Stem Education: Robotics Integration in Science Laboratory

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Abstract: *The aim of the study is investigating the integration of robotics studies into STEM practice in secondary school science labs. The study, consisting of 48 experiments and 48 control groups, was conducted in a private school in Istanbul in the first semester of the 2015-2016 academic years. In the study, experiments were performed in the classical science laboratory in the control group and in the robotics, laboratory using the robotics (Lego Mindstorms EV3) studying set in the experimental group. Academic Achievement Test, STEM Attitude Questionnaire, Robotic Opinion Questionnaire and Motivation Scale for Science Learning were used determine the effect of robotics on students' achievement, motivation and attitudes. The pre and post-test results to determine the success status showed a significant increase in the experimental group compared to the control group. As a result of the study, students in the experimental group who were educated with robotic-assisted science experiments showed increased motivation for learning science, academic achievement, attitudes towards STEM compared to control group students. As a conclusion, it has been determined that robotics-based laboratory applications have many positive contributions to science education.*

Keywords: Robotics, Lego Mindstorms EV3, Science Education, STEM

1. Introduction

In recent years, the place and use of robots in education has increased rapidly, as is the case in all areas [11]. According to science and technology education, it has been seen that the new technological field, called robotics, provides great convenience in STEM education [9]. Robotic equipments are also being used in scientific laboratory activities because of its ease of observation, data acquisition, and time-saving feature [10]. The opportunity to make observations and research, especially in the scientific research steps, has made the use of robots more widespread in science laboratories [9]. In 1967, Papert thought that the LOGO programming method would contribute to the development of children's hand skills and imagination and described the theory of "learning by doing and living" [4]. Inspired by Papert's work, the LEGO company has produced Mindstorms robot sets. With the development of technology, educational robots developed, Simultaneously the company introduced the third-generation programmable robot LEGO Mindstorms EV3 to the world public at the Las Vegas Electronics Consumer Fair [3]. This training education set attracted great attention because it is a new technology allowing even a primary school student to develop robots without help on their own, and educational availability is accepted by many researchers [1].

Figure 1: Lego Mindstorms EV3   Education set

Lego Minstorms EV3 educational set, arm9 robotic bricks, dot matrix displays and speaker on brick, bluetooth, usb and wi-fi connection technology, sensors, light, distance and touch sensitive sensors, infrared receiver and remote control for remote control and servo motors to ensure movement (Lego, 2018).
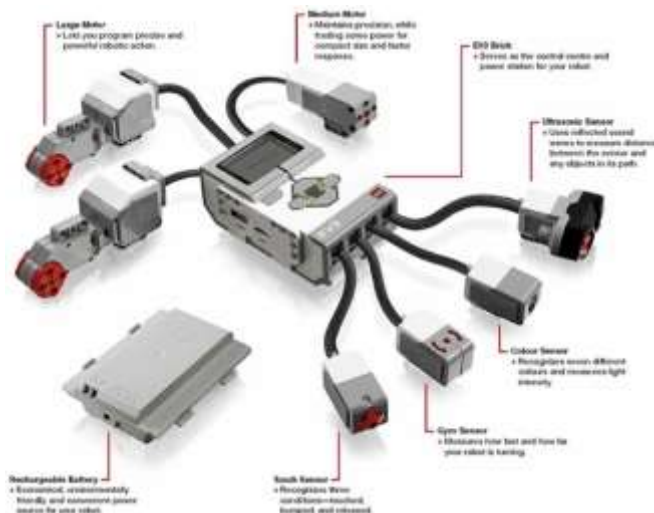
Figure 2: Bricks, sensors and servo motors

Lego Mindstorms EV3 robot can be programmed using a clear symbol base programming interface. The desired movements of the robot are encoded in the programming window by the drag and drop principle. The EV3 interface consists of five sections;

1) **Programming Canvas:** This is the part of the program.
2) **Programming Palettes:** This is the part where the building blocks of the program are located.
3) **Hardware Page:** This is where the EV3 brick is communicated, engines and sensors are connected, and the brick lay programs are installed.
4) **Content Organizer:** A digital workbook with integrated writing is included in this section. It is the part where the project is documented using text, images and video.
5) **Programming Toolbar:** The part where basic tools for working with programming are located.

