motivation scale toward science learning were used as quantitative data collection tools, and semi-structured interview form was used as a qualitative data collection tool. As a result of the study, it was found that the levels of students' creativity, attitude and motivation increased with the robotics coding activities integrated into 5E learning model applied in science subjects. In addition, it was determined that students produced many creative ideas in using robotics coding applications to solve various problems encountered in daily life, and that they were very eager for such applications being used in science classes. In this respect, it is suggested that arduino-assisted robotics coding applications should be implemented in the teaching of 6th grade science subjects.

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Introduction

Science education and teaching play an important role in the education of individuals who are researching, questioning, experimenting, observing, thinking creatively and critically, producing scientific solutions to the problems they face and developing scientific attitudes by increasing their knowledge with their own learning (Ayas et al., 2002). An effective science education occurs in teaching environments that enable learning by doing and experiencing. The constructivist approach, which is focused on by the science curriculum comes to the fore in the creation of these environments. The constructivist approach is an important approach that is based on the principle of active learning, relies on the construction of knowledge by the student in his/her mind by creating connections between his/her prior knowledge and the newly encountered knowledge, makes the realization of conceptual change possible and reveals the process of inquiry (Appleton, 1997; Copley, 1992; Driver, 1983; Fensham et al., 1994; Hand & Treagust, 1991). In this approach, it is important to follow a learning cycle for the facilitation of the learning process and accomplishment of the inquiry process. Various learning cycle models have been developed

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to be able to use the constructivist approach in learning environments. One of these learning models is the 5E learning model. This model is particularly based on the constructivist approach in order to create rich learning environments and increase the quality of science lessons (Bybee, 1997). The use of this approach helps students redefine, organize, analyze and change their ideas by interacting with their peers and environments (Bybee, 1997). In the related literature, it is stated that the teaching organized according to 5E learning model affects students' academic achievement positively, eliminates the misconceptions they have and contributes to the development of positive attitudes toward the course (Biyikli & Yagci, 2015; Devecioglu, 2016; Sahin & Cepni, 2012). In this context, the necessity of integrating the technology required by our age into the 5E learning model in learning environments is an important issue. However, it is generally seen that such robotics coding practices are used in competitions, courses and seminars in out-of-school times and environments yet it is only demonstrated in the context of technology in learning environments (Altin & Pedaste, 2013; Larkins et al., 2013). When the related literature is reviewed, it is seen that the studies in which science education is designed by integrating technology into the 5E learning model are rare (Abdusselam et al., 2018; Celik et al., 2020; Kozcu Cakir & Guven, 2019; Lai et al., 2015; Lye et al., 2014; Piyayodilokchai et al., 2013; Şahin & Baturay, 2016; Sari et al., 2017). When these studies are examined, it is seen that technologies such as augmented reality, robotics coding, interactive simulation, WebQuest media, mobile learning and multimedia have been integrated to science teaching in compliance with the 5E learning model. It is seen that although it has been reported that technological applications integrated into the 5E learning model helped students construct science-related concepts, allowed them to concretize abstract concepts and helped them to create associations with daily life, cognitive and affective domain such as creativity, attitude and motivation have not been addressed in these studies. When we consider learning as a whole, it is necessary to take into account the cognitive domain as well as the affective domain in the integration of technology into learning environments. In this research, the effects of robotics coding applications integrated into the 5E learning model used in science teaching on students' scientific creativity as cognitive domains, robotic attitude and motivation toward science as affective domains were investigated.

Educational technologies

Educational technology is defined as the practices and studies conducted by creating, using and managing appropriate technological resources and processes in order to increase the performance of the students and facilitate their learning (Tas, 2011). In line with the rapid developments in technology in the 21st century, the use of technology in education has increased. Considering the fact that this century's students are intertwined with technology in their daily lives and use continuously, it is inevitable to use and integrate technology in learning environments.

The use of technology in science teaching concretizes abstract concepts, increases students' interests and attitudes toward the lesson, and provides permanent learning by facilitating their understanding (Koc Senol, 2012; Pekdag, 2005). Thus, the use of educational technologies becomes important in the teaching of science subjects and in creating effective learning and teaching environments. In this context, augmented reality, virtual reality, mobile applications, web 3.0/4.0, cloud technology, simulation, social networks, educational and digital games, digital storytelling, artificial intelligence, online learning environments, wearable technology, QR code applications and three-dimensional printing are some of the most widely used and developing educational technologies available today (Adams Becker et al., 2016; Johnson et al., 2015). In addition to these technologies, educational robotics coding applications are among the important technologies (Benitti, 2012; Beran et al., 2011; Johnson et al., 2015; Mubin et al., 2013). Educational robotics coding applications are realized by acquiring basic coding skills.

