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Learning Programming Using Educational Robotics

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Abstract — Research reported in this paper fits into the generic problem of programming learning. In this context, the primary research objective of this study is to analyze if robotics facilitates programming learning. To tackle the problem, we developed a robotic kit and a small course. The robotic kit used Arduino platform and was presented in the context of this course. The course consisted of programming concepts. This course was taught to higher education students, with no previous programming knowledge. In the end, we analyzed the impact of the course. Results demonstrate that students showed interest in using robotics to learn computer programming. Results also showed the main adoption determinants of the robotic kit. Enjoyment is the most relevant to the robotic kit intention to use. However, perceived ease is the dimension that has more impact on robotic kit usage.

Keywords - Educational Robotics; Arduino; Programming Component; Adoption Model.

I. INTRODUCTION

Regardless of the degree of education, the disciplines that involve Computer Programming and Logic of Programming are those that create more difficulties in the courses of Computer Science and some Engineering courses, evidencing high failure rates. Computer programming learning and programming logic learning is a challenging task due to the individual complexities of the subject. In this scenario, it is necessary to search for new means to deal with the complexity that surrounds the programming teaching and learning model, and that stimulates and motivates the student. As Benitini [1] reports, one of the possible solutions is the use of Educational Robotics. For Papert [2] the use of robots as a support for education has a high potential to involve the student in the learning process in the classroom. Benitti [1] and Eguchi [3], [4] also point out that Educational Robotics presents a wide range of practical possibilities that can attract students, bring a non-traditional Educational approach and stimulate the search for solutions. This work aims to investigate the validity of the use of Educational Robotics in the scope of computer programming teaching. The evaluation of the use of Educational Robotics was carried out from a set of classes with students of higher education. This paper attempts to complement our previous research on the use of robotics usage for programming learning [5][29][30]. Previously, experiments based on virtual robots are described, this time, the goal is to test similar concepts in a more tangible approach.

II. EDUCATIONAL ROBOTICS

Robotics is a field of engineering and science that has been gaining more attention in various activities and is increasingly inserted in our society and present in our daily lives, whether at work, on the street or at home. Robotics has a great interest as a learning tool and has been playing an increasingly active role in the construction of knowledge. The significant growth in the supply of robotic kits at all levels of education validates their use and the technical and scientific skills of the students. Educational robotics can be seen as integrated into a traditionalist learning program. Robotics may be part of the programmatic content of the course. It may be even included in a constructivist approach, in which Robotics Consists of the interface between the robot and the software, Software used in robot programming, and electronic and mechanical components [6].

Educational robotics provide a work environment in which the student expands their knowledge by the manipulation and construction of the object. Strengths include the interdisciplinary and multidisciplinary nature beyond transdisciplinary. Educational Robotics, as indicated by some authors, can be a strong ally to motivate students against a range of potentialities and many benefits. This tool empowers collaborative work, promotes a more malleable cognitive development, creating conditions for the student to be the principal factor in the construction of his knowledge [7] [8]. This methodology allows students to manipulate objects, facilitate their learning, and their contact with current technology, which contributes to the development of some skills such as logical reasoning, specific problem-solving critical ability, and even application of theories formulated for a particular activity. Regarding Educational Robotics in the classroom, it is necessary to consider the preparation of teachers for the use of this tool. Therefore, an attempt should be made to develop a teaching methodology considering this new reality. Problem-based learning is a teaching-learning model that recognizes the need to develop problem-solving skills and to help students in acquire essential knowledge and skills [9], [10]. This model uses real problems, not to the study of hypothetical cases with perfect and convergent results. In addressing these real problems, students learn content and develop critical thinking skills (critical thinking skills). In this context the problems must be open, based on a real-world context, should involve students. Problems should allow several hypotheses, which require the effort of

teamwork in its resolution, and allowing the construction of new knowledge based on experiences. Problems should also be in line with the programmatic content addressed to promote the development of higher-level cognitive skills [26].

The Arduino project, born in Italy in 2005, is a hardware and software platform characterized by inexpensive cross-platform, simple, clear programming environment. It uses open source and extensive software and open source and extensive hardware. [27] It is usually associated as a tool to the philosophy of Physical Computing, that is, the concept that covers the creation of physical systems using Software and Hardware capable of responding to inputs from the real world. To achieve this goal, the project proposal aims not only to create easy-to-handle hardware and the resources needed to work with the digital and analog "worlds", but also an affordable development software for interactive project programming. Once programmed, the Arduino can control a range of electronic components such as LEDs, motors, and displays. [24] [25]

Figure 1 shows a summary of the steps required to develop an application in a schematic form, which is designed the Development Cycle. In the analysis of the Development Cycle, it is possible to summarize all the necessary phases until the execution of the created program, being very important its understanding.

