The Effects of Robotics Club on the Students' Performance on Science Process & Scientific Creativity Skills and Perceptions on Robots, Human and Society

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Abstract. The aim of this study is to investigate the impact of a Lego Mindstorms based Robotics course, operated as an after-school Club but intended for the future within the primary science and technology curriculum, on sixth and seventh grade students' achievements of science process skills, scientific creativity and their perceptions on 'robots, human and society'. The Robotics Club introduced robotics and robotics programming through Lego Mindstorms NXT 2.0 and introduced inquiry-based robotics activities related to socio-scientific issues (involving structured, guided or open inquiry). Participants in this study were fourteen sixth grade and nine seventh grade students, who were randomly selected among all sixth and seventh grade students at a private school in Izmir by a committee of science and technology teachers. The students worked collaboratively in groups, and were guided to undertake scientific inquiry using technological designs and robot programming. This paper explains how the robotics course is organized in the light of constructionism theory and a three stage teaching approach, which kinds of creative and process skill activities it includes and an evaluation of how it encourages students to think as a scientific problem solver on real world tasks. The result of this study show that the Robotics club increased students' skills in scientific creativity and science process skills and also changed their perceptions of robots, humans and society in a positive direction. Furthermore, several gender differences were found from administering the instruments and seeking perceptions. While father's profession was related to students' level of scientific creativity and science process skills, the mother's profession has no effect on these skills.

Keywords: Robotics, Science Education, Lego Mindstorms NXT 2.0, Constructionism

1 Introduction

Most developed countries suffer from a lack of student interest in science education (OECD, 2010) and in the way the learning is portrayed. Most students think that science classes are irrelevant to their daily life. While daily life science is seen as complex, interdisciplinary and diverse, the basis of science that is being taught in school is seen as isolated, unrelated and boring. However, as science is an integral part of daily life, science cannot be isolated from society and the intention of science education should be for students to interact with scientific ideas, develop scientific skills in order to transfer scientific ideas to make justified socio-scientific decisions

(Holbrook, 2008). As a result of the lack of interest in science education, students do not want to choose a career based on science, technology and engineering (Smithers & Robinson 1988; Cavas, Cakiroglu & Ertepinar, 2010). For the past decades, especially between 1993 and 2003, the problem was even wider and the topics associated with attitudes of science and technology education was been subject to substantial exploration (Osborne, Simon & Collins, 2003). As a result, many novel approaches to science education revolutionized, Science, Technology, Engineering, and Mathematics (STEM) education in the USA and Inquiry-based Science Education (IBSE) became more dominant in Europe. While the STEM approach is based on integrating mathematics and science with technology and engineering by creating a "meta-discipline," IBSE is basically a learning process or pedagogical approach. Several theories, such as 'constructivism,' 'Bloom's Taxonomy of Learning,' 'Multiple Intelligence,' 'Whole Language' and 'Accelerated Learning' underlie IBSE.

Motivation

The issue of lack of student motivation has been a central topic of many European Commission funded projects (such as PARSEL and POLLEN) through which researchers are investigating innovative and meaningful ways to get students' attention focused on science and to increase their motivation and attitude towards science and technology learning. The primary aim of these projects is to make innovative changes to the traditional science teaching approach and to create modules which motivate students and generate interest toward learning in the fields of science and engineering.

Robotics

In many research report, robotics is seen as intellectually rich (Chambers & Carbonaro, 2003; Flowers & Gossett, 2002; Garcia & McNeill, 2002; Klassner, 2002; Kumar, 2004; Nourbakhsh, 2000; Resnick & Ocko, 1991; Ringwood, Monaghan, & Maloco, 2005; Sargent, Resnick, Martin & Silverman, 1996; Sullivan, 2008; Wagner, 1998; Weinberg, White, Karacal, Engel, & Hu, 2005) and a popular science and technology activity to reach goals defined in many science curriculum.

Robotics applications include mainly hands-on and minds-on activities that are essential part of science teaching and learning, yet largely being left out in many national science curricula. Robotics based education offers students multiple opportunities to design, build and program a robot when they are learning science topics. According to Sullivan (2008), there are strong relationships between the goals of scientific literacy and robotics. She further mentions that four of the six thinking skills characteristic of scientifically literate people are the key elements for the robotics studies. These characteristics are defined as computation, estimation, manipulation and observation in her study. She continues that science inquiry through bought technological design and computer programming activities has positive effects for students to learn science concept better.