It is noted that robotic activities using lego is one of the most effective educational tools that can be used to implement constructivist theory [7]. STEM attitudes and skills are strengthened by the fact that students are able to build problem-based learning and problem-solving skills by doing and living through robots [15]. In the literature, it has been reported that the student's achievement in secondary school mathematics and science courses has been increased due to robot applications aimed at acquiring STEM skills [16]. Moreover, the use of robots consisting of components such as motors, sensors and programs depends on disciplines such as engineering, electronics and computer science, indicating that robots are connected to various disciplines [7]. As students participate in robotics activities, it seems that robots can inevitably learn these disciplines that are inherently interdisciplinary [9]. In the studies conducted, robotic activities have shown that students are more motivated in mathematics and science lessons [1], have found a better environment for expressing themselves [15] and have developed problem solving skills [28]. One of the reasons why the educational robots are an effective learning tool is that it is a suitable educational material for project-based learning, it creates a fun and attractive learning environment where students can keep their perceptions constantly open [5].

1.2. Purpose of the Study

In this study, the integration of robotics studies into STEM application to middle school science laboratory applications was investigated. Within the scope of this context, the aims of the research are to understand;
1) Impact of Robotics activities on STEM attitudes of Grade 7 students,
2) Influence, effect, efficacy of Robotics activities on attitudes to 7th grade students' opinions on Robotics,
3) Influence of robotic activities on the motivation of 7th grade students to learn science,
4) Influence of robotic activities on the academic achievement of 7th grade students.

2. Methodology

Quantitative research design is used in this research (Sofaer, 2002).

2.1 Participants

The universe of the research consists of 96 students studying in 7th grade in a private school in the province of Istanbul, Başakşehir. The number of students selected for control and experimental groups was determined to be equal to 48. The distribution of the students participating in the study is given in Table 1. When the gender distribution chart of the students participating in the research is examined, the distribution of girls and boys in the control and experimental groups were distributed equally.

Table 1: Distribution of Control and Experiment Groups by Gender

Gender	Control Group	Experimental Group	Total
Female	23	25	48
Male	25	24	46
Total	48	48	96

In the study, the data were collected quantitatively by the survey questions in the first semester of the 2015-2016 academic year. Data collection means used; the STEM Attitude Scale (SAS), which is a 5-point likert type questionnaire developed by [14], The Robotic Opinion Questionnaire with 8 questions pre-test and 32 questions, developed by [6] and developed by [29] Likert-type Motivation Scale for Science Learning (MSSL) and multiple-choice Academic Achievement Test (AAT) with 20 questions.

2.2 Instrument Development

STEM Attitude Scale (SAS) used in the study; A scale of 5 likert types developed by [14] is based on this part of the study. As a result of the reliability studies, the Cronbach Alpha internal consistency coefficient of all the scales was determined as 0.88.

Robotic pre-questionnaire the original for the determination of emotions and thoughts before the students meet robotically consists of 8 questions prepared by [14]. The final robotics

questionnaire was prepared by examining the studies of researchers such as [18] and [19]. The validity and reliability study consisted of 32 questions, which were made with 128 students in 7th grade in a different school of equal value, with the result that 4 items were subtracted from the test because the reliability was low and the alpha reliability coefficient of the test was 0,81.

The Motivation Scale for Science Learning (MSSL) developed by [29] is a 5-point Likert-type scale consisting of 23 items. The reliability coefficient of the scale consisting of 5 sub-dimensions as "Motivation for Researching", "Motivation for Performance," "Motivation for Communication," "Motivation for Cooperative Study" and "Motivation for Participation" were found as 0,80 [29].

