Educational Robotics: Forming Scientific Communities in the Classroom

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ABSTRACT
The fact of involving the scientific method in educational institutions of secondary level has a significant weight in the scientific vocation of the high school graduate. Therefore, the current study analyzes as a didactic proposal, the use of the scientific method (to observe and to formulate a question, to investigate theoretically, to construct a hypothesis, to experiment, to collect data, to observe, to conclude, and communicate results), during the teaching of programming in Technician Computing Baccalaureate. The study was carried out in two high schools, in which programming teaching performed with Lego EV3 robots is being taught. A pre-post-test design was carried out with experimental groups (n = 25, with scientific method) and control (n = 26, without scientific method) to find out whether or not the scientific method improves programming learning. The results show a slight-significant difference in learning outcomes of systems programming in the experimental group, compared to the control group.
Keywords: educational robotics, scientific method, programming

INTRODUCTION
In the current global economy, knowledge as human capital has especially relevance. Knowledge societies are consolidated in function of the scientific research that are produced in university centers; In this sense, some studies show the benefits of initiating the scientist's training before entering to superior education (Cheung, Slavin, Kim, & Lake, 2017). Once high school students, understand the scientific method, begin to make choices on their scientific vocation, and are encouraged to continue on this path, when their university career has been selected.

In recent years, Ecuadorian professionals, have demonstrated interest in scientific production, due to the low level evidenced in the university environment. One of the less productive areas in this sense has been computer science, although there is a technical baccalaureate and university degrees in the area. It is necessary to look for alternatives that favor the process of training the scientist in computational disciplines. The search should start with an emphasis on the approaches made in the previous paragraph. The integral formation of the scientist begins before to access the university. So, within the area of computational sciences, what educational strategy can be used to initiate the formation of scientific communities in high schools in Ecuador?

Initiative that stands out as educational innovation in the area of computational sciences

The world community has begun to focus greatly on educational robotics in computer science learning (Slavkovic & Savic, 2016). Robots of different types have been widely used as educational resources at the primary, secondary and higher levels (Merkouris & Chorianopoulos, 2015; Umbleja, 2016; Rodriguez Perez, Gold-Veerkamp, Abke, & Borgeest, 2015; Grandi, Falconi, & Melchiorri); mainly, in teaching-learning processes of programming languages. The motivation for learning programming language, is one of the most worked aspects in classrooms with educational robotics (Curto & Moreno, 2013; Wong & Hsieh, 2016); consequently, favorable learning outcomes are obtained in programming systems. Educational robotics has consolidated in the scientific community of the area of Computer science as object of study by the benefits that its didactic use offers. Educational robotics is an environment of learning in which robots are used to favor the understanding of the subjects of study. But, it is convenient to establish the difference between Teaching Robotics (TR) and Teaching With Robots (TWR). These two ways of working with robots in the classroom are represented in figure 1.

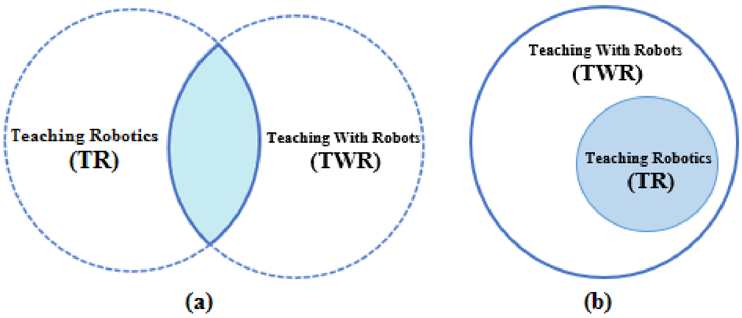

Figure 1.- TR and TWR: Two Representations of Teaching with Robots (Source: Catlin, 2012).

In the context of this research, robotics was used as shown in Figure 1 (a). Since the main object was not to learn to build robots, but to work with educational robotics to learn to program computer systems. According to this, the Lego Mindstorms kit was used, specifically the EV3 model. The choice of this kit was done due to the review of scientific literature in which it was observed that in various parts of the world, the LEGO Mindstorms educational robotic kit is widely used in primary and secondary education (Kee, 2011), and in superior education (Danahy et al., 2014). This is due to their learning curve, this system hides the complexity of electronic circuits and the student focuses mainly on robot assembly and programming learning. Then, educational robotics kits seem to have found a place in the classroom for system programming and algorithm resolution. Which is favorable, since programming is a key element in the area of computational and related sciences.

Scientific production in the area of computational sciences, in Latin America

Despite the educational innovations spread in the field of computer science both in secondary and higher education. These have not promoted the scientific production in the area. Among the evidences found, the descriptive statistics shows that in Latin America does not exist sufficient evidence on the scientific articles published on computational sciences in high impact journals (see Figure 2). Ecuador with just 530 articles, is a clear sign of the poor scientific production in this area, whereas Brazil, the country which produced the most articles that is 49,296 of published articles. Ecuadorian production is really low, which might occur due to the fact that from the technical baccalaureate until the university careers; the disciplines related to the computational sciences are visualized just like technical careers, however, all the engineering process managed in the educational praxis of this area, is appropriate for the scientific production.