Another important study by Chambers, Carbonaro and Murray (2008) at elementary level was carried out to explore the effectiveness of robotic technology with elementary age children, specifically focusing on the children's conceptual

development concerning gear function and mechanical advantage". They found that the robot sessions helped to develop the students' understanding of gear function in relation to direction of turning, relative speed, and number of revolutions.

LEGO Mindstorms
Lego Mindstorms was originated by Papert's studies at the MIT Media laboratory in 1998. Lego Mindstorms is a line of programmable robotics/construction kits and include 619 pieces such as programmable sensor blocks (touch, light, sound and distance) and NXT Intelligent Brick. The first version of Lego Mindstorms, Robotics Invention System (RIS) was released in 1998 and the next one released in 2006 as Lego Mindstorms NXT and the latest version, entitled Lego Mindstorms NXT 2.0 released in 2009. The latest version of the robotics kits with programmable bricks, such as Lego Mindstorms NXT 2.0 and Pico-Crickets, provide students to control the behavior of a tangible model by means of a virtual environment and conduct science experiments, in which young students investigate a socio scientific issue using their scientific process skills both in and out of the classroom (Resnick et al., 1996). For example, a young student struggling in science and math courses might focus and concentrate on the mathematics and science skills needed to program a robot that will move in a desired manner (Rogers, 2010; Garrigan, 1993).

Research Questions
RQ1. Are there significant differences in the pre and post scientific creativity test scores for students, taking note of gender?
RQ2. Are there significant differences in the pre and post science process skills test scores for students, taking note of gender?
RQ3. Are there significant differences in the pre and post robot, human and society perception scores for students, taking note of gender?
RQ4. Are there significant differences in the pre- and post scientific creativity test scores of students in terms of parental professions?

Methods
Participants
A committee for this project, made up of science and technology teachers in the selected school, randomly selected twenty-three 12-13-year-old student volunteers among seven and sixth graders in the entire school. The students stayed in the school an additional one hour extra class time after school. The school was a private school located in Izmir in Turkey. Some demographic properties of the students are shown at Figure 1.
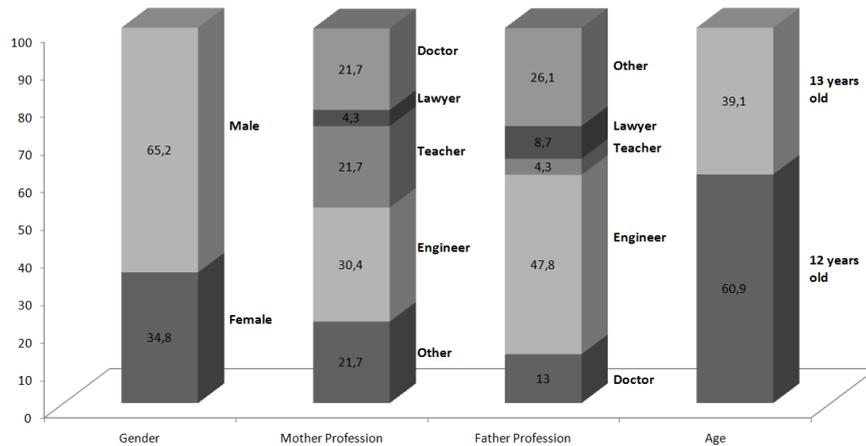
Figure 1. Some demographic factors of students participated to the study

Course content and Pedagogical Approach

The course was designed around three main objectives: (i) recognizing of a robot and its parts (gears, bricks, sensors, and NXT); (ii) working with robots (designing sample robot using cookbook, working with sensors, introduction to programming and programming a robot); and (iii) using robots to find a solution for a socio scientific issue (8 different inquiry based activities). Students worked as a group with the facilitation of two teachers (graduate students at time of the study) to solve problems posed as programming and design challenges. The teachers implemented "structured inquiry" in four different inquiry-based activities and they applied guided inquiry in three activities. For the last activities of the course, students solved socio-scientific issue based problems provided by teachers (open inquiry). In addition to the inquiry learning, the course included direct instruction for short lectures and software demonstrations.

Research Design

In order to address the research questions, an experimental method was used. A pre-test was implemented at beginning of the course and a post-test just after the course ended. The instruments used in this study are explained below.

Instruments

Instruments were used pre- and post-tests to measure students development on the Scientific creativity and the Science process skills and their perceptions on the Robot, and its relationship with Human and Society.

Findings

The results of this study are divided into three sections, namely students' scientific creativity, "Science Process Skills" and "Robot, Human and Society Perceptions". For the reliability of the instruments used in the study were calculated Cronbach alpha and found as .94 for science process skills and .64 for scientific creativity skills. Both of the reliability coefficient shows that the instruments have valid interreliability and can be used for the research purposes.