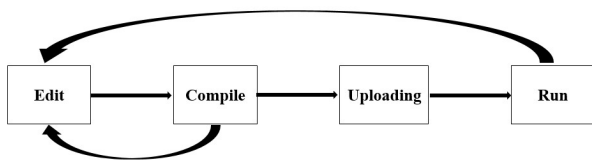


Figure 1. Development cycle.

III. EMPIRICAL WORK

The purpose of this study is to understand how Educational Robotics can be used as an auxiliary tool for Programming. The research methodology is based on design science research [11],[13]. This methodological approach is based on artifacts construction and evaluation. The artifact here is based on literature review, from which we developed a robotic kit with the purpose of enabling and facilitating programming learning. The evaluation phase of the artifact consisted of two studies, one which consisted in understanding better the reality of using a robotic kit as an enabler to programming learning. The second phase consisted of understanding the robotic kit adoption level, by validating the adoption theory in this context, through a survey of the students, who used the robotic kit.

For the proposed activity, a kit of LEDs and sensors was created, consisting of five LEDs, a light sensor, a potentiometer and a temperature sensor so the students could manipulate it through Arduino programming (Figure 2). This kit will be connected to the Arduino, which will allow programming,

quickly, and in this way to verify, at once, if what has been programmed is being executed. [25]

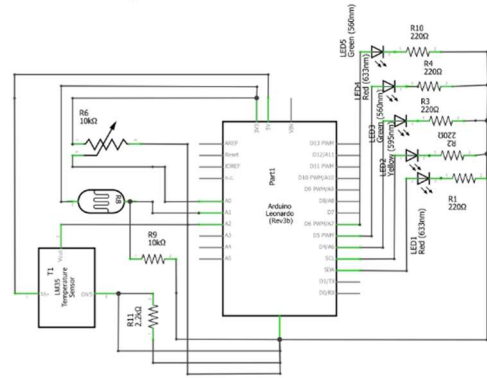


Figure 2. LEDs and sensors Kit.

The first learning kit was used in real classes context; students were challenged to develop code to surpass the challenge. The participants of the study were students from three classes of university education. Two of the classes belong to the degree in Electronic Engineering, and a third group includes postgraduate students in Computer Engineering. The validity of this study was obtained internally with a validity of the investigations proposed to the students. A clear and accessible language was used in the elaboration of the questions so that each subject has an explicit meaning. Closed questions were addressed due to some advantages over open ones, namely quantifiable and easy answers. This methodology guarantees, in this case, also a greater fidelity, since all the answers are subjected to their alternatives, which facilitates a comparison of the results. The first questionnaire aimed to collect data relevant to the study in question.

The proposed program is relatively demanding since, in addition to the programming topics presented, it includes the learning of some hardware concepts used in the LED and sensors kit. The class' s objectives were the following: a) Using Robotics as a learning tool; b) Promote interest in programming using Educational Robotics; c) Promotion of experimental work

To achieve the class' s objectives, students faced a challenge, composed by a threefold activity, during a two-hour class. The challenge was to simulate a traffic light using the LED and sensors kit. The first activity consists of elaboration of a flowchart and organization chart. Then, the pseudo-language in blocks could evaluate the flow of information of the program to be executed. Second activity consists of programming an Arduino, the robotic kit, to simulate a traffic light (times between LED changes of the were defined by the students). The third activity consists of using the light sensor in the kit to simulate the following several situations. If there is no light (light sensor covered), the red and green LEDs must be off, and the yellow LED should be flashing (the time the LED flashes is assigned by the student). If there is light (light sensor uncovered), the led will simulate the traffic light (Part Two).

IV. RESULTS

A. Results of the robotic kit usage in real class context

The present study involved 43 (forty-three) students who attended the second semester of the academic year 2016/2017 in all classes. All the students answered the questionnaires, being 37 men and six women, participants' ages ranged from 18 to 46 years (Figure 3). Figure 4 depicts the real context in which the robotic kit was used.

