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To cite this article:

Erol, O., Sevim-Cirak, N., & Başer Gülsoy, Y. G. (2023). The effects of educational robotics activities on students' attitudes towards STEM and ICT courses. *International Journal of Technology in Education (IJTE)*, *6*(2), 203-223. https://doi.org/10.46328/ijte.365

International Journal of Technology in Education
2023, Vol. 6, No. 2, 203-223 https://doi.org/10.46328/ijte.365

The Effects of Educational Robotics Activities on Students' Attitudes towards STEM and ICT Courses

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Article Info

Article History

Received:
28 September 2022
Accepted:
20 April 2023

Keywords

Educational robotics
Arduino
STEM
ICT course

Abstract

This study aims to investigate the effect of robotics design with Arduino on students' attitudes towards ICT courses and STEM. In this context, robotics design activities with Arduino were conducted with an experimental group, while the current IT curriculum was applied to a control group. The study lasted for a period of 12 weeks and was conducted with 53 middle school students. The Information & Communication Technologies Course Attitude Scale (ICTCAS) and STEM Attitude Scale (SAS) were used as data collection tools. The study's findings revealed that robotics design activities with Arduino increased the students' attitudes towards engineering and technology in the context of STEM and ICT courses. Additionally, the participating students supported the use of robotics activities in their ICT course, and they reportedly found the activities to be fun, interesting, different, difficult, complex, and time-consuming. During the first weeks of the study, the students were excited, very curious, interested, enthusiastic, worried, and hesitant to participate in the activities and avoided them. However, in the subsequent weeks, they gained practical experience related to the activities and took on a more active role in the class.

Introduction

Recent developments in technology have increased the need for people to be well-trained in various areas of technology. In this era, people who produce technology rather than just use it are much needed in today's world (Sáez-López et al., 2016). It is therefore important for education systems to raise well-educated people with sufficient capabilities and the necessary skills to lead nations forward to tomorrow (Fadzil & Saat, 2014). Technology has become more and more complex, and employees are therefore required to gain both new knowledge and 21st-century skills such as communication, creativity, critical thinking, collaboration, and problem-solving (Binkley et al., 2012; Greenstein, 2012). Hence, countries are seeking ways to help their students to develop appropriate skills and to gain the right knowledge in order to design and develop scientific literacy, technology, and innovation that can strengthen their nation's place within the global economy (Zainal et al., 2018). To achieve this goal, it is important to first create a desire in students to study in the STEM field, since people well-trained in STEM areas can more effectively enhance the development of technology (Kandlhofer & Steinbauer, 2016). For many countries, it has become important to increase the number of graduates in the STEM field (Zainal et al., 2018), and this drive has resulted in changes to the educational approach and curricula of numerous countries' national educational system (Sisman et al., 2020). Recently, STEM education has started to become more integrated into the traditional educational settings (Ormond & Zandvliet, 2016) with the aim being to attract an increasing number of students to STEM-related courses and projects, and thereby to motivate them to choose a career within the STEM field in order to fulfill the demand for tomorrow's workforce (Vennix et al., 2018).

Educational robotics (ER) is widely regarded as an effective tool for STEM-based activities that can direct the attention and motivation of students towards STEM fields. Consequently, the use of ER applications in educational settings has become a common approach worldwide (Freeman et al., 2017; Gomoll et al., 2016; Nugent et al., 2016). ER activities are now conducted in many countries (Kandlhofer & Steinbauer, 2016). According to the 2017 Horizon Report, educational robots will likely become even more significant in educational settings in the future (Freeman et al., 2017).

Research on the use of educational robots has demonstrated that ER activities can have a positive impact on students' STEM education (Benitti, 2012). It has been established that ER can be beneficial for teaching and learning in STEM (Nugent et al., 2016). Furthermore, ER has been found to enhance students' attitudes and interest in STEM by fostering the development of various skills in these fields (Sisman et al., 2020). ER activities help students to gain a conceptual understanding of STEM and to enhance their higher-order learning in the STEM field (Benitti, 2012; Eguchi, 2016). Hence, ER is seen as being effective in the teaching of a STEM-oriented curriculum (Alemdar & Rosen, 2011).

Although the literature indicates positive results, studies have generally been conducted in robotics competitions camps or as part of short-term courses as extracurricular activities (Sisman et al., 2020). Hence, the effects of their application in the long-term on students' attitude towards STEM should be investigated deeply in order to gain a more accurate insight with regards to its effects. More studies should therefore be conducted that show how robotics can be integrated and utilized in the STEM field, and thereby create effective STEM curricula and teaching-learning strategies (Alimisis, 2013; Benitti, 2012). To investigate the effects of ER on students' interest and attitudes towards STEM, long-term, well-planned experimental studies should be conducted (Sisman et al., 2020). Hence, the current study aims to investigate the effect of robotics design with Arduino on students' attitudes towards an ICT course and to STEM. Based on this objective, the current study sought answers to the following research questions:

- Is there a significant difference between a participant study group that designed robots with Arduino and a group that learned according to the current IT course curriculum in terms of their attitudes towards ICT courses and STEM?
- What were the participants' experiences with robotics activities?