Scientific creativity

In order to find out the answer for the question related to scientific creativity defined in the methodology part of this study, statistical analyses were done. The results of this test have been presented at Table 1. Table 1 shows that the mean score for scientific creativity on the pretest (M=6.95; SD=2.43) was significantly different from the mean score on the post test (M=9.91; SD=2.41, t(44)=-4.134, p< .05). In order to find the effect size of this difference, Cohen's d value was calculated and was found as .44 and this result shows that there is a medium effect. We can conclude from this result that the pedagogical approach used in the robotic club increased the scientific creativity skills of the students. In terms of gender, both of the girls and boys had better in post test score when compared with the pre test score. However, there is no significant difference between girls' and boys' pre and post test scores related to scientific creativity.

In the study, parental profession was investigated in order to understand the effects of the professions on the science creativity skills of the students. In order to find out it, the parental professions were divided into two group namely, science and non-science professions. The pre and post test scores was analyzed according to these two groups. The test results show that while mother profession has no effects on the science creativity skills of students, the fathers' profession has a positive effect on the science creativity skills of the students. Although significant differences were not found in the students' scores of scientific creativity regarding mothers' profession, students whose mothers' job is related to science have higher mean scores than the other students.

Science Process Skills

Regarding science process skills, significant differences were found. In order to understand the differences between pre and post tests scores, statistical analyses were conducted. The mean score on the pretest of science process skills (M=13.17; SD=4.92) was significantly different than the mean score on the post test (M=18.08; SD=5.12, t(21)=-3.315, p< .05). The effect size was calculated as .34 which shows medium effect.

Table 1. Statistical analysis for the scientific creativity instrument.

Instrument		N	Mean	SD	t	df	P	Cohen's d
Scientific Creativity Test	Pre Test	23	6,95	2,43	-4,134	44	.000*	.44 (M)
	Post Test	23	9,91	2.41				
Scientific Creativity Test (Girls)	Pre Test	8	7,25	2,12	-2,925	14	011*	.28 (S)
	Post Test	8	10,00	1,60				
Scientific Creativity Test (Boys)	Pre Test	15	6,80	2,65	-3,80	28	.005*	.31 (M)
	Post Test	15	9,86	2,80				
Scientific Creativity Test	Boys Post Test	15	9,87	2,80	,123	21	.903	
	Girls Post Test	8	10,00	1,60				
Pre Science Creativity Test (Mother profession)	Science	11	7,45	2,58	,935	21	.361	
	Non Science	12	6,50	2,31				
Post Science Creativity Test (Mother profession)	Science	11	10,18	2,18	,503	21	.620	
	Non Science	12	9,66	2,67				
Pre Science Creativity Test (Father profession)	Science	14	7,21	2,75	,623	21	.540	
	Non Science	9	6,55	1,94				
Post Science Creativity Test (Father profession)	Science	14	10,78	1,84	2,385	21	.027*	.21(S)
	Non Science	9	8,55	2,65				

*p<.05; S: Small; M: Medium effect.

The statistical analysis on the gender issue shows that there was significant difference between girls' and boys' pre and post tests mean scores. According to Table 2, it can be interpreted that the girls are more successful than the boys.

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Table 2. Statistical analysis for the science process skills instrument.

Instrument		n	Mean	SD	t	Df	P	Cohen's d
Science Process Skills	Pre Test	23	13,17	4,92	-3,315	21	.002*	.34 (M)
	Post Test	23	18,08	5,12				
Science Process Skills (Girls)	Pre Test	8	14,75	5,38	-2,853	14	.013*	.27 (S)
	Post Test	8	21,50	3,25				
Science Process Skills (Boys)	Pre Test	15	12,33	4,33	-2,323	28	.028*	.20 (S)
	Post Test	15	16,33	5,06				
Science Process Skills	Boys Post Test	15	16,33	5,06	-1,247	21	.226	
	Girls Post Test	8	21,50	3,25				

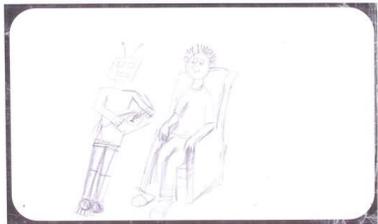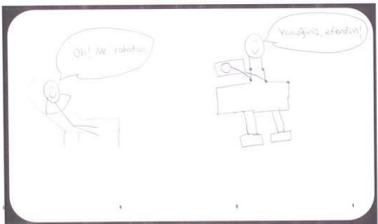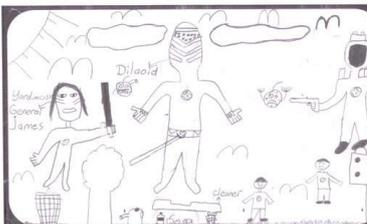*p<.05; S: Small; M: Medium effect.

