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Does the Inclusion of Robots Affect Engineering Students' Achievement in Computer Programming Courses?

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ABSTRACT
Applied courses are difficult to teach to undergraduate engineering students in classical classrooms. To facilitate students' understanding and capture their motivation, technology should be incorporated into classrooms. In the Engineering Faculty, there are courses that are difficult to learn in a classical classroom and laboratory sessions; the programming algorithm course is one such class. Educational robots are required for teaching and learning programming algorithm logic. The Lego Mindstorms EV3 robots represent excellent technology to teach programming algorithm course subjects. The important point about the programming algorithms course is that it enables understanding of the logic of programming, as it enhances students' understanding of what it means when they are coding. This paper investigates how engineering faculty students' achievements are affected by robotics technology when learning computer programming algorithm logics. It analyses a usable solution with the Lego Mindstorms EV3 robot in the engineering classrooms for the introduction to computer programming course. The statistical results showed, Lego robot usage has raised student achievement in the introduction to computer programming course.

Keywords: computer programming, engineering education, learning by doing, robotic learning

INTRODUCTION

Technological development affects all areas of the world. Education follows technological developments and tries to capture technological development opportunities to incorporate into modern teaching methods.

Engineering education courses mostly encourage students to apply; this educational model enables students to learn by doing and to develop real problem-solving skills, concepts and strategies (Bers & Portsmore, 2005). Lego Mindstorms EV3 is the most popular educational robot set used for education. This Lego robotics set is popular for teaching and learning because it enables the individual to learn practically, and it is especially useful for engineering education (Gura, 2011).

The usage of robotics is a wide-ranging trend in educational institutions, from elementary schools to colleges (Miller, Nourbakshs, & Siegwart, 2008). Many innovative studies have been carried out with Lego RCX,

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State of the literature

- The robotics has been used as a tool for teaching courses in the curricula (Eliasz,2009).

Contribution of this paper to the literature

- In the literature, Lego robots had been used in undergraduate level engineering courses such as image processing, artificial intelligent. This study done in introduction to programming course in the 2015-2016 Fall semester at the European University of Lefke to measure students' achievements in that course.

NXT and EV3 (Lego Mindstorms, 2011). Some of the studies have been carried out in undergraduate engineering courses, which are embedded systems (Han & Wook, 2009), and programing courses in computer science.

The programming algorithms course is an important course undergraduate level engineering students and it is a first-year class for all engineering departments. The programming algorithm course consists of two parts, as follows: The first part involves classic classroom teaching and learning, while the second comprises laboratory sessions. In the laboratory sessions, students use computers and compilers to write code, and they see their results on the computer screens. However, according to 2013-2014, 2014-2015 Fall Semester students' grades for the introduction to programming course, they had difficulty passing. Using learning technologies provides students with the ability to facilitate learning that is not possible in the classical classroom (Uzunboylu & Karagözlü, 2015). To make the course more course engineering students, Lego robots represent innovative solution.

For this study, students were divided into two groups, namely an experimental group and a control group. In the laboratory sessions, the experimental group used Lego robot for 6 weeks, while the control group haven't had any experiments with Lego robots. The experimental group did not configure the robot hardware, and they used the basic model of EV3 robots with two extra sensors, one for touch and one for colour/light. Statistical results of this paper make the following contribution to the literature:

- It establishes the necessity of well-developed programming in engineering departments;
- In the literature, there are studies done with Lego robots in undergraduate engineering level courses such as artificial intelligent, image processing. However, this study done with undergraduate-level engineering students used Lego robots in an introduction to programming course to measure their achievements in the 2015–2016 Fall semester at the European University of Lefke, Cyprus; and
- The results illustrate how Lego robot usage affects engineering students' achievement in an introduction to programming course.

LITERATURE REVIEW

A review of the literature resulted in the identification of the following findings:

Recently, robotics has been used as a tool for teaching courses in the curricula (Eliasz, 2009);

Educational robot sets have an advantage when it comes to including hands-on activities in the engineering classroom. Furthermore, it is used in general science and technology to motivate and interest students (Lauwers, Nourbakhsh, & Hammer, 2009); and to increase students' achievement in introduction to programming courses, laboratory sessions are important teaching/learning hours. Enhancing students' interest in laboratory hours through the use of Lego robots and the learning-by-doing educational model will facilitate undergraduate-level engineering students' ability to carry out applications.