Theoretical Framework

In the early 1990s, a new movement named "STEM," which is an acronym standing for Science, Technology, Engineering, and Mathematics, was first presented. At the earlier stage, the National Science Foundation had used the acronym “SMET” rather than “STEM,” due to phonetic reasons, it was changed to STEM (Martín-Páez et al., 2019). STEM is an interdisciplinary approach that combines the four major disciplines of science, technology, engineering, and mathematics (Meng et al., 2014). It aims to develop students' 21st-century skills and produce more STEM-literate citizens (Phang et al., 2017; Zainal et al., 2018). The focus is on applying lessons in daily life and gaining skills such as critical thinking, problem solving, collaboration, and communication (Knezek et al., 2013).

Educational robotics (ER) is a tool that enhances the learning process in STEM and computer science at all educational levels (Rogers & Portsmore, 2004). ER uses principles from various fields such as physics, engineering, mathematics, and technology to design, construct, and use robots (Souza et al., 2018). ER is a powerful, motivating, and engaging tool (Alimisis, 2013). It is considered one of the most effective ways to introduce students in primary and secondary education to the field of STEM (Mosley et al., 2016) through hands-on experience (Bruder & Wedeward, 2003).

The combination of Educational robots (ER) with STEM applications offers alternative learning strategies to students (Holmquist, 2014). Robotics activities generally include, but are not limited to, problem definition, the design and construction of robots, testing, diagnosing, and solving encountered problems, applying revisions, and realizing trade-offs (Sullivan, 2011). When students engage in robotics programming and the writing of algorithms, they are required to utilize their knowledge of programming languages as well as their mathematical skills, and when they design the structure of robots, they need to make use of their scientific skills and knowledge. Since students see the implications of mathematics and science by engaging in robotics activities, they are better able to understand the meaning of the STEM field (Sisman et al., 2020).

ER activities are applied within a constructivist environment in which students actively design and develop robots while learning (Alimisis, 2013). ER activities are generally designed based on constructivist and constructionist experiential learning (Sisman et al., 2020). Seymour Papert, the pioneer who first used interactive educational tools such as computers and robots in the learning process, believed that physical interaction and building are interlinked (Souza et al., 2018). Papert stated that students adjust their knowledge based on new experiences; therefore, through practical activities in which students develop virtual or physical products, they gain and build upon their existing knowledge (Papert, 1986).

During ER activities, children use robotics and software to improve their programming skills for robots.There is a variety of educational robotics for kids that students can utilize in designing programmable robots. Some of these robotics for kids setups are offered by commercial enterprises such as LEGO-MINDSTORMS, while others offer open-source and more cost-effective robotics kits like ArduinoIn robotics-based activities, students program robots using text-based commands such as Arduino IDE or block-based visual programming tools such as Scratch, Mblock, Lego Classroom, etc. In addition, they can incorporate various sensors like color, sound, touch, and infrared to build interactive robots. Hence, students can develop various robots that perform different functions that meet predefined goals and are able to see the results immediately (Alimisis, 2013; Sisman et al., 2020).

ER activities can have a positive impact on students' learning of programming languages (Atmatzidou & Demetriadis, 2016; Cheng et al., 2013; Master et al., 2017), and thereby help them to learn programming and engineering (Petre & Price, 2004). Robotics is also used to teach computer programming concepts like iteration and control structures (Sullivan & Lin, 2012), and to improve students’ skills in several areas such as programming, mechatronics, and robot construction (Ponce et al., 2017). Hence, it is considered to positively contribute to classroom teaching (Benitti, 2012). Moreover, ER activities provide an opportunity for students to create their own products (Lin et al., 2009) and to realize the results of their calculations and knowledge (Sisman et al., 2020). Therefore, ER activities may positively affect students’ attitudes towards STEM, and thereby increase their motivation to pursue studies within the STEM field. In fact, the literature contains a variety of research that demonstrates the positive effect of robotics activities on students’ attitudes and interest towards STEM (Eguchi, 2016; Kandlhofer & Steinbauer, 2016; Karışan & Yurdakul, 2017; Kynigos et al., 2018; Master et al., 2017; Nugent et al., 2016; Zainal et al., 2018). ER activities have been reported to affect the attitudes of students towards their willingness to study robotics, technology, and engineering (Sisman et al., 2020).

Studies have also shown that ER activities help students to develop skills deemed necessary for the modern workforce, such as creativity (Mikropoulos & Bellou, 2013), cooperation (Ardito et al., 2014; Yuen et al., 2014), critical thinking, and logical reasoning (Blanchard et al., 2010; Eguchi, 2016), computational thinking (Atmatzidou & Demetriadis, 2016; Keane et al., 2016), problem-solving (Lin et al., 2009), and communication skills (Nelson, 2014), as well as basic STEM skills like math, science, and engineering design skills (Eguchi, 2016; Kandlhofer & Steinbauer, 2016; Nugent et al., 2016). ER activities enhance cooperative learning by creating a collaborative learning environment (Mitnik et al., 2009) where students can work on problems in small groups, helping them to develop higher-order skills (Menekse et al., 2017).

In addition, the studies also demonstrate that ER is a valuable tool to motivate students in scientific education and to pursue careers within the STEM field (Atmatzidou & Demetriadis, 2016; Morgan et al., 2019). Indeed, a number of researchers have reported the benefits of ER activities on students. For instance, Eguchi (2016) collected data from students who attended a robotics competition in order to understand their attitudes towards STEM, and found that ER increased students’ learning and their motivation to explore the STEM field more in the future. Similarly, Barak and Assal (2018) conducted a study with 32 primary school students over a 15-week period and found that ER helped to create an attractive and rich learning environment for STEM education. In their quasi-experimental studies with sixth-grade students, Karışan and Yurdakul (2017) found that participants who attended STEM activities developed positive attitudes toward science, math, engineering, and 21st-century skills, whereas the attitudes of participants in the Control Group, who took party in activities within a regular science education course, had not significantly changed. They observed that students focused their attention on the STEM activities and even wanted to continue with the activities afterwards and also to complete similar activities (Karışan & Yurdakul, 2017). Recently, Sisman et al. (2020) conducted a study that reported positive attitudes towards STEM among the participants. The study found that the participants held high attitudes towards technology and engineering. The pretest and posttest scores indicated an increase in students' interest in science, technology, engineering, math, and 21st-century skills, with a high effect size. The authors concluded that even students who had positive attitudes towards STEM fields were further enhanced by the end of the training (Sisman et al., 2020).