The Academic Achievement Test (AAT) in the research was created by the researcher by examining the retrospective three-year archive tests prepared and published by the Ministry of National Education of Turkey. During the assessment of the validity of the test, the opinions of three science teachers and a measurement evaluation expert were taken. A pilot study was conducted with 24 students in 7th grade in a different equivalent school, looking at the scientific suitability of the questions with the expert opinion. The difficulty and discrimination indices of the test questions were determined in the direction of the data obtained from the students and the reliability of the test (KR-20) was found as 0,88.

2.3 Application of the Research

The experiments were carried out in the classical science laboratory in the control group and in the robotics laboratory in the experimental group. Pre-tests are applied to the groups before the experiments are performed, information is given about the laboratories where the experiments were to be carried out and the steps of the experiments to be performed were explained. Experimental equipment were introduced for the control group and various robot designs were presented in the experimental group by watching a video and presentation about Lego Mindstorms education sets. Six experiments were selected from the "Force and Motion" and "Light and Sound" units for the experimental activities to be performed in both groups. The distribution of experiments performed in groups according to subjects is shown in Table 2.

Table 2: Distribution of Experiments in Groups by Week

Week	Experimental Activities	Time
1	Information (Preliminary tests are applied and information about experimental activities is given.)	80
2	Preparation Phase (Groups are created and they are asked to work in groups.)	80
3	Friction Experiment	80
4	Kinetic Energy Experiment *	80
5	Speed Experiment *	80
6	Resultant Force Experiment*	80
7	Absorption Experiment	80
8	Light Reflection Experiment	80
9	Evaluation (Activities are evaluated, final tests are applied.)	80

Tests marked with * were re-made by changing the locations of both groups.

The laboratory were conducted for nine weeks. The laboratory working papers of lab experiments were given to the groups at the beginning of each experiment, and data recording requests were requested. After the activities, the final tests were performed and the study was completed.

2.4 Data Analysis

In the analysis of the data, Kolmogorov Smirnov-Z test was applied in order to decide which of the parametric or non-parametric analysis techniques to use, taking into account the SAS, MSSL and AAT scores of the control and experimental groups. In the light of the results, it has been examined whether the determined groups show a normal distribution. In the analysis of quantitative data, parametric tests were preferred (N> 30).

The paired sample t-test and the independent sample t-tests are used to determine whether there was a significant difference in the pre- and post-test scores of SAS, MSSL and AAT of Control and Experiment Groups.

Frequency and percentage values are taken into consideration in the evaluation of other data sources; Robotic Surveys. arithmetic mean, standard deviation, t and p values were calculated by the SPSS-21 program in all tests.

3. Findings

In this section, the results of the following scales applied to the experiment and control group students in the scope of the research
1. STEM Attitude Scale,
2. Robotic Pre and Final Questionnaire,
3. Motivation Scale for Science Learning,
4. Academic Achievement Test.

3.1. Findings Related to STEM Attitude Scale

In the research firstly, the effect of the experimental activities on control and experiment groups on student's attitudes towards STEM is investigated. In this context, the findings of paired and independent sample t tests of STEM Attitude Scale scores applied to control and experimental groups before and after the events are given in Table 3 and Table 4.

Table 3: Results of the Paired Sample T test for the STEM Attitude Scale Pre-test Post-test Scores of Control and Experimental Group Students.

Groups	Tests							
	Pre-test			Post-test				
	n	SD	X	n	SD	X	t	p
Control	48	9,36	95,98	48	10,91	97,19	-1,071	,290
Experimental	48	11,18	94,60	48	9,01	104	-10,169*	,000

Table 4 reveals that the difference in the control group before and after the application is not significant (p> 0.05), but the difference in the experimental group is found to be statistically significant.