Coding

Coding can be defined as the whole or part of a set of commands written to the computer, electronic circuitry, or mechanical systems to carry out an operation or to achieve a specific purpose. Students are able to perform coding with text-based or block-based programs. In text-based coding, codes and commands are created by the students in text form using computer keyboard in line with procedures. In block-based coding, students perform coding by combining the codes in blocks in the form of jigsaw using a drag-and-drop technique without writing any text. In particular, the fact that text-based coding includes its own unique syntax rules, having an abstract nature, and being considered complex for beginners makes coding education difficult to perceive by students (Baser & Ozden, 2015; Erol & Kurt, 2017; Gomes & Mendes, 2007). However, with the development of block-based coding tools, even early-age students can do their own coding and design fun applications without having to learn complex code structures (Resnick et al., 2009). The studies also showed that the implementation of block-based coding in teaching was effective in developing problem solving, creativity, questioning, algorithmic thinking and cognitive skills of students (Czerkawski & Lyman, 2015; Lau & Yuen, 2011; Psycharis & Kallia, 2017; Strawhacker & Bers, 2015; Wang et al., 2012). In this regard, many countries have updated their secondary school curriculum to include coding education (Akpinar & Altun, 2014; Bers et al., 2014; Demirer & Sak, 2016; Lee et al., 2014). Hence, the students who start coding will first identify the problem, produce ideas for the solution proposal, think in an algorithmic and analytical way, make applications, debug the applications and perform effective teaching in collaboration with their friends. In this context, students can do block-based coding with Alice, code of game lab, code.org, scratch, App Inventor, Greenfoot and mBlock without writing any code by drag-and-drop or jigsaw technique. The use of these platforms and tools in educational environments is recommended due to features such as having an easy and useful interface, working with a language similar to the daily language instead of syntax rules, merging code blocks with drag-and-drop instead of writing code, and the ability of code blocks to merge only in the correct way just like jigsaw pieces. Learning the coding allows the creation of various robotics structures.

Robotics

Robotics are functional tools that can be programed to perform a task. The robots can detect the environment by means of sensors and the data obtained are interpreted as programed by the microcontroller or processor thus various reactions are generated. Especially, the use of robots with block-based coding in education has become widespread. The use of such educational robots in science teaching allows students to work with concrete objects, enabling them to deal with real-life problems. Also, in educational robotics applications, students work with engineering materials such as gears, motors and sensors, make coding by using their own imagination and algorithmic thinking, collect data by interacting with their environment and create their own projects in the light of these data. This situation provides students with many skills such as problem solving, critical thinking, discovering their own abilities, learning by doing and living, being more willing to use technology and increasing their level of use (Costa & Fernandes, 2005). Furthermore, educational robotics applications attract students' interest (Prensky, 2010), increase their motivation (Ortiz, 2015), develop their creative, critical and computational thinking skills (Catlin, 2012; Kazimoglu et al., 2012) and contributes positively to their cognitive, affective, social and moral development (Shimada et al., 2012; Wei et al., 2011). In this context, the use of various tools such as coding robots, smart objects, DIY kits, virtual robot coding platforms and robot programing languages has become widespread. Examples of such robotics tools are Lego Mindstorms Kits, VEX IQ Platform Kits, Fischertechnik Kits and Makeblock Kits (Numanoglu & Keser, 2017). Besides, microcontroller arduino sets, which are easy to use and understand in learning environments, whose coding is supported by programs that work with drag-and-drop system, which enable the production of different creative projects with various sensors and allow interaction and communication with the environment, are recommended for science education (Kozcu Cakir & Guven, 2019).

Arduino-assisted robotics coding applications

Arduino is a microcontroller card developed as open-source. This card can be coded as desired by a computer and it may be requested to perform various functions. Especially, the fact that the software and hardware of such microcontroller cards are open-source, being supported by programs with block-based coding (mBlock coding platform), and ability to add advanced technologies to these cards play an important role in the use and spread of arduino-assisted robotics coding applications in teaching environments (Dokmetas, 2016). The use of arduino in science teaching allows students to control the reactions of a model that they touch and see visibly, and makes it possible for learners to investigate the situations they encounter in daily life. This is due to the fact that arduino is equipped with various sensors such as temperature, humidity, speed, sound, light, magnetic, weight, pulse, acceleration, gas, current, voltage, color, vibration, distance and pressure so that students can perceive what is happening around them with their sense organs. This allows students not only to develop different perspectives to better understand the life around them but also to bring a new dimension to their understanding of productivity with the tasks they perform using arduino materials and sensors. In addition, use of arduino-assisted robotics coding applications in science teaching enable students to learn by experimenting, designing and doing, and contribute significantly to the creation of rich learning environments for students as well as the development of their creativity, academic achievement and coding skills (Alimisis & Kynigos, 2009; Koc Senol, 2012; Kozcu Cakir & Guven, 2019; Varnado, 2005; Williams et al., 2007).