Compared to the aforementioned studies, some studies have demonstrated no significantly positive results regarding the use of ER. For instance, Leonard et al. (2016) found that eighth-grade students' attitudes toward STEM did not change significantly after attending ER activities. Similarly, Karaahmetoğlu and Korkmaz (2019) investigated the effects of ER activities with 33 sixth-grade students and found that the students who attended block-based robotics programming activities did not significantly differ from those who used block-based programming tools in terms of their self-perception scores toward basic STEM skills.

Method

In the current study, a pretest-posttest, quasi-experimental design was employed with a control group. The dependent variables of the study were attitude towards ICT courses and attitude towards STEM based on the context of four factors (math, science, engineering & technology, and 21st-century skills). The independent variable was the instructional method applied (robotics design with Arduino, vs. the current IT course curriculum). The research design of the current study is presented in Table 1.

Table 1. Research Design

Group	Pretest	Process	Posttest
Control	ICT Course Attitude Scale STEM Attitude Scale	Current IT course curriculum	ICT Course Attitude Scale STEM Attitude Scale Interview
Experimental		Robotics design with Arduino	

Participants/ Study Groups

This experimental study was conducted with a total of 53 sixth-grade students attending an "Information Technologies and Software" course at a middle school in Turkey. Two different sixth-grade classes were randomly selected as an Experimental Group (n = 27) and a Control Group (n = 26). The participants' demographic characteristics are presented in Table 2. Accordingly, the gender distribution of the participants was similar across both study groups.

Table 2. Participants' Demographic Characteristics

Group		***f***	**%**
Experimental	Male	15	55.6
	Female	12	44.4
	Total	27	100.0
Control	Male	15	57.7
	Female	11	42.3
	Total	26	100.0

Data Collection Tools

In the study, the Information & Communication Technologies Course Attitude Scale (ICTCAS) and the STEM Attitude Scale (SAS) were used as data collection tools. The ICTCAS was developed by Şahin (2010) and includes 20 items under a single factor that determines secondary school students' attitudes towards ICT courses. Şahin (2010) calculated the Cronbach-α reliability coefficient of the scale as .809; whilst in the current study it was calculated as .870. Some of the scale's items were reversed while scoring due to negative expressions.

The SAS was developed by Faber et al. (2013) and later adapted to the Turkish context by Yıldırım and Selvi (2015). The SAS includes 37 items under four factors that determine secondary school students' attitudes towards mathematics, science, engineering and technology, and 21st-century skills within the STEM framework. The scale has eight items under the "math" factor, nine items under "science," nine items under "engineering and technology," and 11 items under the "21st-century skills" factor. In Yıldırım and Selvi's (2015) adaptation study, the Cronbach-α reliability coefficient of the scale was calculated for each of the four factors of the scale as being between .86 and .89, whereas for the current study they were calculated as between .80 and .89 for the four factors. A semi-structured interview form was also used in the current study to ascertain the participants' views on the robotics activities. The form was prepared by the researchers in accordance with expert opinion, and includes questions regarding the participants' general views on ER activities, any motivating and/or challenging factors, and the participants' opinions on the inclusion of robotics activities in an ICT course. Interviews were conducted randomly with six students selected from the Experimental Group following conclusion of the posttests. In addition, throughout the experimental process, the researchers maintained weekly diaries regarding the participants' attitudes and approaches to the activities and their experiences.

Procedure

The intervention of the study lasted for a period of 12 weeks and was implemented as part of an existing two-hour Information Technologies and Software course. The current course curriculum was conducted for both the control and the experimental group at least one hour per week. In the second hour, the control group worked on the robot and robotics concept, draw and modeled their imaginary robots with paper and materials. The experimental group was engaged in robotics design activities with Arduino. All necessary ethical permissions were obtained prior to the commencement of the study, and participatory approval obtained from the students' parents and the school's management. The implementation process for both groups is included in Figure 1 in detail.

Data Analysis

In the study, a 2x2 mixed-design ANOVA was employed in order to analyze changes in the participants' attitude towards the ICT course according to group (control/experimental) and time period (pretest/posttest). In addition, MANOVA was employed to examine changes in the participants' attitudes towards STEM in the context of four factors (math, science, engineering & technology, and 21st-century skills) by group (control/experimental), and also by time period (pretest/posttest). Prior to performing MANOVA, the data were analyzed for the assumptions of MANOVA. The values required for the univariate normality condition (skewness, kurtosis values and histogram, Q-Q plot) were examined, and it was observed that all factor variables in each group showed a normal distribution.