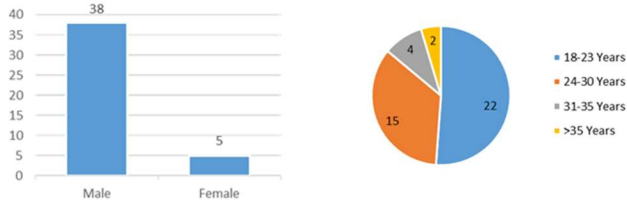


Figure 3. Sample characteristics.

The analysis was based mainly on negative responses, highlighting difficulties and problems identified by students. It is possible to understand the aspects where the students revealed critical difficulties. Thus, defining the information and notes that can be improved in practices with Educational Robotics.

In the understanding of the task (what to do during practice) in question 1 (Figure 5), it was possible to identify problems related to the task description.

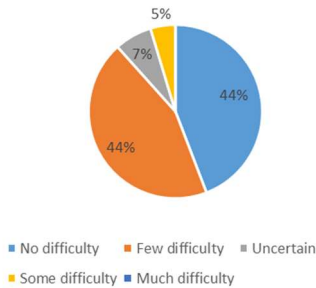


Figure 4. Perceived difficulty level.

Almost half of the students (44%) answered that they had no difficulty performing the tasks. The same percentage was almost all positive and showed that the practice helped in the concretization of new Programming concepts.

The questionnaire has the following questions:

- Students felt difficulties in applying the concepts of Programming Logic.
- Students felt difficulty in working out the solution to the proposed practice.
- Students felt difficulty in understanding the objectives of the proposed practice.
- Students felt difficulty in applying the concepts of programming logic (decision structures, repetition structures, etc.) in the solution.

- Students used "IDE" without problems.
- Pedagogical Robotics helped in learning or did you increase your knowledge in programming concepts
- The responses given by the hardware to the programming performed clear and coherent.
- Students perceived clearly the resources (LEDs, sensors, etc.).
- The use of the hardware occurred without problems or difficulties.
- Robotics an interesting tool for teaching programming.

The analysis allows relating the use of Educational Robotics with the help of programming. It is possible to note that the use is relevant for teaching and learning programming, as shown in Figure 6 when it is perceived the responses majority are between 58% of "totally agree" and 37% "partially agree". There is almost no disagreement in the use of Educational Robotics when it is verified that the exclusively negative responses of "partially disagree" and "totally disagree" are only 5%.

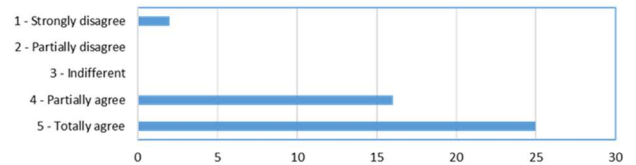


Figure 5. Educational Robotics is an interesting instrument for teaching programming.

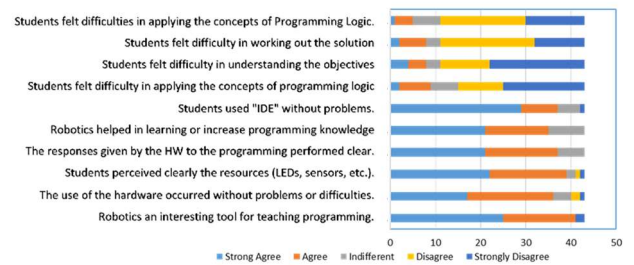


Figure 6. Questions on the robotic kit usage for programming learning.

Figure 7 depicts the questions directly related to the understanding of the goal of the activity and development of the same are presented on It is noticed that the majority of the students were able to reach the requested solution. The application of programming and logic concepts were found to be acceptable. Concerning the evaluation of the activity performed, all responses were very positive

The analysis of responses was positive in all the questions, except for some criticisms and negative notes, mainly related to problems in the kit of LED's and sensors. The issues that are directly related to the particular technological aspects of the LED kit and sensors, such as unexpected behaviors arising from sensor operation and physical communication difficulties. All the practice using Robotics should assume inconsistencies in actions in the LED and sensor kit, as this is subject to interference from elements external to the programming (e.g.

variation of light sensor brightness). Some of the negative responses come from these problems that were not considered in the activity. The students' experience and, consequently, their critical capacity should also be considered. Often, some of the answers given by the students do not have enough detail to identify the problem or its difficulties accurately. However, even with small details in the answers, it is possible to notice a predominantly positive scenario in the students, showing the potentialities of a formal process for the development of programming practices using Educational Robotics.

