EDUCATIONAL ROBOTICS PROJECTS THAT PROMOTE INNOVATION AND SOCIAL COMMITMENT SKILLS

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ABSTRACT

The course of the University Social Project (PSU) of the Pontificia Universidad Javeriana in Colombia, provides spaces for undergraduate students of electronic engineering, in which they can articulate and implement the relationship between their profession and social challenges in the country. At PSU, students apply their disciplinary knowledge in training activities and technical advice, which contribute to the transformation of the context in which they carry out their social practice. In recent years, some students have had the opportunity to carry out projects where they must conceive, design, and implement a product that solves one of the problems of vulnerable communities. These projects have initially focused on generating new products or prototypes of educational robotics for students and teachers of low-income schools. Through the development of this project using the CDIO initiative, students can apply their existing knowledge in real-life problems or real-life situations. They also can learn about how to carry-out a user-centred design, how to apply an Iterative and incremental development methodology, and how to perform a rigorous user validation. This kind of project fosters the acquisition of skills such as innovation and social engagement skills. This paper shows the methodology used for the development of these educational robotics products and some examples of products developed by students. We also discuss how this type of project can promote innovation and social engagement skills. Finally, the new perspectives and lessons learned are detailed.

KEYWORDS

Educational robotics, Engineering Education, Social Commitment, Innovation and Creativity skills, Standards 5, 7

INTRODUCTION

University Social Project (Proyecto Social Universitario - PSU) is a mandatory theoretical-practical course for final year engineering students of the Electronics Engineering Program at the Pontificia Universidad Javeriana, Colombia. This course provides students with the opportunity of knowing part of the social reality of the country and apply their knowledge and skills to contribute to the solution of problems faced by communities and institutions in situations of economic and social vulnerability.

Students in the PSU course have 60 hours of fieldwork at a beneficiary institution during the academic semester. In addition to this fieldwork, they have a two-hour weekly meeting with the course professor. During these meetings, students participate in workshops and conferences that invite them to reflect on social responsibility (Lopez et al., 2011).

The activities of electronic engineering students during their fieldwork have mainly focused on training and technical service activities. However, the development of projects where students conceive, design, and implement products that solve the problems or needs of the beneficiary institutions or communities has recently been explored. This kind of project provides students with the opportunity to apply their knowledge and skills to solve real-life problems and validate their ideas with end-users and potential clients. Besides, these projects foster the development of 21st-century skills such as creativity, innovation, and social commitment.

The projects carried out in the last two years have focused on the development of educational robotics products that contribute to educational innovation in low-income educational institutions. The purpose of this paper is to present how the CDIO philosophy was adapted to guide the work of students in the development and validation of robotics educational products. We also present how the use of strategies such as user-centred design and incremental and iterative development methodology help students achieve the development of products that meet the educational needs of teachers and students of low-income institutions.

This paper is structured as follows: first, the methodology based on the CDIO initiative used in product development projects is introduced. Then, examples of students' projects in the field of educational robotics are presented. Later, the challenges and potential of these projects are also discussed. Finally, lessons and new perspectives are given.

METHODOLOGY TO DEVELOP EDUCATIONAL ROBOTICS PRODUCTS

Recently, in the PSU course, a new line of work has been created in which senior students of electronic engineering can propose innovative solutions to problems or needs in institutions or communities in vulnerable conditions. The projects that have been developed have focused on the development of educational robotics products that facilitate educational innovation in low-income educational institutions (Bravo et al., 2018).

Students who choose this line of work, have 60 hours in the semester to conceive, design and implement and validate with end users a prototype of educational robotics product that supports the teaching and learning processes. This product must be designed so that it can be easily adopted by low-income educational institutions. Therefore, the product developed by students should be low cost and easily replicable.

For the development of the product, the user-centred design approach has been adopted in such a way that the solution developed satisfies the need of the users (Institute of Design Stanford, 2010). For this reason, the students must involve the end-users and potential customers at all stages of product development.
Students are assigned one or more mentors who provide advice on the different stages of product development and validation. This mentor is usually a volunteer professor who is an expert on the subject of the project, in this case, an expert in educational robotics or educational technology. Students also have the support of a schoolteacher for the validation of ideas and the product developed in a real context. As for the PSU course professor, its role in the project is to find the mentors and schoolteachers who will support students in project

development. This professor is also responsible for verifying that students comply with the proposed work plan.

