Working with Engineering Students and Kids Using Arduino in a Multidisciplinary Experience

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***Abstract*— It is a multidisciplinary project between Mechanical, Mechatronics, Control and Automation, Electronics and Electrical engineering undergraduate students that aims to improve children's interest about the technological, programming and mathematical areas. The students formulated classes for students between 11 and 15 years old. In those classes, they practice many different applications using Arduino. The results cannot just be analyzed from the perspective of children's improvement, but also in a way to develop didactically and socially the undergrad students.**

Keywords—Education, Arduino, Extension programs, PISA, Science, Mathematics, Programming

I. INTRODUCTION

Over the past years, Brazil's performance in exams as PISA (Programme for International Student Assessment) was not satisfactory. In the last PISA, released in 2016, reveals that Brazil's score is below the OECD (Organisation for Economic Co-operation and Development) average, following a sequence of bad results. In Brazil, about 70% of students fail to achieve the most basic level of proficiency in mathematics and less than 1% of students can be considered "top performers" in math and science. While in countries like Singapore the number of top performers is about 33% [2] [3] [4]. This result comes, in part, from the precarious elementary education in Brazil, where the mathematics is seen as an obstacle and without applicability. This demands a new teaching method, that changes this situation and stimulate students

In the small city of *São Tiago*, at the locality of *Campo das Vertentes* in *Minas Gerais*, Professor Ronaldo Antônio de Castro manages the team "*Café com Bytes*", which is composed of scholars from the state-run public school *Afonso Pena Júnior*. The way found to bring those scholars to the team were through robotics' competitions [10] [11].

The team has shown a great development at the robotics' competitions, this can be confirmed by the recent results, as in 2012 they won the local and the national competition, reaching the international tournament RoboCup, in Mexico, where they got the awards for "Best Programming" and "Super Teen".

The participation on a robotics' team demands that the student apply concepts of mathematics and physics, to the programming and robots set ups, and consequently awaken the interest in the programming area. This causes such a positive impact on the team's members, and at the whole community,

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because to set up a robot for competitions, you need help from people out the school.

As a small city of 11000 inhabitants, these awards are seen as a victory for the whole city. This result motivates not only the students from the school where the team is located but also students that are getting to school in the future. The school hosted a national competition in 2014, showing the effectiveness of this action, as a way to boost cooperation between schools and teenagers from different places around Brazil.

The communication between science and others social spheres benefits both sides. This kind of project brings science closer to children and teenagers, what makes the new generations more interested in science [1] [5] [6]. Also is important the ethical and human view from the university extension programs that promotes the communication between science and children/teenagers, with the goal to awaken the interest in many areas of science as possible, and with these projects spread a culture that valorizes and do science. Therefore, in this project students applied Math and Physics concept's on projects using the open-source prototyping platform Arduino, during theoretical and practical classes. What made students more interested in mathematics [12].

II. PROBLEM

A. Elementary and High School Situation

Brazil's negative records in math not only appear when compared to other countries. In comparison with Reading and Science scores at PISA exams, in Brazil, math loses, even though that in the last six PISA exams, students of 15 years old shown some evolution, but mathematics still has the worst score, 377, while Reading score is 407 and Science score is 401 [8]. Things just get worse when you look at the results of how many students could not pass Level 2 in math exams, 70% of Brazil students in PISA tests [13].

Facing this sad reality in Brazil, where the bigger part of students in elementary and high schools do not get along with math and physics, we can also see that we are lagging far behind in computer's programming. At the technological areas of the higher education, as Engineering, the scenario is even worse, because many students fail in Calculus courses and subjects that demand logical reasoning, as computer programming. Hence, Brazil needs this kind of action that comes to capacitate children and teenagers, and raise their awareness about math and the tech areas. This opportunities are leading students to the professional world [9].

The magazine *Nova Escola* proposed a debate about the teaching of programming in elementary schools and agrees that the computer programming should be taught to children, even in subjects that are not correlated with the math/science areas.

When contextualized, the programming can be a great ally at the teaching of basic subjects, as Portuguese and math. Mathematics' teacher, can use programming to study numbers and basic operations in the field of arithmetic, and a teacher of Portuguese, on the other hand, can use it as a tool in the process of literacy. Regardless of the way, what matters is that programming's teaching in schools is a means to an end, not an end in itself that should be seen as a new way to raise the engagement of students with the knowledge [7].

B. Case Study Analysis

To make students like math it is necessary that they see the application in what they are learning, so they will need to study something to apply on a project. As an example, in one the classes prepared that used the ultrasonic sensor to find out the distance between the sensor and some target. For this, it is used a basic formula from the physics, that involves sound's velocity, distance and time. Thus, students applied the formula in a practical and absorbing class.

This project did not just benefit the students that attended the classes, but also the undergraduates that had a great development as professionals and as human beings. One of the reasons of this project was to create professional that stick their actions on ethical principles. At the view's point of the extended learning, more than just give the technical knowledge to undergrad students is also important to give them the opportunities to put into practice the technical knowledge in service of the community. This activity is so important to the education of a student as a human being, that MEC (Ministry of Education - Brazil) includes in their evaluation programs/projects of extension as one of the items evaluated at the Assessment of Teaching Conditions. This project is in accordance with the guidelines from the pedagogical projects of the Engineering's courses of PUC Minas (Pontifical Catholic University of Minas Gerais), because it is in service of the society, meeting its necessities and demands from different areas, as Electronics and IT. Thus, enabling the interaction

between society and university, articulating theory and practice, in addition to shape professional citizens.