B. Second study: adoption level of robotic learning kit in programming learning

We developed a second study by proposing the validation of the adoption theory [14], [15] of information systems, in this case in the adoption of robotic kit. For validating the model in this context, we developed a survey to be answered voluntarily by the students, who were exposed to the robotic kit. The questionnaire operationalized the following dimensions: enjoyment, perceived usefulness, perceived ease of use, intention to use, and use of the robotic kit. The technology adoption theory [14], [15] proposes that enjoy, perceived ease of use (PEOU) have a positive impact on perceived usefulness (PU). Students enjoyment and PU have positive impacts on intention to use the robotic kit (IU). Moreover, PEOU with IU have positive impacts on the actual robotic kit usage.

Data were analyzed using PLS/SEM method [16], [17]. In this method data analysis have two phases, the first phase which analyses the quality of the measurement model, and the second phase which analyze the structural model quality.

1) Measurement model results

We assessed the composite reliability of the constructs to evaluate internal consistency, individual indicator reliability, and average variance extracted (AVE) to evaluate the constructs convergent validity. All loadings were above 0.7, Alpha de Cronbach was above 0.78, and AVE was also above 0.5, these results show the reliability of the constructs according to thumb rule criteria [18]. Besides these tests, the construct intercorrelation criterion and cross-loadings result assessed discriminant validity of all latent variable. Table I, Table II, and Table III, present the correspondent results of the constructs validity and quality of the measurement model. Meaning that all constructs are independent of one another, and all items measure the latent variables.

The latent variables of the model, enjoy, PU, PEOU, IU, and use are well measures by all the questions posed to the students. Thus, the reliability and validity of the measurement model was confirmed in PLS.

TABLE I. CROSS LOADING VALIDATION

	Enjoy	IU	PEOU	PU	Use
E1	0,883	0,4267	0,088	0,195	-0,084
E2	0,951	0,567	0,366	0,419	0,149
IU1	0,516	0,949	0,427	0,586	0,525
IU2	0,529	0,935	0,417	0,415	0,482
PEOU3	0,194	0,325	0,903	0,629	0,602

PEOU4	0,305	0,484	0,909	0,627	0,640
PU1	0,388	0,510	0,565	0,924	0,625
PU2	0,232	0,483	0,619	0,910	0,668
PU3	0,346	0,463	0,689	0,877	0,588
USE	0,061	0,535	0,686	0,693	1,000

TABLE II. QUALITY CRITERIA

	AVE	Composite Reliability	R ²	Cronbach's Alpha	Communality	Redundancy
Enjoy	0.842	0.914		0.819	0.842	
IU	0.887	0.940	0.438	0.874	0.887	0.255
PEOU	0.821	0.902		0.782	0.821	
PU	0.817	0.931	0.510	0.888	0.817	0.078
Use	1.000	1.000	0.535	1.000	1.000	0.224

TABLE III. CONSTRUCT INTERCORRELATION

	Enjoy	IU	PEOU	PU
Enjoy	1.000			
IU	0.554	1.000		
PEOU	0.276	0.448	1.000	
PU	0.3582	0.537	0.693	1.000
Use	0.061	0.535	0.686	0.693

1) Structural model results

The second phase of this second study assessed the validity of the structural model, by calculating the coefficients of determination (R²), and the size and significance of path coefficients between the constructs. All the hypotheses were significant, as shown in Table IV.

TABLE IV. HYPOTHESES RESULTS

Hypothesis	Independent Variable	Dependent Variable	β	T-Value	P Value
H1	Enjoy	-> IU	0.415	3,294	0,001
H2	Enjoy	-> PU	0.180	1,788	0,041
H3	PEOU	-> PU	0.643	7,599	0,000
H4	PEOU	-> Use	0.558	5,896	0,000
H5	PU	-> IU	0.389	2,762	0,004
H6	IU	-> Use	0.285	2,367	0,011

Hypothesis 1: is significant ($\beta=0,415$; significant for $p<0,001$), confirming that students' enjoyment level has a positive impact on the intention to use the robotic kit in programming learning context.

Hypothesis 2: is significant ($\beta=0,180$; significant for $p<0,050$), confirming that enjoyment level has a positive impact on the perceived usefulness of the robotic kit.