Based on the CDIO approach, the methodology used in the PSU course to develop innovative solutions in educational robotics involves the following stages:

Stage 1: Conceive

Due to time constraints, students are informed about what the problem is or the need they must solve. They are asked a guiding question that describes a design challenge. This guiding question will guide the students' work throughout the product development process. An example of a guiding question is the following: *As an engineer, how would you design an educational robot that helps sixth-grade students in low-income schools understand mathematical concepts such as the Cartesian plane, angles, and geometric figures*.
At this stage, students should carry out a consultation process with end-users, potential clients, experts, and bibliography sources to understand the challenge they are trying to solve. This consultation process involves conducting interviews, focus groups, observations, and a comparative evaluation process.

To guide students in the student research process, they are asked a series of essential questions. For example, what difficulties do students have in understanding the problem of the Cartesian plane? What difficulties does the teacher have to present the theme of the class? What tools does the teacher use to present the topic? What teaching method does the teacher use to explain the subject? How can an educational robot help the teacher explain the issue? Have the students or the teacher used educational robots?

Once the students have understood the challenge and have observed it from the perspective of the end-users, the next step is to define the functional and non-functional requirements that the product to be designed should have. Due to time constraints, mentors give students basic project requirements. Students along with the mentor must refine and prioritize these requirements according to the lessons learned from the performed inquiry process.

Then, an agreement is reached with the student on which of these requirements he will implement and validate during the course. The student will generate a work plan with the activities to be carried out and the delivery dates. To achieve a functional prototype for schools, the following semester another student will resume the project and implement other functionalities. This process is repeated until a prototype is developed that can be taken to schools.

Stage 2: Design

The iterative and incremental development methodology was selected to design the product prototype. Students begin with the grouping and prioritization of the requirements to be implemented. Then they select the first set of requirements and generate possible design solutions. After that, they select the best solution and include it in the design. Subsequently, students perform design verification with end-users using rapid and low-cost prototypes (e.g., paper prototypes). Next, students choose a new set of requirements and the process is repeated until all the requirements are included in the design.

Stage 3: Implementation

In this stage, the prototype of the educational robotics product is built and validated (Daniela, 2019). Students are provided with craft materials, electronic components (for example, microcontrollers, motors, sensors), mechanical parts, and 3D printers to build the product prototype. Once the prototype is finished, students validate it with end-users and potential customers.

The validation process includes the design of a learning experience that uses the designed prototype. It also involves the design of the data collection instruments. The designed learning experience is implemented in a school under real conditions. The results of this stage are possible improvements to the design. It is also possible that new design requirements may be identified (Mikropoulos, 2013).

At this stage, students must generate a detailed document of the work done in the semester. Also, technical manuals, source codes, and learning experience guides are generated. This documentation is essential for the continuity of the project.

EXAMPLE OF DEVELOPED EDUCATIONAL ROBOTICS PRODUCTS

In this section, two projects carried out during the PSU course are described. These projects arise from the need to promote educational innovation in low-income institutions. In the first project, students were asked to develop a robotic arm to teach mathematical concepts. The project requirements were to design a low-cost robotic arm that is easily replicable by teachers and students. Also, the robot should have the option of being teleoperated through mobile devices or via wired control in case students do not have access to a mobile device or computer. Figure *3* shows the result of the engineering design process of the robotic arm. Students validated the designed arm robot and generated a report with improvements in design.

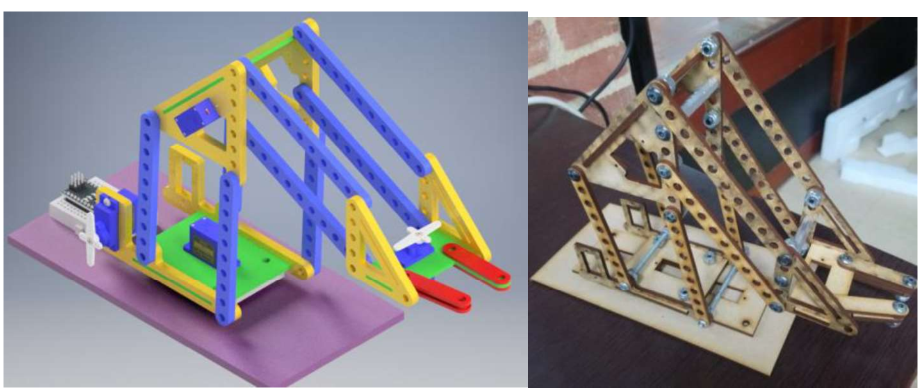

Figure 3. Arm Robot to teach mathematics

This project continued in the following semester with another group of electronic engineering students. These students were asked to improve the design of the robotic arm and to develop robotic educational activities based on the robotic arm that supports the teaching of the Cartesian plane and geometric figures. Two examples of designed learning experiences are:

- **Activity 1 - Reveal the riddle**: The activity consists in strengthening the knowledge of geometric figures in students between 5 and 7 years old. The designed activity proposes that students use the robot to join the points of a given numerical sequence. Next, students must determine what geometric figures they drew.