Table 4: Results of the Independent Sample T test for the STEM Attitude Scale Pre-test Post-test Scores of Control and Experimental Group Students

Tests	Groups							
	Control			Experimental				
	n	SD	X	n	SD	X	t	p
Sci. Pre-Test	48	4,64	23,57	48	4,56	23,82	,112	,911
Math. Pre-Test	48	4,17	22,33	48	4,81	22,91	,634	,528
Eng. And Tec. Pre- Test	48	3,96	21,55	48	3,83	22,12	-,288	,774
21st Skill Pre - Test	48	3,41	23,95	48	2,94	24,04	1,559	,113
Sci. Post Test	48	4,40	25,08	48	4,15	28,91	-2,27*	,015
Math. Post Test	48	7,23	23,70	48	4,06	25,45	-,398*	,020
Eng. And Tec. Post Test	48	3,96	24,95	48	3,99	29,75	-,45*	,033
21st Skill Post test	48	3,96	25,98	48	3,14	28,18	-5,26	,028

As shown in Table 4, there is no significant difference between the control and the experimental group in terms of all sub-dimensions before the application (p> 0.05) and there is a significant difference in favor of the experimental group after the application. (p <0,05).

3.2. Robotic Survey Findings

The frequencies and percentage distributions of the yes / no content robotic pre-questionnaire to determine student's attitudes and opinions about robotics are given in Table 5.

Table 5: Robotic Preliminary Survey Results of Students in the Experiment Group

Question	Yes		No	
	f	%	f	%
1	18	37,5	30	62,5
2	20	41,6	28	58,4
3	40	83,3	8	16,7
4	40	83,3	8	16,7
5	35	72,9	13	27,1
6	36	75	12	25
7	30	62,5	18	37,5
8	16	33,3	32	66,7
9	10	20,8	38	79,2
10	20	41,6	28	58,4

Table 6 shows the findings of a four-part robotic final questionnaire applied to students in the experimental group after robotic activities.

Table 6: Results of the Robotic Final Survey of the Experiment Group Students

Q	Yes		No	
	Frequency	%	Frequency	%
1	43	89,5	8	10,5
2	40	83,3	8	16,7
3	38	79,1	10	20,9
4	16	33,3	32	76,7
5	42	87,5	8	12,5
6	40	83,3	8	16,7
7	36	75	12	25
8	20	41,6	26	58,4
9	40	83,3	8	16,7

10	45	,93,7	3	16,3
11	36	75	12	25
12	34	70,8	12	29,2
13	42	87,5	6	12,5
14	36	75	12	25
15	44	91,6	4	18,4
16	46	95,8	2	4,2
17	32	66,6	16	33,4
18	40	83,3	8	16,7
19	28	58,3	20	41,7
20	34	70,8	14	29,2
21	44	91,6	4	18,4
22	38	79,1	10	20,9
23	38	79,1	10	20,9
24	42	87,5	6	12,5
25	40	83,3	8	16,7
26	32	66,6	16	33,4
27	44	91,6	4	18,4
28	28	58,3	20	41,7
29	42	87,5	6	12,5
30	44	91,6	4	18,4
31	36	75	12	25
32	34	70,8	14	29,2

3.3 Findings of Motivation Scale for Science Learning

Table 7 shows that the results of independent sample t tests of the Motivation Scale for Science Learning to be applied to the experimental and control groups before and after the activities.

Table 7: Results of the Paired Sample T test for the Motivation Scale for Science Pre- Post-test Scores of both groups.

Tests	Groups								
	Control			Exp					
	n	SD	X	n	SD	X	t	df	p
MSSL pre Test	48	11.61	67.08	48	12.71	64.27	-2.123	94	.261
MSSL Son Test	48	13.49	71.58	48	16.03	78.02	-6.44*	94	.036

Table 7 shows that there is no significant difference between the control and the experimental group after the application of the motivation data for learning the science. There is also a significant positive difference in the experimental group after the control group.

3.4. Findings of Academic Achievement Test

Finally, the findings of the independent sample t tests of the Academic Achievement Test data applied to the experimental and control group students before and after the events are given in Table 8.