Particularly in the literature, it is emphasized that arduino-assisted robotics coding applications facilitate the teaching of abstract and difficult to understand concepts in science subjects and it is stated that such applications should be included in the teaching of science subjects such as force and motion, matter and heat, electricity, light and sound (Grubbs, 2013; Hacker, 2003; Kozcu Cakir & Guven, 2019). Moreover, with Piaget's period of abstract operations (age 12 and later), students begin to learn abstract concepts, perform mental operations, and develop hypotheses and provide analytical solutions to problems (Piaget, 1973). Therefore, teaching experiences based on arduino-assisted robotics coding applications should be provided in order to enable students in the abstract operations period to infer meaningful learning on science subjects with intense abstract and complex concepts, to be willing to learn scientific knowledge about science, to produce new ideas by adapting new knowledge to different fields and daily life, and to provide creative solutions to the problems faced in daily life. Furthermore, by including such applications in the courses on science subjects, emphasis should be placed not only on students' learning at the cognitive level (such as creativity), but also on increasing their interest, attitudes and motivation toward technology applications and science teaching. In this context, the aim of the research is to determine the effects of arduino-assisted robotics coding applications integrated into the 5E learning model used in science teaching on students' scientific creativity as cognitive domains, robotics attitude and motivation toward science as affective domains. Accordingly, the following research questions were examined.

1. What is the effect of arduino-assisted robotics coding activities on students' levels of science creativity in 6th grade science subjects?
2. What is the effect of arduino-assisted robotics coding activities on students' levels of robotics attitude in 6th grade science subjects?

Table 1. Research Design.

Pretest	Application	Posttest
Scientific Creativity Scale Robotics Attitude Scale Motivation Scale Toward Science Learning	Arduino-Assisted Robotics Coding Activities Integrated into the 5E Learning Model	Scientific Creativity Scale Robotics Attitude Scale Motivation Scale Toward Science Learning Semi-Structured Interview Form

3. What is the effect of implementing arduino-assisted robotics coding activities on students' levels of science motivation in 6th grade science subjects?
4. How is the creativity of secondary school 6th grade students in linking arduino-assisted robotics coding with daily life?
5. What are the attitudes of middle school 6th grade students toward robotics applications in science subjects?
6. How is the motivation of the 6th grade students for the science course in which robotics coding applications are performed?

Method

Research model

In this research, a mixed research method was applied including both qualitative and quantitative data collection and analysis process. The design classification of the research is convergent parallel mixed research method (Cresswell & Plano Clark, 2015). The qualitative and quantitative data collection process and analysis in this type of design takes place simultaneously or in close time zones (Fetters et al., 2013). In the quantitative dimension of the research, the single-subject experimental design was used. After this process, we aimed to obtain more detailed information about the subject by using semi-structured interview form. The design of the research was given in Table 1.

Study group

The study group of the research consists of 6th grade students in a private college located in Mugla province in the 2018–2019 academic year. The reason for the selection of the students of the study group in a private college is that the related college has facilities such as technology-supported equipment, science-equipped laboratories and robotics coding classes. In this direction, the study group was determined with purposive sampling method and the study was carried out with the participation of 11 students (6 females and 5 males) in the 6th grade. The ages of the participants were between 11–13.

Data collection tools

Scientific creativity scale

The original scale was developed by Hu and Adey (2002), translated into Turkish by Aktamis (2007), and its validity and reliability calculations were made. The scale consists of 6 open-ended items. These items are used to question what the secondary school students can do with simple materials in the laboratory related to their scientific creativity, what path to follow to test a situation, and their thoughts about an imaginary and possible situation. Scale items are evaluated in terms of fluency, flexibility and originality dimensions from scientific creativity levels. For the reliability of the scale, the researchers evaluated the students' responses to the scale items separately and the consistency between the evaluators was found to be between 0.89–1.00.

Robotics attitude scale

The scale was developed by Cross et al. (2016) in order to measure the attitudes of secondary school students toward robotics activities, and it was adapted to Turkish after validity and reliability studies were conducted by Sisman and Kucuk (2018). The scale consists of 24 items and 5-point Likert type. The scale has four sub-dimensions: learning desire (12 items), self-confidence (5 items), computational thinking (3 items), and teamwork (3 items). The overall Cronbach's Alpha reliability coefficient of the scale was calculated as 0.93.

Motivation scale toward science learning

The scale was developed by Tuan et al. (2005), and translated by Basdas (2007) who also made the validity and reliability studies. The scale consists of 35 items and 5-point Likert type. The scale consists of six sub-domains which are self-efficacy (7 items), active learning strategies (8 items), science learning value (5 items), performance goal (4 items), achievement goal (5 items) and learning environment stimulation (5 items). The overall Cronbach's Alpha reliability coefficient of the scale was calculated as 0.83.

Semi-structured interview form

The interview form was used to determine the opinions of secondary school 6th grade students about the arduino-assisted robotics coding applications on science subjects. The interview form included 4 open-ended questions consisting of semi-structured questions. These questions were prepared by the researchers and aim to reveal the students' thoughts about creativity related to robotics coding applications (1 item), robotics attitude (2 item) and motivation toward science learning (1 item). In order to ensure the construct validity of these questions, expert opinions (one specialist in science education, one specialist in robotics coding and one specialist in measurement and evaluation) were consulted. Necessary corrections were made according to expert opinions and final form of interview form was given. In this context, interviews were conducted with each of the 6th grade students separately with 15-minute semi-structured questions. The interview data were recorded by voice recorder.