Lego Robot Sets in Education

Several robot sets of different types and brands are available on the market. A robot is a computing device that shows students the results of writing code in the real world (Kaloti-Hallak & Armoni, 2015). Robot technology

helps to apply hands-on activities in the classroom. Furthermore, it is used in general science and technology to motivate and attract the attention of students (Lauwers et al., 2009).

The Lego robotics set is useful for learning programming, mathematics, the automation process and physics; it enables students to understand how the programming code works, nurtures ideas about programming robots and gives an understanding of how things work and affect their real life. In other words, it enables students to use technology.

Technology-based learning is achieved using the Lego robotic set in the engineering curriculum (Gura, 2011). Educational robots can be used for many areas of the curriculum. When the students see a robot in education, they think it is just an engineering topic, but educational robots are also used in different areas such as science, technology and mathematic.

The Lego robotics set encourages students to realise their creativity, and it helps them to analyse situations and use critical thinking skills to solve real-world problems. In this way, the students interact via teamwork, and they can engage with an innovative curriculum involving technology (Shamlian, 2006). The Lego robotics set is convenient for innovative teaching models.

The modern robotics set includes materials, such as motors, gears and sensors, which are designed for use in engineering areas. These materials provide an opportunity for students to gain experience using robots in designing and building (Bers et al., 2002).

RESEARCH METHOD

The quantitative analysis method was used for this study, and it was conducted with 100 students from Engineering Faculty departments, specifically the Computer Engineering, Electric-Electronic, Electronic Communication, Software and Civil Engineering departments. The control and experimental groups each included 50 engineering students, and each group had approximately the same student profile. The course was designed as two parts, namely theoretical and laboratory sessions. In the laboratory hours, pedagogical methods related to the learning-by-doing educational model were used. At the beginning of the course, students answered 30 questions to assess their achievements; at the end of the 6 weeks, the same questions were answered again by the same students. The research sought to determine how the Lego robot affected students' achievements in the introduction to computer programming course from the students' responses.

RESEARCH DESIGN

The introduction to computer programming course is available as three or four credits according to the department in the Engineering Faculty. The content of the course includes the following: problem solving concepts for computers (constants, variables, data types and functions); planning the solution (communication with computers, using tools, software development cycles); introduction to programming structures; and algorithm instruction, flowchart symbols, conditions (if/else, nested/if, while, repeat, until) and problem solving with decisions (multiple if/then/else). In the course's laboratory sessions in this study, students started to learn basic programming logic for writing code on compilers using computers. The experimental group started to learn the body of robots, sensors and their functions, such as how to detect objects with touch sensors, how to follow lines with colour sensors, how to design the robot to be controlled remotely with an infrared sensor and how to use motors and processors. Students in this group were divided into subgroups of five students. Each group used one Lego robot and one computer. The robots were given to students and then they tried to find solutions to each assignment as a group. Each week, students used the Lego robot set with prepared laboratory work according to the programming algorithm course outline. At the end of the 6 weeks, students responded to questions to evaluate their achievement tests. In addition, before and after the laboratory sessions each week, students answered questions about the goals of that week's applications. The achievement test questions were derived from the laboratory assignments.

Table 1. Subjects and Examples with Lego Robots

Subjects	Flowchart	Algorithm	Example
Problem-solving Steps for computer	X		Robot goes forward for 3 seconds
Understanding input/output processes	X	X	Write 'Hello World' on Lego Bricks screen
Conditions	X	X	If the touch sensor is pressed, then the Lego robot will go forward for 3 seconds
If-else	X	X	If the touch sensor is pressed, then the Lego robot will go forward for 3 seconds; otherwise, the motor will stop
Nested-if	X	X	If green is found, turn 360°; otherwise, say 'no green'
Case	X	X	Case 1: Find green Say 'green' Case 2: Find red Say 'red' Case 3: Find blue Say 'blue'
While statement	X	X	While counting < 3, press touch sensor Say 'Hello World'
Repeat until	X	X	Repeat Display 'Hello World' Until count = 4
For statement	X	X	Move Lego robot 3 seconds forwards, then turn and move forward 3 seconds two times