- **Activity 2 - Find the treasure:** This activity, designed for students between 8 and 11, seeks to strengthen the theme of operations with vectors in the Cartesian plane. Students use the robot to mark certain points on the Cartesian plane. Then, they must do some geometric and vector operations to find out where the treasure is on the Cartesian plane.

In the second project, students were asked to design an expressive robot for the implementation of storytelling activities in non-technical school subjects. The requirements given to the students were that the robot must be inexpensive, play audio files, and be able to express emotions such as happiness, sadness, calm, and anger. Engineering students carried out a consultation process with students and teachers at the school to obtain other design requirements and validate possible solution ideas. The result of the engineering design process was the development of a prototype robot actor that is capable of expressing emotions through faces projected on an LED matrix and an intuitive interface for the teleoperation of the robot actor (see Figure *4*). In the designed interface, the user can choose emotional faces, play audios, and control the movement of the robot.

Figure 4. Expressive robot actor prototype and its control interface

The students carried out a validation of the prototypes developed with children between 4 and 6 years old (see Figure *5*). This validation allowed them to identify possible improvements in the design of the robots and the interface.


Figure 5. Storytelling activities with children

DISCUSSION

Product development projects provide students with rich contexts to apply their knowledge and skills in solving real problems facing vulnerable communities. The development of these product prototypes not only promotes social commitment but also fosters creativity and innovation skills in students.

This new line of work has pleased the students of the course because they are having the experience to design a user-centred product. They have the opportunity to validate most ideas with the user through rapid prototypes. This allowed them to realize that many times what they imagined did not work and needed to rethink their idea. This interaction with users also allowed them to discover new design requirements and restrictions.

Students also value the support they have during the execution of the project. They had one or more expert mentors on the subject of the project, the support of a schoolteacher to perform validations, and the accompaniment of the course teacher. The mentor's role is key to the development of the project. The mentor is the person who guides the student through the entire product development process. The fact that the mentor is an expert in the subject of the project makes the product development process quick and successful. For example, the mentor is that he is already clear about the basic requirements of the product to be developed and students can start from those requirements. The inquiry process that students have helps refine these requirements so that they adapt to the context and the target users. In addition to the training that social responsibility students have, the mentors provided students with training on user-centred design, design thinking, incremental and iterative product development, innovation process, design of data collection instruments, among others.

Something interesting about the projects proposed to the students is that many of them are linked to research projects that are being carried out in the engineering faculty. For example, the low-cost expressive robot actor project arose from the robotic theatre research project for educational purposes. This makes many of the solutions students develop innovative in the market. For example, an educational robot that allows to easily implement robotics storytelling activities in the classroom has not been identified. That is why the projects developed in the course can become an entrepreneurial project for students and teachers. We also hope to link people from the university's innovation department to the course. They will be able to support accompanying teachers and students to mature the idea and achieve a product that can be transferred to the market.

NEW PERSPECTIVES AND LESSONS LEARNED

The activities that students do in the PSU course have been limited to training and technical support activities in beneficiary institutions. Recently a new line of work has been created in which students develop prototypes of products that seek to solve a need or problem faced by vulnerable communities. Currently, product development has focused on educational technology solutions for low-income educational institutions. It is expected to expand this work area to other fields.

A limitation of this proposal is that the number of students who can participate in product development projects is limited. It depends on the number of volunteer professors that are available to accompany students in product development. We are dedicating efforts to increase the number of volunteer mentors participating in the course. For example, we are planning to link graduates and entrepreneurs to advise the students' work on the project.

The time constraint in the course for the development of a product prototype was resolved by dividing the project into different stages of development. In one semester, a student is responsible for implementing a set of requirements and the following semester another student implements the pending requirements. The process is repeated until a functional and validated prototype is achieved. To ensure the continuity of the projects, students must document their work well.

Our strategy to bring the prototypes of products developed to the school is through the students of the courses that develop training activities. These students help generate didactic material and carry out teacher training and implement learning activities that use the developed prototype.

Finally, it is expected to find resources to be able to donate prototypes developed together with educational material (e.g., booklets) to schools. Also, providing schools with an accompaniment for the appropriation of this educational technology through the students of the PSU course.

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