Robot, Human and Society

In order to understand students' perception on the robot, human and society, an instrument developed by researchers was implemented. Students were asked to draw a picture related to relationship among the Robot, and its relationship with Human and Society and then students were also asked to explain the picture they drawn writing some sentences about it. Figure 2 shows some examples from students' drawings.

According to drawings made by the students,

(i) the number of robots depicted in the students' drawings in the post test had increased when compared with the pre test. The result of this situation can be explained by intensive robot activities during the out-of-school course period.

(ii) The robot drawings were also analyzed by their moving. The students have drawn the robots as active and dynamic in the post test. The lego mindstroms NXT provides students to control their robots and manipulate their movements. Probably, this advantage improved the students' thinking about the robots.

(iii) Another important result from the students' drawings is related to interaction with the living things. The post drawings of students include robots which interact more with the living things when it compared with the pre-drawings. As it stated in the methodology part, the robot course includes socio-scientific issues and activities for living things. It is thought that the robot activities based on living things increased students' perception on the living things.

(iv) Regarding the violence in the drawings, only five students drew robots in which they depict violence. However, the number of violence in the post – drawings has decreased. Only 2 students drew the violence elements in their drawings.

(v) The course also included the robot, human and society issues and discussed with the students at the first stages of the courses. This situation helped the students to understand the use of robots for humankind. It is shown that the three students used environmental protection issues linked with the robots in their drawing, 8 students drawn their robots which are related to environmental protection issues.

(vi) In general, the students did not use weapon in their drawings both in the pre- and post-test. However, the picture of robots which makes a service to the society has increased.

Figure 2. Drawings by the participants in the pre- and post-tests on Robot, Human and Society

Pre Test	*Post Test*
Robots can help to the people	*Robots provide a great convenience in human life. Robots can help us for war, home based works and various social activities.*
Robots make human works easy	*Robots are very useful for human. Making a robot contributes to development of technology.*

(vii) The number of smiling robots has also increased from 8 to 11.

(viii) In the pre-test, the students used human properties in their drawings however, the number of robots who look like human has decreased. Instead of human, they used more robots which look like animal.

Conclusions and Implications

The robotics introductory out-of-school course suggests that the Lego Mindstorms NXT 2.0 is an outstanding tool to teach science topics to young students for many reasons.

First of all, students have an opportunity to develop their problem solving skills since they designed, developed and tested their robots to explore a socio scientific issue (for example: traffic accidents can be eliminated using robotics).

The course shows that student motivation towards science and technology increased. Students wanted to stay to complete assignments that require more than the one hour of course time. During the implementation phase of the course, students worked as teams and the team work helped them to develop their inter-personal, communication and team building skills (Mauch, 2001).

Most of the time, students saw their mistakes immediately after trying to run their robots if they have any problem with the programming. Such mistakes are great learning experience for students.

Although the findings of this study indicate advantages of the robotics course on students' attitudes and motivation towards science and technology, there are also logistical issues, such as money and time, associated with implementation of this course within the formal school curriculum. One of the biggest problems is the cost of the Lego Mindstorms NXT 2.0. Secondly, working with robots requires block course hours to complete some assignments with robots and programming.

It can be concluded that robotics seems to be an excellent tool for science and technology education. However, as it is indicated in the report of the TERECoP project (Alimisis, 2009), the pedagogy of teaching robotics is still in its infancy and the research regarding robotics learning in science and technology is limited (Penner, 2001). For this reason, further research is needed to clarify the educational use of robotics in science and technology education.

Limitation and Importance of Study

The sample of the study does not represent the students who continue their education in the primary schools in Turkey. The reason for the limitation of the sample is sourced from the cost of the Lego Mindstorms NXT 2.0. For that reason, only 23 students was participated the study. The same problems occurs in the many studies on the Robotics and these studies suggested that further studies need more students to learn much more on the educational usage of Lego Mindstorms NXT particularly on the science education. The current study is important and has a value because of the

first pilot study in Izmir; implementing on science and technology curriculum in Turkey. Furthermore it also includes results of students' perception on the robot, human and society.

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