Implementation of the research

The research was carried out for two course duration (40 min + 40 min) for 11 weeks including two weeks of data collection, four weeks of coding training and five weeks of robotics coding activities integrated into 5E learning model. The study was conducted in 6th grade STEM elective course. Within the scope of this course, students perform various activities and experiments related to the subjects (light, sound, electricity, etc.) in the Science curriculum. Within the scope of this study, these activities and experiments were conducted by researchers with arduino-assisted robotics coding applications integrated into 5E learning model. The applications were carried out in a classroom environment where students took an active role and the teacher was a guide in accordance with the 5E learning model based on the constructivist approach. Content related to the research process and the weeks are presented in Table 2.

A sample course content is given below regarding the arduino-assisted robotics coding applications integrated into 5E learning model performed within the scope of the study.

Engagement: Students' prior knowledge about renewable energy, energy conversion, energy efficiency and environmental pollution are reviewed. The teacher starts the lesson with an

Table 2. Implementation Process of The Research.

Weeks	Applications
1st Week Implementation of data collection tools	Scientific Creativity Scale Motivation Scale Toward Science Learning Robotics Attitude Scale
2nd Week Coding Education	What is the concept of Computational Thinking? How do we sort the processes in daily life? What is code? How does computer do operations using codes? What is coding?
3rd Week Coding Education	What is an algorithm? How do we express the operations in daily life algorithmically? Linear algorithms, conditional algorithms and repetitive operations Computer coding
4th Week Coding Education	Presentation of coding media and platforms Coding with Scratch and mBlock
5th Week Coding Education	Creating a cyclic algorithm (Maze-bee-drawing shapes-debugging in algorithm) Conditional algorithms Nested loops
6th Weeks Robotics coding	Activity 1: Light-directed Solar Panel
7th Week Robotics coding	Activity 2: Making Ammeter-Voltmeter
8th Week Robotics coding	Activity 3: Does Each Substance Conduct Electricity?
9th Week Robotics coding	Activity 4: Making Pulse Meter
10th Week Robotics coding	Activity 5: Is Sound an Energy?
11th Week Implementation of data collection tools	Scientific Creativity Scale Motivation Scale Toward Science Learning Robotics Attitude Scale Semi-Structured Interview Form

interesting question about the subject. For example, the teacher asks the class "What kind of model and design would you make for more efficient operation of solar panels as one of renewable energy sources? "Students produce a variety of ideas using brainstorming techniques. The teacher records these ideas and creates a discussion environment in class accordingly.

Exploration: Groups are formed for the collaborative work of the students, and each group is provided with robotics materials such as arduino microcontroller, solar panel, light sensor, breadboard, jumper cables, servo motor. The teacher introduces these materials to the students and gives information about their use. The students create an algorithm for the robotics mechanism and perform the teacher-guided coding on the mBlock coding platform based on this algorithm. In the last case, the codes are transferred to the robotics mechanism and the operation of the assembly is checked.

Explanation: The teacher creates group and classroom discussion environments by asking students about the mechanism regarding renewable energy, clean energy, efficiency and energy use. In line with these discussions, necessary explanations are made to students under the guidance of the teacher.

Elaboration: The students are asked questions "Why is the use of renewable energy sources is important for the environment?", "Similar to the sample model generated with robotics coding applications, what other projects can be created to contribute to efficiency of energy use?" Students are asked to present sample projects in which energy efficiency is provided, similar to the house model which is mounted with solar panels by using the arduino-assisted robotics coding.

Evaluation: The students were asked to write a science diary about the activity. The science diary included the following contents; "the purpose of the activity", "the learned science concept and the scientific information about it", "affective experiences related to the activity" and "integration of the activity into daily life". The science diaries were evaluated by the researchers by means of the rubrics prepared.

Data analysis

In the research, quantitative data obtained from scientific creativity, robotics attitude and motivation toward science learning scales were analyzed with SPSS 21 program. As the scores obtained from these scales did not distribute normally and the number of data is less than 30, one of the non-parametric tests, Wilcoxon signed rankings test was used to compare the pre-post-test mean scores of the measurements between the dependent groups. For Wilcoxon signed rankings test, the effect size (r) was calculated. The guidelines (proposed by Cohen, 1988) for interpreting this value are: .10 = small effect, .30 = moderate effect, .50 = large effect. In addition, the criteria determined by Hu and Adey (2002) were used in scoring the scientific creativity scale. The scoring criteria were 1 point for each answer produced accordingly (fluency score), +1 point for each proposed different application (flexibility score), 2 points for each answer seen in less than 5% and 1 point for 5% to 10% (originality score).

Audio recordings obtained from semi-structured interviews were translated into text on computer and analyzed by using descriptive analysis method from qualitative analysis methods. Frequency and percentage values for these descriptions are given.

Some operations were performed in relation to reliability and validity of the data collected in the current study on the basis of the concepts of transferability, and consistency. The detailed description method was applied to enhance the transferability of the results of the research. Within the context of the description method, direct quotations were made from the statements of the students. Consistency analysis method was used within the concept of "consistency" regarding the reliability of qualitative data. In line with this method, an expert in qualitative research looked at the research as an outsider and conducted an examination of the consistency of the researchers in the process of the construction of data collection tools, data collection, analysis and interpretation. The required arrangements were made for these analyses by the researchers.