Hypothesis 3: is significant ($\beta=0,643$; significant for $p<0,001$), confirming that perceived ease of use (PEOU) has a positive impact on perceived usefulness (PU) of the robotic kit.

Hypothesis 4: is significant ($\beta=0,558$; significant for $p<0,001$), confirming that perceived ease of use has a positive impact on the robotic kit usage.

Hypothesis 5: is significant ($\beta=0,389$; significant for $p<0,010$), confirming that perceived usefulness (PU) has a positive impact on intention to use the robotic kit.

Hypothesis 6: is significant ($\beta=0,285$; significant for $p<0,050$), confirming that intention to use of the robotic kit has a positive impact on the use of the kit.

Figure 8 shows the structural model results; this model explains 54% of the robotic kit usage in programming learning context. Results show that the usage is more explained by the perceived ease of use of the robotic kit, than by the intention to use of the kit. Intention to use the robotic kit is explained in 44% by enjoyment and by perceived usefulness. Perceived usefulness is explained by enjoyment and by perceived ease of use in 51%, as the latest has a more positive impact on usefulness than enjoyment.

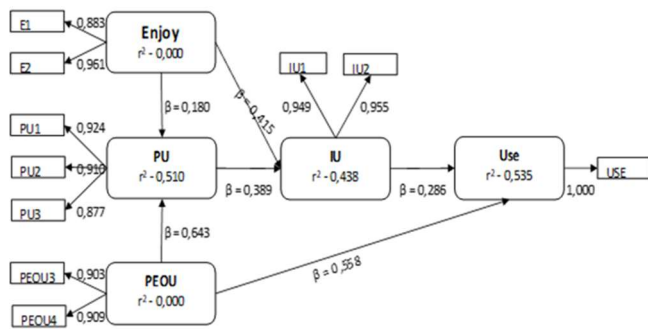


Figure 7. Structural model of the robotic kit adoption for programming learning .

V. DISCUSSION

The analysis of the results of the present study showed that the method used had a positive impact on students. For the generality of the participants, the model revealed good perspectives for the learning of the programming, since it became more motivating and attractive. Similar results were also obtained in other studies [19], [21]. The method used covers the development and evaluation of practices, through systematic and formal means, using artifacts and theoretical bases that involve Electronic Educational Robotics and Programming.

This perspective may be an interesting alternative to an Educational proposal for the teaching-learning of programming, directed to the interest of the students, becoming responsible for learning and development [22], [23]. In this way, Robotics brings together all the conditions to provide a set of interdisciplinary activities that promote transversal learning

of the various themes. The activities involving Robotics are characterized by giving students an almost infinite number of problems to be solved. Sometimes these problems can be unexpected, even for the teacher who coordinates the activity.

VI. CONCLUSIONS

Educational Robotics for teaching programming is an Educational resource of great potential, both in matters related to student motivation and in the diversity of tools and support that can be offered to teachers. However, its application in the classroom is not an easy task and must be accompanied by appropriate methods for effective learning while providing useful assessment tools. With the results obtained from this experiment, it was possible to visualize positive aspects in the adoption of Educational Robotics, as well as aspects to be improved. This work also emphasized aspects related to Educational Robotics that the method does not cover, does not collaborate or is limited. This research had an exploratory character, resorting to a small sample for the experience. However, these tests allowed the definition of the problem and the formulation of a proposed solution, through an investigation into the possible difficulties of the students in programming, when using Educational Robotics.

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APPENDIX: A QUESTIONNAIRE

Enjoy	E1	I consider that the use of Arduinio for programing is fun.
	E2	I consider the use of Arduinio in programing is agreeable.
Intention to Use	IU1	I intend to continue programing using Arduino.
	IU2	Since I have access to Arduino, I plan to use it.
Use	USE	I consider myself a frequent user of Arduino.
Percieved Usefulness	PU1	Arduino usage improves my performance in programing.
	PU2	Arduino usage improves my productivity.
	PU3	Arduino usage improves my efficacy in programing.
	PU4	I consider usefulness the usage of Arduino.
Perceived Ease of Use	PEOU1	Programing learning is easy.
	PEOU2	I consider easy to do programing with Arduino.
	PEOU3	It is easy for me to become na advanced Arduino user.
	PEOU4	It is easy to use Arduino.