- Invited paper -

Robotics Based Strategies to Support Computational Thinking: The Case of the Pascual Bravo Industrial Technical Institute

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Abstract

At present there are different public and private companies that support the Colombian government in the initiative of taking the technological processes and of research and innovation to the classrooms in order to generate a knowledge that propitiates great changes in the society and that at the same time helps to mitigate some national problematic. This generates great changes inside the school and the student, achieving significant learning in various areas of knowledge such as environmental, physical, electronic, mathematics, programming, and mechanics, among others. This article presents some strategies, such as robotics clubs, and how their problem-based teaching methodology collaborates in the development of competences of various types and the achievement of computational thinking in students. In addition, mention is made of the results of the project developed at the Pascual Bravo Industrial Technical Institute in Medellin-Colombia, which was presented at the XXII CACIC Congress in Argentina

Keywords: Gamification, Computational Thinking, Robotics.

1. Introduction

In Colombia, as in most Latin American countries, the low academic level in primary and secondary school is remarkable, as indicated by the PISA tests (www.oecd.org/pisa/home/) and the ICFES state tests (Colombian Institute for the Promotion of Higher Education). According to Caro [3] in the document "Summary 2005 to 2009 ICFES", it is forced to rethink education in a different way, where it is urgent to change the traditional model for strategies and tools that generate great motivation in students. On the other hand, Contreras [14] shows different ways of applying the concept of robotics using "project learning" or "problem-based learning" that with ICT could generate great advances in teaching-learning processes.

To complement this idea, there is already much research on the use of ICT, which in a simple and practical way generate great changes throughout the educational community. For its part, the Ministry of Education in Colombia and other public and private sector companies have undertaken different strategies as an action to encourage research and innovation not only in universities but also in public and private schools throughout the country.

One of these strategies consists of robotics and innobotics clubs, where the Industrial Technical Institute Pascual Bravo (Colombia) has participated with students of different degrees and specialties. Sections 2 and 3 address important definitions of computational thinking and educational robotics; as well as some important experiences with children and adolescents in the school where they expose some significant achievements that seek an integral and competitive education. Section 4 describes the different competences that can be developed in projects of this type. Section 5 describes several strategies of the Ministry of Education in Colombia where the school has participated. Section 6 details the process covered in the robotics project and the steps that broadly show the importance of educational robotics and academic competence in the acquisition of knowledge in programming and electronic areas. Finally, we present the conclusions.

2. Educational Robotics and Computational Thinking

Educational robotics according to Acuña [1], makes its appearance in the 60's, when some researchers such as Seymour Papert, Marvin Minsky and Mitchel Resnik, proposed the construction of didactic robots with the support of the company LEGO, so that the children interacted with them [4]. It should be mentioned that this company leads the market for educational robots. Then, in the 80's, these devices were popularized, achieving to include them within schools activities through important

projects that allowed the student to obtain major competences in areas such as mathematics, computer science, electronics and mechanics. At the same time they have fun and play when proposing solutions to specific problems.

Computational thinking is very important nowadays since it allows the development of competences and as expressed by Wing ([6], [7]) is a fundamental skill for the whole world and not only for students and professionals of the area of computation, since it is an approach that allows to solve problems in an innovative way. Computational thinking generates in the student the ability to perform various types of analysis such as the ascending-descending, to be creative and to generate a divergent-abstract thinking that allows approaching a problem in a more simple and creative way. This thinking is of high level of complexity since it is related to the development of ideas and to the abstract-mathematical and engineering thinking, but in turn can be used in multiple scenarios. It does not depend on a programming language or specific software but on the skills that allow us to face problems with more clarity as mentioned by the author in [7].

There is already an approach by Papert [8] in which it is desired to link information technologies with constructionism, since for example, computational thinking forces not only the appropriation of concepts but also the objects of study (programs, animations , video games, robots). These objects materialize in some way the learning achieving an enrichment of it.

Educational robotics as well as computational thinking in recent years have gone hand in hand thanks to the incursion of this in the classroom, being reflected in many researchers at all levels of education. This type of project, as [1] says, is common to find in national programs or educational policies of cities or countries. For example there are national initiatives such as in Costa Rica or locally in some cities in countries such as Mexico, Brazil, Chile, Colombia and the United States.