Findings

Quantitative findings

Findings related to the first research question

The responses of the students to the scientific creativity scale before and after the applications were scored according to the dimensions of fluency, flexibility and originality. In this context, the total scores of fluency, flexibility, originality, and scientific creativity for students' responses to the scientific creativity scale were analyzed by Wilcoxon signed rankings test and the related findings were given in Table 3.

When Table 3 was examined, it was found that the scores of the students' scientific creativity scale on fluency, flexibility and originality dimensions and the total scores of scientific creativity showed statistically significant differences before and after the applications of arduino-assisted robotics coding activities in science subjects [$z_{(fluency)} = -2.829$, $z_{(flexibility)} = -2.687$, $z_{(originality)} = -2.274$, $z_{(scientific\ creativity)} = -2.096$, $p < .05$]. When the average and totals of difference scores are taken into consideration, it is seen that these observed differences are in favor of positive rankings, i.e. posttest scores. The effect sizes of these determined differences were found to be high ($r_{fluency} = .89$, $r_{flexibility} = .85$, $r_{originality} = .86$, $r_{scientific\ creativity} = .66$). According to these results, it can be stated that arduino-assisted robotics coding activities in the 6th grade science

Table 3. Wilcoxon Signed Rankings Test Results Related to Scientific Creativity Scale.

Dimensions of Scientific Creativity	Pre-Posttest	n	Mean Rank	Rank Sum	z	p
Fluency	Negative Rank	0	0.00	0.00	−2.829	.005
	Positive Rank	10	5.50	55.00		
	Equal	0				
Flexibility	Negative Rank	0	.00	.00	−2.687	.007
	Positive Rank	9	5.00	45.00		
	Equal	1				
Originality	Negative Rank	0	.00	.00	−2.714	.007
	Positive Rank	8	4.50	36.00		
	Equal	2				
Scientific creativity	Negative Rank	1	7.00	7.00	−2.096	.036
(Total score of the scale)	Positive Rank	9	5.33	48.00		
	Equal	0				

Table 4. Results of Wilcoxon Signed Rankings Test on Robotics Attitude Scale.

Robotics Attitude Dimensions	Posttest – Pretest	n	Mean Rank	Rank Sum	z	p
Learning desire	Negative Rank	0	0.00	0.00	−2.940	.003
	Positive Rank	11	6.00	66.00		
	Equal	0				
Self-Confidence	Negative Rank	1	1.50	1.50	−2.316	.021
	Positive Rank	7	4.93	34.50		
	Equal	3				
Computational thinking	Negative Rank	0	0.00	0.00	−2.264	.024
	Positive Rank	6	3.50	21.00		
	Equal	5				
Teamwork	Negative Rank	0	0.00	0.00	−2.214	.027
	Positive Rank	6	3.50	21.00		
	Equal	5				
Robotics attitude	Negative Rank	0	0.00	0.00	−2.937	.003
(Total score of the scale)	Positive Rank	11	6.00	66.00		
	Equal	0				

subjects have a significant effect on the students to produce many ideas and solutions (fluency), to propose different ideas than suggested ones (flexibility) and to produce unordinary ideas (originality). Hence, it can be stated that such practices play an important role in improving students' level of scientific creativity.

Findings related to the second research question

The scores of the secondary school 6th grade students on learning desire, self-confidence, computational thinking, teamwork dimensions regarding pre and post applications robotics attitude scale were analyzed with wilcoxon signed rankings test and the related findings are given in Table 4.

When Table 4 was examined, it was found that the scores of the students in terms of learning desire, self-confidence, computational thinking and teamwork dimensions and the total scores of the scale showed a statistically significant difference before and after the applications of arduino-assisted robotics coding activities in science subjects [$z_{(learning\ desire)} = -2.940$, $z_{(self\text{-}confidence)} = -2.316$, $z_{(computational\ thinking)} = -2.264$, $z_{(teamwork)} = -2.214$, $z_{(robotics\ attitude)} = -2.937$, $p < .05$)]. When the mean and sum of the difference scores are taken into consideration, it is seen that these differences observed in the dimensions of learning desire, self-confidence, computational thinking, teamwork and the whole scale are in favor of positive rankings, i.e. posttest scores. The effect sizes of these determined differences were found to be high ($r_{learning\ desire} = .89$, $r_{self\text{-}confidence} = .70$, $r_{computational\ thinking} = .68$, $r_{teamwork} = .67$, $r_{robotics\ attitude} = .89$). According to these results, it can be stated that arduino-assisted robotics coding activities have a significant effect on

Table 5. The Results of Wilcoxon Signed Rankings Test Related to Motivation Scale Toward Science Learning.