Week	Control Group		Experimental Group	
	1st Hour	*2nd Hour*	*1st Hour*	*2nd Hour*
1st	Data Collection (Pre-test)		Data Collection (Pre-test)	
2nd	**Unit 1:** Information and Communication Technologies	**Phase 1:** Programming basics, robotics & engineering	**Unit 1:** Information and Communication Technologies	**Phase1:** Introduction to robotics and Arduino Block-based coding tool: Mblock Basic coding activities with Mblock
3rd				
4th				
5th	**Unit 2** :Ethics and Safety		**Unit 2** :Ethics and Safety	
6th		**Phase 2:** Designing and modeling robots (drawing and modeling with paper and materials)		**Phase 2:** Arduino Activities with Specific Components (LED and Buzzer, Button, LDR Light Sensor, LM35 Heat Sensor, HCSR04 Ultrasonic, Distance Sensor, Servo Motor, DC Motor)
7th				
8th	**Unit3:** Computer Networks		**Unit 3:** Computer Networks	
9th				
10th		**Phase 3:** Presentation (Showing and explaining the imaginary robots with peers)		**Phase 3:** Arduino Project Competition (Obstacle Avoiding Robot Design & Maze)
11th	**Unit 4:** Office Tools		**Unit 4:** Office Tools	
12th				
13th				
14th	Data Collection (Post-test)		Data Collection (Post-test)	

Figure 1. Course Content of Each Group

For the multivariate normal distribution, Mahalanobis distance values and outliers were examined, and it was established that the distance values were not higher than the critical value of 18.47 (Akbulut, 2010; Pearson & Hartley, 1958). For linearity, scatter plots of each factor were examined, and it was seen that all the plots were elliptical. When the Box's M-value was examined, it was revealed that the variance-covariance matrix homogeneity assumption was met ($p > .05$). As a result of the correlation made with the assumption of multiple linear connections, it was seen that a relationship existed between all of the factor variables and that there was no value that would cause a singularity problem.

Also, as a result of the MANOVA analysis, separate ANOVA tests were conducted in order to better examine the effect of any significant differences according to each factor. In case of any significant differences found as a result of the analysis, the simple main effect analysis was conducted in order to examine the change in detail for each dependent variable (ICT Course Attitude and STEM Attitude factors). An independent *t*-test was used while comparing the means according to each group (between groups), and dependent samples (paired) *t*-test was conducted separately for each group to compare the mean values according to the time period (pretest/posttest). The significance value was divided by the number of tests by applying the Bonferroni correction in order to prevent statistical errors in all main effect analyses.

To determine the magnitude of any differences, η^2 effect size value was then examined. According to Cohen (1988), if the effect size value is between .01 and .06, it is accepted as being "small," between .06 and .14 as "medium," and .14 or above as a "large" effect. In cases where no difference was established, statistical power was reported. Furthermore, the data were analyzed in the context of its normal distribution, and it was seen that the data showed normal distribution for both groups and for all measurements.

Data obtained from the interviews conducted and from the researcher diaries were interpreted by way of descriptive analysis. The purpose of this qualitative data analysis was to summarize and interpret the findings obtained from interviews and diaries (Yıldırım & Şimşek, 2003). In addition, direct quotations from interviews are frequently included in order to support the findings.

Findings

Table 3 presents the descriptive statistics of the participants' attitude towards ICT course scores and attitude towards STEM factor scores for the Experimental and Control groups.

Table 3. Descriptive Statistics

Variable		**Pretest**		**Posttest**	
		M	***SD***	***M***	***SD***
ICT Course Attitude	Experimental Group	69.19	10.60	76.30	12.71
	Control Group	67.27	11.37	67.80	13.28
STEM Factor 1: Math	Experimental Group	29.16	6.15	31.07	5.97
	Control Group	29.62	6.18	30.76	6.06
STEM Factor 2: Science	Experimental Group	37.04	5.84	37.07	4.98
	Control Group	32.50	6.80	35.04	4.65
STEM Factor 3: Engineering and Technology	Experimental Group	33.67	5.39	36.41	4.88
	Control Group	30.23	6.62	33.46	3.17
STEM Factor 4: 21st-century skills	Experimental Group	46.26	5.19	46.56	5.37
	Control Group	41.93	7.85	44.85	3.86

According to Table 4, there was no significant difference found to exist between the students' ICT Course Attitude Scale scores based on the group variable ($F(1,51) = 3.136$, $p = .83$, Power = .412). However, there was a significant difference found based on the time variable ($F(1,51) = 6.358$, $p < .05$, $\eta^2 = .111$) and the interaction effect of the time and group variables between students' scores on the ICT Course Attitude Scale ($F(1,51) = 4{,}694$, $p < .05$, $\eta^2 = .084$). So, it could be argued that scores of the students' ICT Course Attitude Scale differed based on the time variable (pretest/posttest) and group variable (Arduino/current course content) through the interaction effect. Furthermore, the effect size values (Time: $\eta^2 = .111$ and Time*Group: $\eta^2 = .084$) demonstrated a large effect (Cohen, 1988).

Table 4. ANOVA Results of Participants' Attitudes towards ICT Course Scores based on Group and Time Variables

Source	***SS***	***df***	***MS***	***F***	***p***	**η^2**	**Observed Power**
Between Groups							
Groups	716.93	1	716.93	3.14	.083	.058	.412
Error	11658.30	51	228.59				
Within Groups							
Time	387.53	1	387.53	6.36	.015	.111	.696
Time * Group	286.10	1	286.10	4.69	.035	.084	.566
Error	3108.56	51	60.95				
Total	16157.42	105					

In addition, the Experimental and Control group participants' ICT Course Attitude Scale scores based on the time variable are presented in Figure 2.