Table 8: Results of the Independent Sample T test for the Academic Achievement Test Learning Pre-test Post-test Scores of Control and Experimental Group

Tests	Groups								
	Control			Exp					
	N	SD	X	N	SD	X	t	df	p
AAT pre Test	48	10,42	53,85	48	12,31	52,87	,850	96	,773
AAT Post Test	48	10,11	68,43	48	12,12	73,85	-2,38*	96	,012

* p < 0,05

In the pre-test, there is no difference in the academic achievement between the control and the experimental group, and the post-test after the activities show a positive increase of 27.07% in the control group and 39.68% in the experimental group.

4. Discussion

Recently in Turkey, robotics kits are used in laboratories as well as private schools in more developed countries. Universities have been performing courses to elementary school students through educational faculties [23]. When literature is examined, it is observed that robotic activities are being done intensively at the middle school level [11. The reason for the selection of this age group is that children have begun to think from abstract to concrete thought [10].

In this section, the results of the findings gathered using four different materials are described and discussed in previous studies. The STEM Attitude Scale, Motivation Scale for Science Learning, Robotic Opinion Questionnaire and Academic Achievement Test is used in this study where the integration of robotic activities into science laboratory activities was examined.

As shown in Table 3, the statistical evaluation of the pre and post-tests applied to experimental and control groups was performed by paired sample t-test. When the pre- and post-test results of the groups were examined, it was found that there was a 9,40-point increase in the experimental group of 1.21 points in the control group and this increase was statistically significant (P = 000). We believe that this increase in the experimental group is the result of students' robotic activities towards the STEM. This difference is more evident in the experimental group, although there is a statistically small difference in the positive direction between the pre-test and the post-test in the control group. These are also different according to the STEM disciplines. According to the results shown in Table 4, there is a difference of 3.83 in the final science post-test, 1.75 in the final mathematics post-test, 4.8 in the last engineering and technology post-test, and 2.2 in the 21st century skills post-test. From the data, it is seen that the difference is most in science and engineering-technology tests, and the least in the mathematics test. It can be argued that the reason for this is that students perform their learning process in robotic supported laboratory activities by means of technology support and they are motivated more by the robots they designed. As a result, in the development of student's attitudes towards the STEM, robotic laboratory experimentation activities have been achieved to be more effective than traditional laboratory activities. These results are in line with the studies in the literature [26], [21], [5]. Ludi [26] emphasized that robotic activities are a good motivational tool for students to participate in STEM activities. They also suggest that robotic activities are effective tools to stimulate learning in the learning / teaching context for the STEM. Kim [5] and Üçgül [21] stated that the use of robots led students to engineering professions, increasing students' knowledge on technology, computing, coding and the STEM.

According to the findings of Robotics Preliminary Survey, most of the students stated that they did not have any information about Lego Mindstorm sets (Table 5). Those children did not use a professional set before, but they spent time with pieces of Lego which are not smart bricks and motors (Questions 1 and 2). While the students think that they can learn science concepts through the robots they will use in the activities they are going to perform, they also stated that they will have difficulty in designing and programming the robot (Question 7-10). A large majority (83.3%) of the students stated that they were good with technology and liked working in a group while 33.3% emphasized that it would be difficult to program the robot by 20.8%.

The findings from the Robotics Final Questionnaire given in Table 6 are presented in four sections.

The first part is about the satisfaction of the students in laboratory activities carried out by robotics. Students stated that they found the activities fun, that they had fun while designing the robot, and that it was difficult during programming and design. While the students indicated the most difficult parts as coding (33,3%) and the combining of the Lego parts (41,6%), the other users gave mostly positive opinions (% 75,0- 89.5%).

The second part deals with the contribution of robotic activities to academic achievement. Students reported that they were learning concepts more easily with robotic activities (93.6%) and that they were more interested in the topic and increased motivation (95.8%).