Motivation Dimensions	Posttest – Pretest	n	Mean Rank	Rank Sum	z	p
Self-efficacy	Negative Rank	0	.00	.00	−2.812	.005
	Positive Rank	10	5.50	55.00		
	Equal	1				
Active learning strategies	Negative Rank	1	7.50	7.50	−2.047	.041
	Positive Rank	9	5.28	47.50		
	Equal	1				
Science learning value	Negative Rank	1	2.50	2.50	−2.736	.006
	Positive Rank	10	6.35	63.50		
	Equal	0				
Performance goal	Negative Rank	0	.00	.00	−2.677	.007
	Positive Rank	9	5.00	45.00		
	Equal	2				
Achievement goal	Negative Rank	0	.00	.00	−2.684	.007
	Positive Rank	9	5.00	45.00		
	Equal	2				
Learning environment stimulation	Negative Rank	1	2.50	2.50	−2.732	.006
	Positive Rank	10	6.35	63.50		
	Equal	0				
Motivation toward science learning (Total score of the scale)	Negative Rank	0	.00	.00	−2.934	.003
	Positive Rank	11	6.00	66.00		
	Equal	0				

students' learning desire, self-confidence, computational thinking and teamwork in secondary school 6th grade science subjects. Moreover, it can be stated that arduino-assisted robotics coding activities increase students' attitudes toward robotics.

Findings related to the third research question

The scores of the secondary school 6th grade students on self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation dimensions regarding pre and post applications motivation scale toward science learning were analyzed with wilcoxon signed rankings test and the related findings were given in Table 5.

When Table 5 was examined, it was determined that the implementation of arduino-assisted robotics coding activities in science subjects showed that students' pre and post application scores on self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation regarding their motivation for science and total scores of the scale showed a statistically significant difference [$z_{(\text{self-efficacy})} = -2.812$, $z_{(\text{active learning strategies})} = -2.047$, $z_{(\text{science learning value})} = -2.736$, $z_{(\text{performance goal})} = -2.677$, $z_{(\text{achievement goal})} = -2.684$, $z_{(\text{learning environment stimulation})} = -2.732$, $z_{(\text{motivation toward science learning})} = -2.934$, $p < .05$)]. When the mean and sum of the difference scores are taken into consideration, it is seen that these differences observed in the dimensions of self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, learning environment stimulation and in the whole scale are in favor of positive rankings, i.e. posttest score. The effect sizes of these determined differences were found to be high ($r_{\text{self-efficacy}} = .85$, $r_{\text{active learning strategies}} = .62$, $r_{\text{science learning value}} = .83$, $r_{\text{performance goal}} = .81$, $r_{\text{achievement goal}} = .81$, $r_{\text{learning environment stimulation}} = .82$, $r_{\text{motivation toward science learning}} = .88$). According to these results, the application of arduino-assisted robotics coding activities in the 6th grade science subjects has a significant effect on improving students' self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation. Furthermore, it can be stated that the application of arduino-assisted robotics coding activities on science subjects increases the motivation of students toward science learning.

Table 6. Students' Opinions about The Situations in Which Daily Life Is Linked with Robotics Coding Applications.

Students' opinions	f	%
Solving traffic problem	1	4
To help the visually impaired to find their way	3	12
To meet the nutritional needs of animals	1	4
To facilitate the daily lives of the elderly	1	4
To use solar energy efficiently	6	24
To ensure timely watering of plants	2	8
To ensure recycling	4	16
To prevent air, soil and water pollution	5	20
To identify health problems	1	4
To ensure security in homes	1	4

Qualitative findings

Findings related to the fourth research question

The students were asked "*Which problems you observe or encounter in daily life can be solved by using arduino-assisted robotics coding application?*" during the interviews conducted after the applications. The frequency and percentage values of the students' responses to this question are given in Table 6.

When Table 6 is examined, it is seen that students state that they can use arduino-assisted robotics coding applications to solve various problems they face in daily life. These situations are found to be related to traffic, people with disabilities, animals, elderly people, energy, plants, recycling, environment and pollution, health and safety. In addition, it was observed that students produced many ideas (fluency) by using arduino-assisted robotics coding applications (10 students produced 25 ideas in total). Most of these ideas produced by the students were found to be different from the proposed ideas (flexibility). In addition, it was found that students produced an unordinary number of ideas (originality) in using arduino-assisted robotics coding applications to solve various problems they face in daily life (ideas encountered in less than 5% and 5% – 10% people). In this context, it can be said that secondary school 6th grade students have high creativity in linking arduino-assisted robotics coding practices with daily life. The students' responses on this are as follows:

> Student-5: *I would like to make a feeding machine for animals living on the street with robotics coding. This machine will detect the animal that wants to be fed with the help of sensors and give it food in a container.*

> Student-7: *I can use my pulse sensor to check my health. If I have a problem with my heart rate and pulsation, then I would think that I should go to the doctor immediately.*

Findings related to the fifth research question

The students were asked "*Do you want to learn science subjects with arduino-assisted robotics applications? Why?*" and "*Do you want to receive advanced education in Arduino-assisted robotics coding applications? Why?"* during the interviews conducted after the applications. The frequency and percentage values of the students' responses to the first question were given in Table 7.