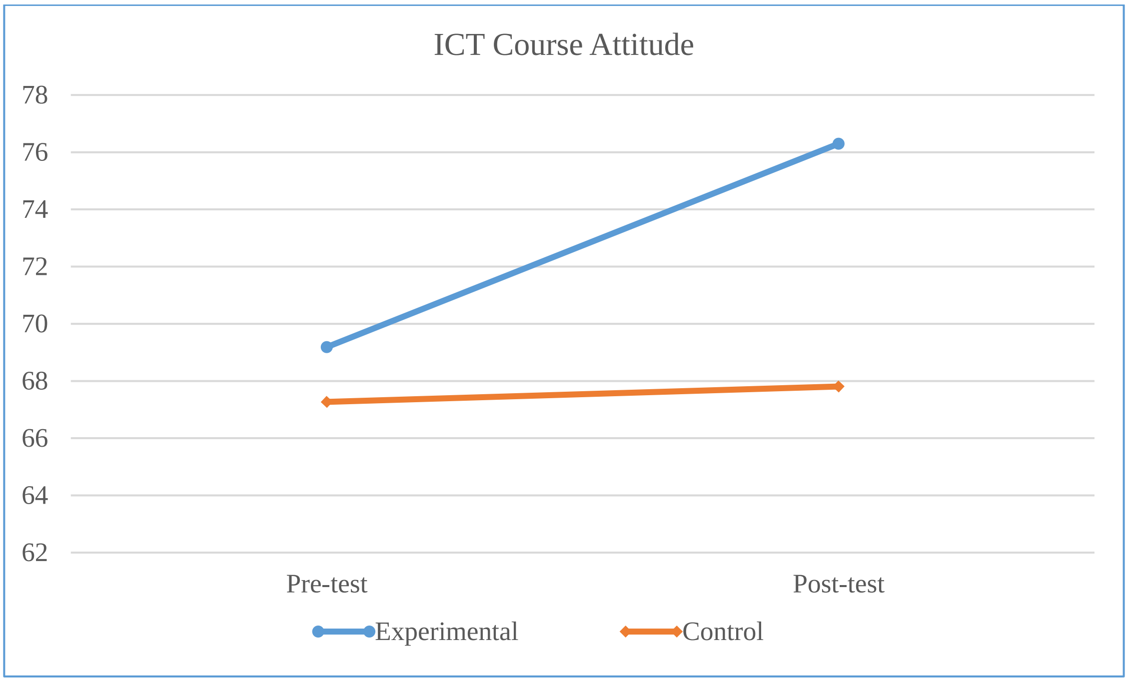

Figure 2. Students' ICT Course Attitudes Score Changes According to Time Variable

The conducted analyses of variance demonstrated that the time variable and the interaction of the time and group variables had a significant effect on the students' ICT Course Attitudes Scale scores. According to Figure 2, the attitude score increased for the Experimental Group but remained almost the same for the Control Group. A simple main effect analysis was performed to measure whether or not the attitude scores changes according to the group and time variables were significant.

When the students' ICT Course Attitudes Scale scores within the groups were compared according to the time variable, the Control Group showed a slight increase between the pretest and posttest ($t(25) = -0.245$, $p = .808$) which was not significant, whereas the Experimental Group did show a significant difference ($t(26) = -3.392$, $p < .025$). Therefore, it can be said that the students' ICT Course Attitudes Scale scores for the Experimental Group increased significantly from pretest to posttest. When the change in the attitude scores according to the group variable (between groups) was examined, it was found that no significant difference existed between the pretest scores of the Control and Experimental groups ($t(51) = 0.635$, $p = .529$), but that a significant difference was found between their posttest scores ($t(51) = 2.378$, $p < .25$). Accordingly, it can be said that the pretest scores of the Experimental and Control groups were similar, but that the posttest scores were highly in favor of the Experimental Group.

In addition, the MANOVA test was conducted to examine the participants' attitudes towards STEM in the context of four dimensions of the STEM Attitude Scale (math, science, Engineering & Technology, 21st-century skills); the results of which are presented in Table 5.

Table 5. MANOVA Results for Students' Attitudes towards STEM Factors based on Time and Group Variables

	Wilks' Λ	***F***	**Hypothesis *df***	**Error *df***	***p***	**η^2**	**Observed Power**
Group	.800	2.997	4.000	48.000	.028	.200	.756
Time	.704	5.042	4.000	48.000	.002	.296	.946
Time * Group	.921	1.033	4.000	48.000	.400	.079	.301

According to Table 5, there was a significant difference found between the students' attitudes towards STEM factor scores (math, science, Engineering & Technology, 21st-century skills) based on the group variable (Wilks'Λ = *.800*, $F(4,48) = 2.997$, $p < .05$) and the time variable (Wilks'Λ = .704, $F(4,48) = 5.042$, $p < .05$). However, there was no significant difference found based on the interaction effect of the time and group variables between the participants' attitudes towards STEM factor (math, science, Engineering & Technology, 21st-century skills) scores (Wilks'Λ = .921, $F(4,48) = 1.033$, $p = .400$). Although there was no significant difference in time and group interaction, it could be stated that the math, science, engineering and technology, 21st-century skills attitude scores of the participants differed based on the group variable (Arduino/current course content) and also the time variable (pretest to posttest) separately.

In order to ascertain which factor was the source of the difference, ANOVA tests were conducted for each of the four factors. In other words, separate ANOVA tests were conducted in order to separately and more closely examine the effect of the group and time variables for each factor; the results of which are presented in Table 6.