The Lego robot was used in the introduction to computer programming course's laboratory sessions with an experimental group of students to facilitate the students' understanding of and motivation to engage with programming algorithm logic. During the laboratory hours, students learned how the Lego robotics set would be used in programming, and they tried to understand algorithm logic within the learning-by-doing education model framework. **Table 1** shows the subjects that were included in the computer programming algorithm course laboratory hours in general, as well as examples from each subject covered using Lego robots.

Figures 1 and **2** shows the laboratory session exercises, which are brief descriptions of one laboratory example carried out with the Lego robots. In this laboratory session, the experimental group tried to find solutions to questions, following this, they saw the outcomes of the solutions with the Lego robot.

Figures 4 and **5** show the same example solved by the control group, but these students saw the robot action on the computer with a game program designed by Sprankle and Hubbard (2012).

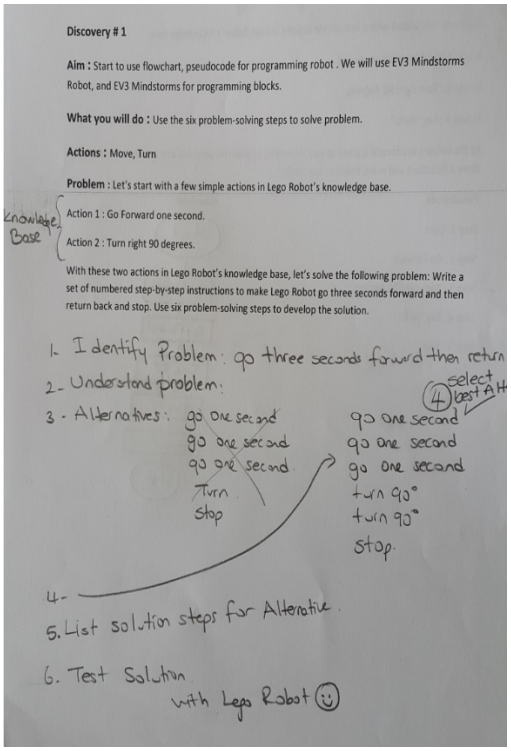

Figure 1. Laboratory exercise including six problem-solving steps with the robot

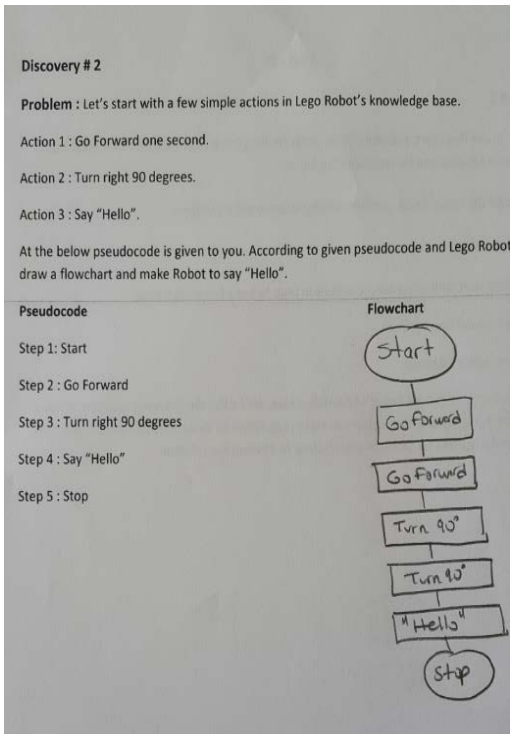