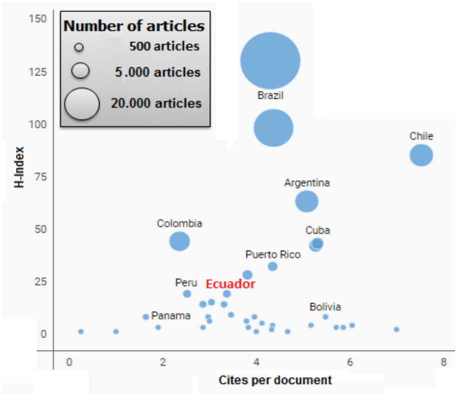

Figure 2.- production of scientific articles in computing sciences area in Latin America 2015-2016 (SCImago, 2016)

Conformation of scientific communities in technical baccalaureate.

Based on this background, it is considered that one of the elementary subjects in the area of computer science is computer programming, in addition, Ecuadorian high schools have begun to incorporate educational robotics within their learning environments, due to the good results in student academic performance. In the present study, educational robotics was combined with the cycle of the scientific method to see the effect they cause as an educational resource in the learning achievements of a specific field of Informatics. So, the research question which guided the study was raised: What effect does the combination of educational robotics with scientific method have on programming learning?

Objectives of the study:

To combine educational robotics (Lego EV3) with the scientific method to use them as an educational resource in the teaching of computer programming.

To analyze the impact of the educational resource (Lego EV3 + scientific method) on the learning achievements in programming of computational systems.

Hypothesis of the study

According to the central research question and the objectives of this study, the following hypotheses were designed:

H1: There are significant statistical differences between students who use scientific methodology in their programming classes (Lego EV3, with scientific method) and students who do not use it (Lego EV3, without scientific method) with regards to programming knowledge of computing systems, Before starting the educational intervention.

H2: There are significant statistical differences between students who use scientific methodology in their programming classes (Lego EV3, with scientific method) and students who do not use it (Lego EV3, without scientific method) with regards to programming knowledge of computing systems; Once the educational intervention is completed.

RESEARCH METHODOLOGY

Design of the study and participants

The research was quantitative and a quasi-experimental design was used with control group (Creswell, 2009; Hernández, Fernández and Baptista, 2010). The groups (control and experimental) were made up of students from third high school class of two high schools. Both groups were using Lego EV3 in their schools educational robots during programming teaching. The experimental group was incorporated the scientific method to its programming teaching process, for the purpose of the present study. The experimental group had 25 students and the control group had 26 students. In the total sample, 30 men and 21 women were counted, with an average age of 18 years old. In addition, to initiate the study, ethical norms of researching with human beings were taken into account by which written consent was obtained.

Procedure
Within the framework of the involvement project with the community that the Technical University of Machala had. The researchers of the present study, carried out the research in two schools of the Province of El Oro. In this sense, before the investigation process, in both schools (Control and experimental) an induction was carried out in which teachers and students were involved. Only the experimental group was trained during induction on scientific method. Students and teachers were then asked to sign a consent and collaboration form, all participants voluntarily expressed their agreement.
The study took place during the academic year 2016, from May to September. With the collaboration of the teachers of the subject, before starting classes in the month of April, standard micro-curricular planning was designed for both groups of students, in this way both control and experimental group received equivalent training. The unique difference was that the experimental group in its planning had the scientific method incorporated.
In order to set up the micro-curricular planning of the experimental group (Lego EV3 + scientific method), the researchers along with the teacher of the subject, searched correspondence between each phase of the scientific method of the design, construction and programming of the Lego EV3 robot (see figure 2).

Framework of educational robotics with scientific method.
The experimental group's lesson plan design was produced accordingly based on guidelines, which should be followed by students; this ensured the correspondence of the scientific method with educational robotics, the details of these guidelines are listed below:
Observation & ask question: for the observation stage and question formulation of the research, students were asked to think of: what kind of robot they wanted to design? And what challenges would the robot have to face? For this, students were invited to see some videos of LEGO EV3 robots already built and in operation.
Background research: In this phase, students were asked to review the LEGO EV3 robot, manuals for the requirements to assemble the robot they had in mind, and were also told about some selected links of the Internet for their search. This theoretical review would guarantee that the robot can be assemble.
Hypothesis: according to the selected robot for assembling, students were requested to set challenges, for the robot to try to achieve them. These challenges constitute the research hypothesis.
Experiment: at this stage the student performed all the tests to see if the robot managed to carry out the challenge.
Collecting data: data from the tests carried to the LEGO EV3 robot were collected for further analysis.
Analyze data: Students with the support of both researchers and teacher, placed their data in the SPSS statistical software for further analysis.
Conclusions: according to the data analysis performed in SPSS, the student with the support of both, the researchers and the teacher of the subject; made conclusions about the tests performed with the robot and the challenge proposed.
Report of results: finally, the stages of the design, construction and programming of the robot were placed in a scientific poster with the support of the teacher of the subject.