When Table 7 is examined, it is seen that all of the students are willing to learn with arduino-assisted robotics coding applications on science subjects. Furthermore, it was determined that the students expressed various opinions about the reasons for their willingness. The most prominent student opinion was found that the use of arduino-assisted robotics coding applications in science subjects provided a fun learning environment (f: 10). Besides, the students stated that they wanted such applications to be used in science classes since they allowed them to discover new things (f:8) and since robots interest them (f:8). In this context, it can be said that students' attitudes toward robotics applications in science subjects are high. The students' responses on this are as follows:

Table 7. Students' Willingness to Use Robotics Applications in Science Subjects and Their Reasons.

Willingness	f	%
Willing	10	100
Unwilling	0	0
Reasons		
Providing a fun learning environment	10	20.8
Allowing me to discover new things	8	16.6
Robots interest me	8	16.6
Arousing curiosity for robotics technologies	6	12.5
Enjoying the robotics mechanism	6	12.5
Being curious about how robots work	5	10.4
Desire to learn about robotics	5	10.4

Table 8. Students' Willingness to Receive Training on Robotics Coding Applications and Their Reasons.

Willingness	f	%
Willing	10	100
Unwilling	0	0
Reasons		
To be better in my future profession	8	19.2
To solve the problems we face in daily life	7	16.8
To follow technology closely	7	16.8
To make learning enjoyable	6	14.4
To participate in competitions related to robots	5	12.0
Because I like robotics applications	5	12.0
To be able to look at situations from different perspectives	3	7.2

Student-4: *I would very much like to learn with arduino-assisted robotics coding applications in science class. Because robotics coding application makes me produce new things.*

Student-9: *I would like robotics coding to be used in science classes and learn the subjects in this way. Because robots interest me, and I enjoy building them.*

The frequency and percentage values of the students' responses to the second question were given in Table 8.

When Table 8 is examined, it is seen that all of the students are willing to receive advanced level education about arduino-assisted robotics coding applications. Furthermore, it was determined that the students expressed various opinions about the reasons for their willingness. It was determined that students stated the most in their opinions that robotics coding applications would be beneficial in becoming better in their future profession. In addition, the students stated that they would like to receive education in order to use the robotics coding applications to solve the problems they face in daily life and to follow the technology closely. Besides, the students stated that they would like to receive advanced education on this subject because they find such applications enjoyable. In this context, it can be said that it is important for students to have positive attitudes toward such applications in their education about robotics coding. The students' responses on this are as follows:

Student-6: *I would like to study robotics coding. Because it is fun to work with robots.*

Student-10: *I would like to study robotics coding. Because I want to take part in robot-related competitions.*

Findings related to the sixth research question

The students were asked "*What do you think about science courses where Arduino-assisted robotics coding applications are realized?*" during the interviews conducted after the applications. The frequency and percentage values of the students' responses to this question are given in Table 9.

Table 9. Students' Opinions about Science Courses Where Robotics Coding Applications Are Performed.

Students' opinions	f	%
Science lessons are now more fun	10	18.0
It is exciting to use technological tools in science class	9	16.2
I'm more willing to attend science class	9	16.2
It is easier for me to understand science subjects	8	14.4
I like to link science subjects with everyday life	7	12.6
It is exciting to build a robotics mechanism in science class	7	12.6
Using technology in science class makes science easier to learn	5	9.0

When Table 9 is examined, it is seen that the students express various opinions about science courses in which arduino-assisted robotics coding applications are performed. In these opinions, students stated that science lessons were now more fun, that it was exciting to use technological tools, and that it was easier to understand science subjects and they were more willing to participate in the lesson. Moreover, the students emphasized that they liked the associations by giving examples from daily life in science classes and that it was exciting to establish a robotics mechanism. In this context, it can be said that students have high motivation for science courses where robotics coding applications are realized. The students' responses on this are as follows:

Student 2: *Science lessons are now very fun. Now I am more willing to participate in the lesson because we build robotics mechanisms.*

Student-10: *I understand science better when we use technology in science class. Science lessons are a lot of fun.*

Discussion and conclusion

In the first result of the research, it was determined that the use of arduino-assisted robotics coding applications in science teaching supported the development of students' scientific creativity. In addition, it was determined that students produced ideas by associating with the robotics coding applications for problematic issues related with environment, traffic, energy, recycling, health and safety; and that the ideas produced were different and that they designed unordinary applications. Considering the fact that students produced a large number of ideas, proposed different ideas and designed unordinary applications, it can be said that they improved their creativity by means of robotics coding applications. This improvement might have several reasons. The first reason may be that students use various robotics sensors, such as heat, temperature, pulse, light, sound, and current, to provide an easy way for them to relate science subjects to daily life, and provide experiences in this direction in robotics coding applications conducted within the scope of the study. In this way, the students make an effort to produce ideas to find solutions to the problems they observe or encounter in the vicinity of these sensors and try to reach conclusions by concretizing these ideas with robotics mechanisms. It can be said that this situation improves students' creativity by enabling them to think differently and critically. The second reason may be that robotics coding applications allow students to think from different perspectives in line with a given problem situation (for example; what can be done to ensure that solar panels generate energy from sunlight in the most efficient way?) and to produce unordinary ideas by establishing new robotics mechanisms. Hence, students will design new mechanisms and projects in line with their creativity in an effort to produce solutions focusing on a problem. It can be said that this situation increases students' development by stimulating their creativity. With regard to this situation, Costa and Fernandes (2008) found that robot competitions and robot project applications contributed positively to students' cognitive development such as problem solving and finding different practical solutions to problems. Catlin (2012) emphasized that robotics coding applications were effective in building creative environments for students. Kucuk and Sisman (2017) stated that robotics applications with young age students improved students' imagination, created a product development environment and developed their contextual thinking skills.