Table 6. ANOVA Results for STEM Factors Means based on Group and Time Variables

Source		***SS***	***df***	***MS***	***F***	***p***	**η²**	**Observed Power**
Math	Between Groups							
	Groups	.104	1	.104	.002	.967	.000	.050
	Error	3,136.670	51	61.503				
	Within Groups							
	Time	61.314	1	61.314	4.825	.033	.086	.577
	Time * Group	3.578	1	3.578	.282	.598	.005	.082
	Error	648.026	51	12.706				
	Total	3,849.692	105					
Science	Between Groups							
	Groups	286.096	1	286.096	5.866	.019	.103	.661
	Error	2,487.564	51	48.776				
	Within Groups							
	Time	43.929	1	43.929	3.017	.088	.056	.399
	Time * Group	41.439	1	41.439	2.845	.098	.053	.380
	Error	742.712	51	14.563				
	Total	3,601.740	105					
Engineering & Technology	Between Groups							
	Groups	269.720	1	269.720	7.237	**.010**	.124	.752
	Error	1,900.695	51	37.269				
	Within Groups							
	Time	236.156	1	236.156	14.744	**.000**	.224	.965
	Time * Group	1.590	1	1.590	.099	.754	.002	.061
	Error	816.900	51	16.018				
	Total	3,225.061	105					
21st Century Skills	Between Groups							
	Groups	242.051	1	242.051	5.322	.025	.094	.619
	Error	2,319.345	51	45.477				
	Within Groups							
	Time	68.639	1	68.639	3.354	.073	.062	.435
	Time * Group	45.696	1	45.696	2.233	.141	.042	.311
	Error	1,043.738	51	20.465				
	Total	3,719.469	105					

$p < .0125$

When the factor scores were examined, it could be seen that no significant difference was found to exist between the participants' math, science, and 21st-century skills attitude scores, based on the group and time variables, and the interaction effect. Also, no significant difference was found between the participants' attitudes towards engineering and technology scores based on the interaction effect of the time and group variables ($F(1,51) = .099$, $p = .754$, Power = .061), but there was a significant difference found based on the group variable ($F(1,51) = 7.237$, $p < .0125$, $\eta^2 = .124$) and time variable ($F(1,51) = 14.744$, $p < .0125$, $\eta^2 = .224$). Although there was no significant difference found according to time and group interaction, it could be argued that the engineering and technology attitude scores of the participants differed based on the group variable (Arduino/current course content) and time variable (pretest to posttest) separately. Also, the effect size value demonstrated a low-level effect for the group variable ($\eta^2 = .124$) and a medium-level effect for the time ($\eta^2 = .224$) variable (Cohen, 1988). In order to analyze the interaction effect in more detail, the Experimental and Control groups' engineering and technology attitudes scores based on the time variable are presented in Figure 3.

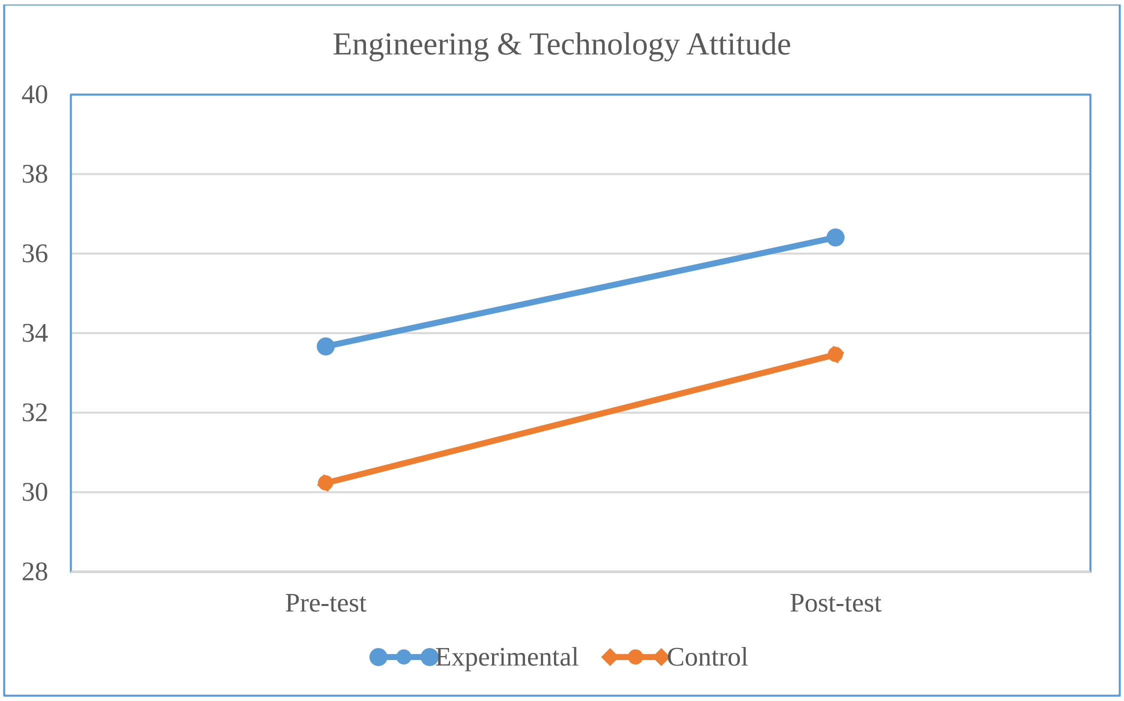

Figure 3. Students' Attitudes towards Engineering & Technology Attitude Score Changes According to Time Variable