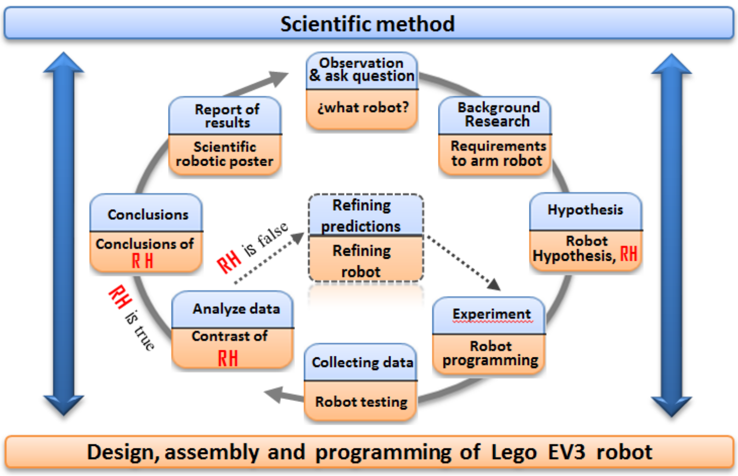

Figure 2.- Scientific method corresponding and construction of robot Lego EV3

During the months that the study lasted, programming classes were done by setting up Lego EV3 robots and programming them. For the month of September / 2016, the study ended, the data of official student scores in the subject, in both groups, were collected for analysis. Also, as part of the completion of the research project, the high school considered as an experimental group held a science and technology fair with the robots and scientific posters which were developed during the study.

Data Analysis

After obtaining the data of the students' scores of both groups (control and experimental), first Shapiro-Wilk test (due to sample size) was used in order to determine the normality of samples from the experimental and control groups. Then, to check for significant differences between groups in both pre-test and post-test, Mann-Whitney U-test was used. Finally, after the comparison between groups, the non-parametric statistical method was used to analyze the size of the effect for two independent groups (Grissom & Kim, 2012); In addition, to categorize the resulting sizes of the effect, it was stated what Cohen mentioned (1992; cited in Rienties et al., 2013): 2, which is considered as a small effect; 5, medium effect; 8, big effect. .

RESULTS

Tests of normality in the experimental group generated the value p = 0.008, with which it was determined that the sample was not normally distributed. In the control group; the value p = 0.004 determined that the sample was neither normally distributed.
Contrasting hypotheses 1: in table 1, regarding to the pre-test, no statistically significant differences were observed between control and experimental group (U = 306.00; Z = -0.36; p = 0.72). This indicated that in both groups, students before starting treatment, had the same skills in system programming. In addition, the size of the effect for the difference between the groups was, relatively small. Consequently, h1 was rejected.

Table 1. Comparison of the scores gotten before the treatment, by using Mann-Whitney's U test

Group	N	Mean rank	Sum of rank	Mann-Whitney U	Z	p	Effect size
Experimental	25	25,24	631,00	306,00	-0,36	0,72	0,47
Control	26	26,73	695,00				

Contrasting hypotheses 2: in table 2, regarding to post-test statistically significant differences were observed between the control and experimental groups (U = 146.50, Z = -3.38, p = 0.00), in which difference the Experimental group had an average range higher than the control group. In addition, the effect size for the difference between groups was relatively moderate. Therefore, h2 was accepted.

Table 2. Comparison of the scores gotten after the treatment, by using Mann-Whitney's U test

Group	N	Mean rank	Sum of rank	Mann-Whitney U	Z	p	Effect size
Experimental	25	33,14	828,50	146,50	-3,38	0,00	0,23
Control	26	19,13	497,50				

CONCLUSIONS

First of all, the scientific method combined with educational robotic learning environments, favors the learning achievements in programming in the area of Informatics. In addition, the design, assembly and programming of robots benefit from the structure of the scientific method, since each phase of the robot's construction; a phase of the scientific method can be selected. This is the key of the lesson plans design for teaching-learning of computer programming in baccalaureate.

These findings suggest that scientific method combined with educational robotics are an approximation to the conformation of scientific communities in the area of computational sciences in secondary schools. Students participate in studies framed in the structure of the scientific method and expose their results through a scientific poster at fairs. In order to start some training with students as a scientist in the schools, which help setting new challenges in the scientific production of the area of Computer Science in Universities.

The quasi-experimental character of this study is a contribution to the educational reality of Ecuador, and it is supposed to be a key piece to go forth within the scientific objectives of higher education. In addition, the proposal reflects the need to raise and develop more initiatives of this type in the secondary field, due to the positive collaboration of teachers and students.

The linking projects of the universities with the community open a range of possibilities to propose alternatives that favor the formation of scientific communities at the secondary level, especially in high school baccalaureate, where students are about to choosing their university majoring. The initial formation of the scientist as an approximation is liable to the efforts that are made in the last years of high-school.

FUTURE WORK

The present research is a pilot project that is part of a larger and more comprehensive program that searches for connect high school students with scientific method. In this context, a longitudinal study will be carried out with the framework of figure 2 to analyze the Secondary school students' perceptions about scientific method.

ACKNOWLEDGMENTS

This research was approved and financed by the Technical University of Machala, through resolution #122/2016 of the University Council.

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