Figure 2. Laboratory exercise on drawing a flowchart

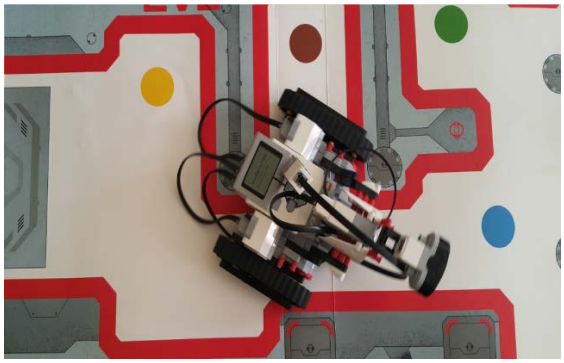

Figure 3. Lego Robot in action

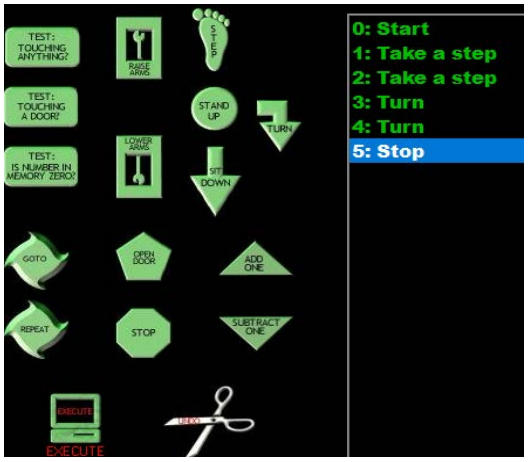

Figure 4. Control group of students used Sprankle and Hubbard's (2012) game robot (Otto)

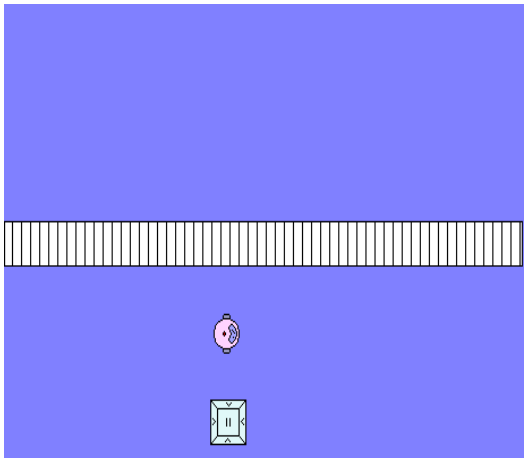

Figure 5. The Otto robot in action

DATA COLLECTION AND ANALYSIS

The collected data were quantitative. There were thirty elaborate questions employed to find outcomes to measure the students' understanding and improve the achievement scores on robots in the introduction to computer programming course. Item difficulty analysis was carried out for the 30 questions, and 30 multiple-choice

questions were used in this study (Appendix). To prove the study's reliability, two experts checked all the data. After the quantitative data were collected, they were entered into SPSS 22.0 software, and the mean scores were obtained as a result.

RESULTS

The analysis focussed on how Lego robot usage affects student achievements in the computer programming laboratory sessions. The survey sample included engineering faculty students in the European University of Lefke in Cyprus. The students answered 30 questions related to the course outline. The questions, results and some conclusions are shown in **Figure 6**.