A simple main effect analysis was conducted to evaluate changes in the scores according to the group and time variables. When the engineering and technology attitude scores within the groups were compared according to the time variable, there was no significant difference found to exist between the pretest and posttest scores of the Control Group ($t(25) = -2.490$, $p = .020$), whereas for the Experimental Group there was a significant difference found between their pretest and posttest scores ($t(26) = -3{,}127$, $p < .0125$). Accordingly, it can be said that the engineering and technology attitude scores for the Experimental Group increased significantly from pretest to posttest. When the change in engineering and technology attitude scores according to the group variable (between groups) was examined, it could be seen that no significant difference was found to exist between the pretest scores of the Control and Experimental groups ($t(51) = 2.077$, $p = .043$), but there was a significant difference found between their posttest scores ($t(51) = 2.597$, $p < .0125$). Therefore, it can be said that the pretest scores of the Experimental and Control groups were shown to be similar, but that the posttest scores were highly in favor of the Experimental Group.

Participants' Experiences with Robotics Activities

Robotics applications within the scope of the current study consist of activities that include the students' higher-level thinking skills, rather than just information acquisition and memorization, as the result of the learners' active participation. In this context, the ER activities applied in the current study differed from the current curriculum by including high-level thinking skills. In order to investigate the participants' opinions regarding the ER activities, interviews were conducted with the students at the completion of the study, and researcher diaries were also maintained throughout the process.

During the interviews, the students were asked about their opinions (likes and dislikes, what was considered motivating or challenging, etc.) regarding the ER activities. When the students' general thoughts on robotics activities were examined, it was seen that the students found the activities to be fun, interesting, different, difficult, complex, and time-consuming. In addition, the students stated that they liked the activities since it allowed them to design and code the robots, to see how their robots worked, and to control their robot using a computer. However, they also stated that sometimes they did not like situations such as when their robots did not work the way they had designed them to, or when they were struggling to identify and locate an error in their prototype (hardware and/or software) when they had insufficient time and/or materials. A selection of the student participants' views are as follows:

- *"It was fun to make robots in the computer course."* (S_1)
- *"I already love robots, so I was excitedly waiting for each lesson to happen."* (S_2)
- *"I didn't even want to finish the lesson, so I kept on going as it was a good experience for me."* (S_4)
- *", I was very happy when I managed to turn on the lamp."* (S_1)
- *"I was so excited when my robot moved."* (S_5)
- *"It was very interesting to do these activities in the lesson; it was very different for me."* (S_6)
- *"I sometimes had a hard time in the lesson as it was very complicated in terms of what and where we had to connect cables and pieces."* (S_3)
- *"First connecting the cables, then building the robot, and then trying to run it all took too long. Sometimes what we did was left unfinished when the lesson time was over."* (S_4)
- *"The thing that made me happy the most was that what I did was programmed from the computer. When I added blocks from the computer and clicked on the green flag, the lamp lit up, the robot moved and then stopped."* (S_2)
- *"I never thought that something I assembled would work when I programmed it from a computer."* (S_5)
- *"I think there should have been more material as I could not do some of the applications."* (S_3)
- *"I was very confused; had I connected the cables incorrectly or written the code wrong? I had a hard time with it at first."* (S_4)
- *"It was very difficult to build the robot and correctly place the right parts. I had to do it again when I got it wrong, and so it took too long."* (S_6)

When the opinions regarding the inclusion of robotics activities in the ICT course were examined, it was seen that a large proportion of the students supported the use of robotics activities in their ICT course. The students stated that the current IT course was sometimes boring, did not allow them to practice, and included similar and repetitive subjects. Some sample views from the students are as follows:

- *"I was very bored writing in MS Word on our computer course, and so I liked it even though it was difficult to make the robots and to do the coding. This semester, our lessons were much more fun."* (S_1)
- *"We were always doing the same thing in our computer course; we were playing games most of the time and so it was like a free lesson sometimes."* (S_2)
- *"It was boring not doing anything in our computer course. I was tired of just listening, but now we are doing something."* (S_3)
- *"We were coming to the lab last semester, our teacher was telling us something and we were just listening, and then we just played games. However, we always did something this semester, and I did not realize how quick the lesson time passed."* (S_4)
- *"Computer courses should be like this anyway; different from other lessons."* (S_5)

In addition, when the researcher diaries were examined, it was seen that some of the students were excited, very curious, interested, and enthusiastic whilst doing the ER activities; however, some of the students were worried and hesitant to participate in the activities, and avoided them during the initial few weeks. In the subsequent weeks, it was seen that the students gained practicality related to the ER activities, and took on a more active role in both the robot prototyping and coding processes. During the ER activities, the students generally experienced difficulties in completing the prototype correctly, and they sought help from their teachers and peers after having encountered problems. However, they experienced fewer problems during the coding process and overcame them largely through trial and error. The researchers stated in their diaries that a block-based coding tool makes it easier for students to overcome the problems they experience. The general opinion that emerges from the examination of the researchers' diaries is that the students experience fun and like doing the ER activities, even when they experience difficulties in some of the robotics activities.