In this regard, the undergraduate students made children think about the social value and possibilities of the project ongoing. It was worked through the Arduino platform ideas to promote social inclusion because the classes were taught in this context. Think and simulate projects that help special needs people to integrate into society, in one the practical classes students were challenged to design a pedestrian semaphore with a sound signal for the blind. Beyond that, the three cornerstones of the University were worked, Education, Research, and Extension. About the undergraduates, we can say society demands a professional that has a complete formation, not only technical but also ethical, humanistic and cultural, that can work in a multidisciplinary team. Thus, the participation of students in this project, undergraduates and teenagers, contributes that they act with responsibility, competence, and justice, and therefore, paving the way to a better country. As described in the Institutional Development Plan - PUC Minas (2011, p. 62): "The vocation of this university is the formation of a qualified student, scientifically and technically, that knows how to perform with professionalism and responsibility in it area and, furthermore, that has it behavior stuck on ideals of justice and solidarity".

Projects like this become the engaged student body more responsible, given that they need to prepare activities, correct tests, keep the timetable and learn a little bit of the reality of the children/students. It is worth mentioning, that this kind of experience is being valued at the labor market. From projects like that, the students involved rethink about their activities (reflection - action), enhancing their knowledge and methodology, added to the joy of construct the interaction between university and society.

Nowadays the labor market of engineering areas is more and more inviting, and students are showing less interest to become teachers. With this activity, the undergrad students will be in direct contact with the classroom and maybe they will act as teachers, so is expected that grow inside them the desire to become educators. Thus this is very useful to universities because this can be considered a training during the undergraduate period.

In conclusion, the activities made in this project seek a collective process of reflection and learning, in a democratic way, between educators, student, and community.

III. Implementation, Development, and Results

Throughout the trial lessons, it was possible to obtain promising results in relation what we expected, that was if the students would understand well the content that would be taught and if the lessons were suitable to that age group. For this purpose, we had two lessons with the test group. The first one was used to introduce the Arduino platform, and to blink a LED with timing. Thus, they were challenged to simulate a semaphore. To accomplish this it was necessary to teach basic electronics and basic programming in C, emphasizing commands as turn on/turn off the LED and the delay.

The second lesson was equally fortunate; using a car we explored the same concepts of the first lesson, digital output, and timing, also the idea of functions in a superficial way, which was not an obstacle at all. A maze was built and the challenge was to cross it without hitting the walls. This created a competition among the groups, what made them pursue ways to improve their projects, leading then to change repeatedly the program; therefore they became familiar with their programs.

Students got really excited with the fact that they programmed a car and the competitiveness produced the need to refine the program. Cases as those should be explored emphatically during the course, since it showed only good consequences to the group.

Figure 1 - Second class.

The group's performance was really good, presenting positive results both in programming as well at the car's adjustment. The function's understanding became even clearer, with this, we could introduce the notion of the library. The analogy that we used to introduce the idea of a library (of programming), was the real library, where the books were the functions, containing the instructions to be followed, and therefore all the functions together were the library.

Throughout each practice chosen the will to keep learning the programming language just grew more.

IV. Project's Main Features

A. Prediction of Public Participation and Target Audience

Children and teenagers between 11 and 16 years old, that have it a high level of skill and want it to learn, students from private schools of Belo Horizonte and metropolitan area.
The majority of the students come from the second part of the elementary school and high school.
Which were beneficiaries of the project “Enriquecimento da aprendizagem para desenvolvimento de habilidades: crianças e adolescentes que gostam de aprender” ("Enrichment of learning for the development of abilities: children and adolescent.")

B. Structure

The location of the activities was at the IT labs of the university, in the building 34. Two different kinds of Arduino's sets, both were bought at the first project.
The first set has the following items:

- Arduino Uno;
- LEDs;
- Resistors;
- Protoboard;
- Cable jumpers;
- Ultrasonic sensor;
- DC Motor 5.9 V;
- H-Bridge L298N;
- Bluetooth module HC-05;
- VGA camera;
- Wifi module;

The second kit was designed to work together with a car, so, it has:

- Arduino Uno
- Acrylic chassis, with four motors and four wheels,
- H-Bridge L298N;
- DC motor shield;
- Remote control;
- Bluetooth module;
- Batteries;
- Ultrasonic sensor HC-SR04

V. Conclusion

At the end of the project we could point out the results within the different parts that composed it.

A. Project Students

They learned about Computing, Math, and Microcontroller's Programming, in the same way that they improved their logical thinking and the professional capacity, and last but not least, they became knowledge disseminators and through them the primary reason of extension's programs will be fulfilled, that is to strengthen the link between society and university.

B. Undergraduate Students

From the Academia perspective they developed the ability to formulate problems and projects, and they did a reflection between theory and practice, but they also had a humanistic formation and improved their ethical and critical attitude, which caused a reflection about the professional practice.

C. Professor

In the same way of the undergrad students, the Professor has also developed the ability to formulate problems and projects, reflected about the binomial theory/practice, and created a motivation to find new teaching methodologies and a reorientation of didactic-pedagogical practice.

D. Institution

The institutional mission was fulfilled, contributing with a positive marketing and strengthened the bond between university and society.

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