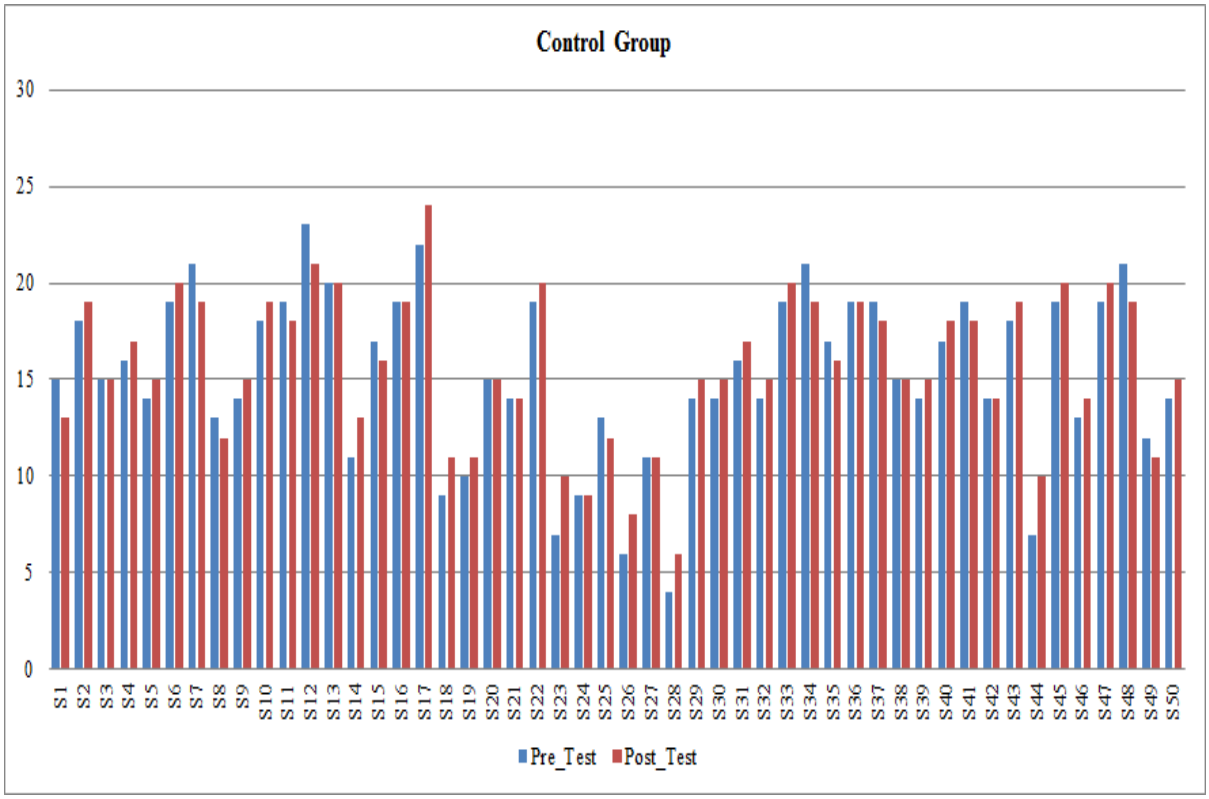

Figure 6. Results of control group students' achievement test scores on the pre- and post-tests; Lego robots were not used for this group

The results of the control group students' pre- and post-tests answers are introduced as a histogram in **Figure 6**. The blue histograms represent the frequency of students' pre-test answers, while the red histograms show the post-test results. In the control group, which hasn't had a task with Lego robot, there was no significant change regarding achievement. However, for the student group that used the Lego robot, the post-test results significantly changed; this meant that the students' understanding improved (see **Figure 7**).

Cohen's *d* calculations were used in this study to find the standardised difference between the means before and after the 6-week session, and the alpha value used was 0.05 for all statistical analyses. The paired samples *t* test is employed in **Table 2** to show descriptive statistics for pre- and post-test scores of the control group; the two-tailed significance was equal to 0.051, which is greater than 0.05. The data from the control group show that there was no improvement in the students' achievement without the Lego robots in the introduction to computer programming course.