Discussion

Students' attitudes and interest towards STEM are important to increase their STEM skills (Sisman et al., 2020). Positive STEM experiences at an early age are seen as a way to motivate students to pursuing a career in STEM, and hence this interest may lead to the further economic development of countries (Maltese & Tai, 2010). Based on this view, the current quasi-experimental study aimed to investigate the effect of robotics design with Arduino on students' attitudes towards an ICT course and to STEM. For this purpose, 53 sixth-grade students enrolled to an "Information Technologies and Software" course were selected and randomly assigned to either an Experimental Group or a Control Group.

The study showed that the participant students' attitudes towards the ICT course changed significantly when they engaged with the robotics design with Ardunio. Although all of the participants showed similar attitudes towards the ICT course at the beginning of the study, by the end, the participants from the Experimental Group showed significantly higher positive attitudes towards the ICT course compared to those in the Control Group. Mataric et al. (2007) claimed that the use of technological materials captured the attention of students, and thereby increased the effectiveness of the ER activities. In the current study, the use of robotics motivated the students to engage in the activities and was seen to positively affect their attitude towards the ICT course. In fact, the qualitative data showed that the participants from the Experimental Group favored the use of robotics activities in the ICT course as the regular ICT course generally includes similar and repetitive subjects, and also that it did not allow them time to practice what they had learned. Hence, according to the students, the regular ICT course was sometimes considered to be boring, whilst the ER activities were seen as being fun, interesting, and different, yet for some they were difficult, complex, and time-consuming. ER activities help to make students more active since it requires them to design and develop robots as part of their learning (Alimisis, 2013). In the current study, the participants liked to design and code the robots, to see the results of their design and coding work, and to control their robots using a computer. Nevertheless, they also emphasized that they did not like situations such as when their robots did not work the way they had intended or designed them to, when they were struggling to find the error in their prototype (hardware and/or software), or when they had insufficient time and/or materials available. It is therefore suggested that students should be observed during ER activities and to provide them with appropriate help and support as and when needed. This approach may help them to develop more a positive attitude towards the course, as well as to the STEM field in general. Students' positive perception towards their learning environment may also lead to more positive attitudes towards STEM, and to increased motivation to participate in STEM-related activities in the future (Fraser, 2007).

The current study showed that the participants' attitudes towards the STEM field also changed. Whilst at the beginning of the study the participants were shown to share similar attitudes, by the end of the study the participants who had engaged in the robotics activities (Experimental Group) showed higher levels of positive attitude towards the STEM field than their peers in the Control Group who followed the current course content. Whilst the Experimental Group's students' attitudes towards math, science, and 21st-century skills did not change, their engineering and technology attitude scores increased significantly from pretest to posttest.

Other studies in the literature found a variety of findings regarding this same issue. For instance, Karışan and Yurdakul (2017) reported that participants who took part in STEM activities developed positive attitudes toward science, math, engineering, and 21st-century skills, whereas the attitudes of participants who received regular science course activities did not show any significantly attitudinal change. Hence, the authors claimed that it was an expected result since the traditional classroom environment may be seen to demotivate rather than motivate students towards the STEM field (Roberts, 2012). On the other hand, in a study by Sisman et al. (2020), the researchers found that students received the lowest scores in the Math factor of their STEM scale. According to them, this may have been caused by the courses the students were enrolled to including robotics activities, with the students' attention having been focused on the design and programming of the robots. Finally, in a research study conducted with secondary school students, Leonard et al. (2016) found that robotics activities and game design had a positive effect on the students' thinking skills, but did not affect their attitude towards the STEM field. According to the researchers, this was due to limitations of their study, and also to the loss of the subject. While 124 students participated in the study, only 76 of them completed the study's questionnaire. Besides, there were also cultural differences to consider among the participants.

Unfried et al. (2015) suggested that changes to STEM attitudes in students requires a prolonged process since they need time to adapt to the STEM way of teaching and learning; and in the current study, the participants undertook robotics activities for a period of just 12 weeks. Although the students may not have had adequate time to properly adapt themselves to STEM, the nature of the robotics activities would have likely played a significant role in their attitudes towards STEM. First, at the secondary education level, linking robotics projects with math and science still remains at a limited level (Benitti, 2012). Secondary school students do not need to employ mathematic skills in ER activities, thus, the effect of robotics might be seen as limited, while ER may have had a positive contribution on these fields (Sisman et al., 2020). It has been stated that if students solve real-life problems by using their math skills in ER activities, they can develop more positive attitudes towards math (Shankar et al., 2013). Hence, robotics activities should be designed in such a way that requires secondary school students' math and science skills in order that their attitudes towards these STEM fields can also change significantly. As suggested by Sisman et al. (2020), field-oriented ER activities should be designed so as to make the learning process more effective.

Conclusion

This study shows that Arduino and educational robotics applications, in particular, increase students' attitudes towards ICT courses and STEM, which combines disciplines such as science, technology, engineering, and mathematics. Furthermore, student feedback reveals that educational robotics activities are enjoyable, captivating, intriguing, and hands-on. Consequently, the use of robots in ICT education enhances attitudes towards ICT and STEM.

Although the current study suggests that integrating ER activities into courses can lead to positive results, such as increased attitudes towards ICT courses and STEM fields, it also has certain limitations. First, the study was limited to only 53 sixth-grade students, and thus similar studies with larger sample sizes and across different grades are needed. Additionally, the robotics activities used in this study only focused on engineering, design, and technology. Therefore, future studies should take a more holistic approach to STEM teaching and learning by incorporating robotics activities that include both science and math elements. Moreover, the study utilized the Arduino microcontroller card, and future studies could explore the use of different robotics kits or microcontrollers.

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