The third part is aimed at determining participant's contributions to the social skills of robotics activities. Here, students showed a high positive attitude and emphasized that they increased their highest technology (91,6%).

In the fourth chapter, they declare that they will give importance to the activities performed with robotics in the future and they will recommend it to students or people.

Overall, participants were positively (71% -91%) positive when they were asked about their use of robotics in educational / laboratory practices. From these results it was understood that doing robotic activities in secondary school science teaching and laboratory practice enabled students to gain a positive attitude towards science.

According to the results obtained from the Motivation Scale for Learning Science in Table 7, the motivation for learning science before the activities was similar (p> 0.05). There is a difference of 6.64 points between the groups in the results of MSSL post test which is applied after the activities and this difference is found statistically significant (p <0.05). From these results it can be concluded that robotic activities are more motivating for students to learn science than classical science laboratory activities. This result can be attributed to that technological tools in the robotics activities keep the students mentally and physically active. These results coincide with the results of other researchers [22], [12], [10], [2], [17]. Spolaôr and Benitti [22] who have tried to use

robots made with the Lego Mindstorms robotic experiment set in the science laboratory. This technique was increased the motivation of students and interest in participation in science and technology clubs. Bonaccorso [12] stated that robotic activities have developed positive attitudes towards robot science courses and that these activities have an impact on their career choices. Finally, Özdoğru [10], Şenol and Büyük [2] stated that robotic studies in their study significantly increase the motivation of students to science courses.

As seen in the findings in Table 8, which shows Academic Achievement for the fourth of the research problem, there is no difference between the pre-tests of the students in the experimental and control groups, while the final test scores of the experimental and control groups show an increase of 21.97 and 14.58, respectively.

According to findings; there is a statistically significant difference between the ABT post test scores of the students in the experiment and control groups at the significance level of 0.05 in favor of the experimental group (p <0.05). Accordingly, it can be said that the robotic-assisted activities in the experimental group have a greater impact on the academic success of the students than in the classical laboratory activities. This result coincides to the previously studies [8];[4]; [20]; Afari and Khine [8] , Yudin [4], and Karim [20] stated that robotic activities are affected in mathematical, physics, school and science success.

5. Conclusion

In recent years, the world as it is in developed countries, science education and robotics have been used in laboratory activities in Turkey.

This technique also has been used in elementary and middle schools. On the other hand, special courses for college students and nationwide competitions by various organizations have been organized to give a direction to the young individuals. These organizations also aimed to establish future professional groups in the target country and encourage young individuals to participate robotics activities and to increase their knowledge. In this study, the advantages and disadvantages of robotic activities in the scope of secondary school science curriculum are stated as follows.

Advantages: Since the experiments with robotics are visual and active, students have had fun, entertained, encouraged group work, gained the ability to experiment with tools, encouraged creative ideas, facilitated the relationship among the STEM disciplines and gave an idea about the professions.

Disadvantages: Students were forced in the design of robotics, combine Lego parts and program robots.

Advantages: In my observations during robot activities in the lab, the students who are capable, able to grasp the technology better and use the technology and direct the group are noticed easily?

Lego Mindstorms also reveals the abilities of students as well as the many achievements of robotic education and laboratory practice in the middle school.

6. Recommendations

Robotic-assisted laboratory activities in the research led students to develop their perceptions and attitudes towards STEM fields, to increase motivation and academic achievement for science learning. The following lines have been suggested to researchers;

- The methods in this study can be carried out by students at different grade levels.
- The positive and negative aspects of training with technology / robotics can be explored.
- Different STEM disciplines can be planned with robotics activities.
- The pedagogical impact of technology / robotics activities can be studied.
- Robotic activities can be applied to STEM disciplines to identify students' skills and career choices earlier.
- STEM programs can be created in schools.
- Instead of forcing elementary and junior high school pupils to participate in STEM at an early stage, plans can be drawn up by determining their ability.
- An appropriate curriculum can be targeted to increase student's STEM areas

Acknowledgement

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