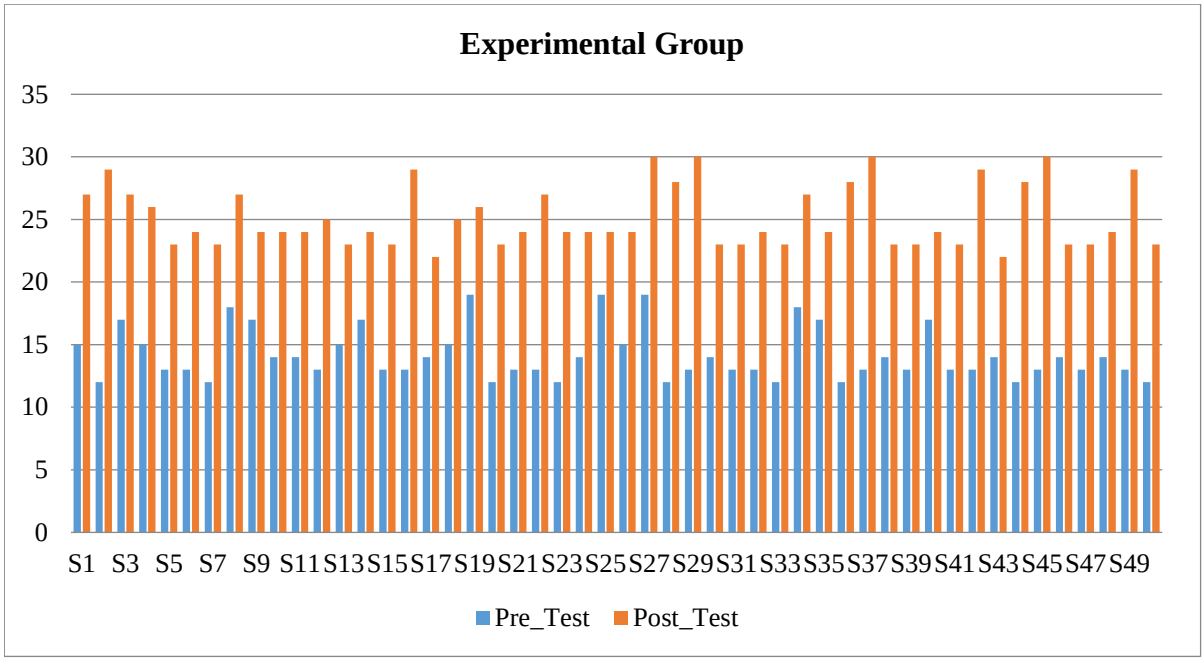

Figure 7. Results of experimental group students' achievement test scores on the pre- and post-tests; Lego robots were used in this group

Table 2. Comparison of Control Group's Results on the Pre- and Post-tests

		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig.
Pair 1	Pre-test–Post-test	–.36000	1.27391	.18016	–.72204	.00204	-1.998	49	.051

Table 3. Comparison of Experimental Group's Results on the Pre- and Post-tests

		Mean	Std. deviation	Std. error mean	Lower	Upper	*t*	*df*	Sig.
Pair 1	Pre-test–post-Test	–10.70000	2.94958	.53852	–11.80139	–9.59861	–19.869	29	.000002

Table 3 shows the statistical results of the pre- and post-tests for the experimental group. As mentioned before, the students used the Lego robot for 6 weeks; **Table 3** shows the achievement test results after 6 weeks using the paired-samples *t* test; given that the *p* value was equal to 0.000002, it can be concluded that there were significant differences identified ($p<0.05$). The results show that the students were positive in their attitudes toward practising the computer programming course with the Lego robots, and they learnt programming algorithms well with the Lego robot.

CONCLUSION

This study proposes that Lego robots used in the introduction to programming course based on a learning-by-doing educational model for engineering education. The aim of the study was to present a comparison of teaching an undergraduate engineering course, namely the introduction to programming, with (experimental group) and without (control group) the Lego EV3 robot in the European University of Lefke at 2015-2016 Fall semester. The study experience using Lego robots in this course has been very positive. According to the statistical results, the students who were in the experimental group showed better achievement than the control group of

students. Lauwers, Nourbakhsh, and Hammer (2009) found robot sets made students interest in course and results of study evidence the Lego EV3 is a good educational tool to use in introduction to programming course for engineering students and it can be used in other courses as well because of the price and its robust nature. The Lego robot enables engineering students to be creative and lets them work in collaboration with their classmates. It also improves the students' analytical thinking skills.

The results show that, pair sample t-test calculation of experimental group p value was less than 0.05 and control group p value was greater than 0.05, so there was significantly differences between two groups achievements.

These results related to the 2015-2016 Fall semester introduction to computer programming courses in an Engineering Faculty at the European University of Lefke. Eliasz (2009) suggested robotics has been used as a tool and according to study results, the Lego robots will continue to be used in these courses; in future work, we will introduce the Lego robots into other engineering courses as well.

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