In the second result of the research, it was found that the use of arduino-assisted robotics coding applications in science teaching improved students' attitudes toward robotics. Besides, in the interviews, students stated that robots provided a fun learning environment, supported discovery of new things in the classroom environment and attracted their interest. Furthermore, the students also emphasized their willingness to receive advanced training in robotics coding applications. The applications made here may have led to positive development of attitude as one of the affective domains because they enable students to produce something using technology, make students actively participate in classes, make the lesson fun, complete the task given in collaboration with groups, and allow to design something new, different and creative. According to Zint (2002), attitudes are learnable and teachable. The interest, excitement and curiosity of something leads to the development of a positive emotion and attitude toward a lesson or something, thus enables achievement in it. Therefore, attitude, which is one of the affective characteristics in cognitive development, is important. Thus, it is seen that attitude develops positively in the studies where robotics applications are made experimentally (Akkoc Okkesim et al., 2019; Fokides et al., 2017).

In the final result of the research, it was determined that the use of arduino-assisted robotics coding applications in science teaching positively affected students' motivation toward science. Also, in the interviews, students stated that the courses were fun with robotics coding, the use of technological tools in the courses was exciting, and science subjects were easier to understand with such applications. In the literature, it was reported that robotics coding applications not only enabled students to develop their cognitive processes but also activated motivating factors (Anderman & Young, 1994; Lee & Brophy, 1996; Pintrich, 2003). Considering that motivation is one of the important factors in the success of students' as one of their cognitive skills (Anderman & Midgley, 1997; George, 2006; Guay et al., 2010), the effect of developing motivation on learning in the classroom environment has become important. In this respect, the robotics coding applications in the study enable the students to participate actively in the courses by using different methods such as cooperative learning, project based learning and 5E learning model. In addition, such applications are more stimulating and exciting in the classroom environment makes science subjects easier to understand. For these reasons, robotics coding applications may have had a positive effect on students' motivation. Also, such applications are thought to have positive effects on motivation because they are fun (You & Kapila, 2017) and facilitate learning and it is stated in the literature that such activities lead to a positive development of motivation toward the course (Álvarez & Larrañaga, 2016; Ortiz, 2015; Zengin, 2016).

As a conclusion, this present research results showed that the use of arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching improve students' scientific creativity, attitudes toward robotics and motivation toward science. In this context, the use of robotics coding applications in the teaching of science subjects is important for the development of students' cognitive and affective domains because, with such applications, students firstly generate ideas for the solution of a problem related to daily life in which science concepts are involved, create algorithms and perform block-based coding in line with these algorithms. Then, students use science concepts to set up robotics devices and reach the solution of the problem. Thus, students are exposed to situations requiring creativity such as generating new ideas and creating algorithms. In addition, abstract concepts (e.g., the concepts of renewable energy, energy efficiency, electricity, voltage, current, pulse, electrical conductivity and sound included in the current study) are embodied with technological applications, and an active learning environment is created through cooperation and teamwork. This has a positive effect on students' affective domain such as attitude and motivation. In relation to this, Kozcu Cakir and Guven (2019) stated that in a science teaching where the concept of pulse, which is an abstract concept, was integrated into the 5E learning model through arduino-assisted robotics coding applications students constructed abstract concepts more easily in their minds, their computational thinking skills improved, their attitudes toward technology increased and they related science concepts to daily life. Scaradozzi et al. (2015), on the other hand, stated that the use of such applications in classroom activities enables students to cooperate and work in groups, leading to creation of active learning environments.

Recommendations

It is recommended to establish robotics mechanisms in the concretization of abstract concepts in science courses, the students be given coding training first in order to realize the applications and then to start robotics applications and conduct courses with associations to daily life. However, the generalizability of the study results is limited due to a small number of participants. A quasi-experimental study with a larger number of participants should be considered in the future. In addition, this study can provide researchers with guidance in examining the effects of robotics coding applications integrated into 5E learning model in science teaching on different variables. Moreover, it is recommended that teachers receive in-service trainings for such applications and schools should establish laboratories with adequate technical equipment for robotics coding applications.

Limitations

Several limitations were present in the study reported here. The limitations of the current study include the following; (a) there is no control group, thus, there is a problem related to the internal validity, (b) the school selected is a private school having rich physical conditions and equipments, (c) the number of the participants is small, thus, the generalizability is low, (d) only the subjects of energy, sound, electricity and circulation system are addressed, (e) only the Arduino microcontroller card and its basic components are used as it is easy to use and cheap and (f) mBlock program is used as the coding platform as it is block-based and easy to use.

Compliance with ethical standards

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Disclosure statement

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