3. Some Experiences in Latin America

There are already a large number of research projects oriented towards the acquisition of competences thanks to the use of robots and programming languages of all kinds. These projects propose to generate new strategies so that from a young age the student can acquire certain skills that will help him/her later in his/her university formation process. Some of these projects are described below:

1) *Programming for Children and Adolescents*. Currently it is possible to find several programming environments for children of whom we can highlight Alice[1] and Scratch[2]. Scratch for example, allows making personal projects such as creating games, telling stories and making animations. This is built on the ideas of the constructivism of Kafai and Resnick Logo [4], Papert [8] and Kay Etoys [2]. One of the most important aspects of Scratch is that it encourages self-learning through personal practice and collaboration with others, as Maloney and Resnick [4] claim. This process of learning by making 'artifacts' or 'programs' allows students to construct and check, reconstruct, modify, and improve learning objects as posed by Papert [8].

2) *Robotics Clubs*. In Costa Rica, as says Jiménez [10], "Robotics Clubs" are created to encourage the study of science and technology in some primary and secondary institutions with work sessions of at least 40 hours. The methodology used basically consists, according to this same author, to generate a pleasant, challenging, and critical thinking generator, which encourages teamwork and experimental work, which included analysis, design, construction and programming activities in Robolab 2.9 or NXT-G. In addition project-based work helps develop a number of cross-cutting competences such as planning, communication and creativity; where some of the proposed challenges had to do with the selection and classification of objects or identification and tracking of color, sound, light and distance patterns. In this research, three dimensions were analyzed: student performance, design and construction skills and programming skills, which show important results that suggest that this strategy is well received by students.

3) *University of Cundinamarca and Educational Robotics*. As reference Márquez [5], the research group of Nano Engineering of the University of Cundinamarca-Colombia, together with schools located in the Savannah of Bogota, decided to create a free basic robotics course, which was programmed as an in-

[1] Free and open object-oriented educational programming language with an integrated development environment (IDE), programmed in Java, uses a simple "drag-and-drop" environment to create animations using 3D models.

[2] Free visual programming language oriented to teaching by creating games.

person course, supported by virtual information, supported in the Moodle platform, where basic electronic material was provided, which was complemented in class. The robots built by the students belong to the category of "autonomous robots line followers", which as its name indicates should follow a circuit marked by a line where the route is qualified in the shortest possible time. In total, six analog robots one hundred percent functional were built, demonstrating the feasibility of implementing robotics in the classroom. As for the observed results, they are similar to the research presented previously, both in the aspect of robot construction, and in student motivation, which emphasizes commitment, appropriation of knowledge, development and achievement of tasks.

4. Competences to be developed in Basic, Middle and Technical Education Students

In order to understand the importance of robotics championships in secondary education, in the acquisition of competences and in the development of computational thinking, it is essential to review what Marqués [13] poses as indispensable technological competences to develop such as the management of virtual platforms, management of office tools, communication tools such as email, design and construction of websites in various content and school levels, as well as search and analysis of information.

In addition to these competences, the Ministry of National Education in Colombia [11] has also set some competences that the Colombian Education System must develop in students. These are of three kinds: basic, civic and labor.

Within the *Basic Competences* are those of technological thinking that allude to the construction of technology concepts, to test them through the design and construction of prototypes. Next to this is the technique that allows the knowledge of tools that enable the development of activities and finally the communicative that permeates these two generating interdisciplinary work in favor of developments. On the other hand, we have *Citizen Competences* that allow a healthy coexistence not only in school life but in other contexts.

To conclude we have the *Labor Competences* that are subdivided into two. Within the General Labor competences are the *Intellectuals* referring to the decision making and solution of problems; the *Personal* that have to do with the behavior and attitudes expected in the productive environments; the *Interpersonal* that generate adaptation to the work environments like the work in equipment, leadership, handling of conflicts, among others. In the same way we have the *Organizational* ones that refer to the ability to apply the strategic thinking in different situations of the company, like the information management, orientation to the service, among others. Lastly, we have the *Technological* that allow young people to identify, transform and innovate procedures; and *Business and entrepreneurship* that are useful for creating, leading and sustaining business units on their own.

Finally and specifically in the specialty of Programming and Maintenance of computers, of Pascual Bravo Industrial Technical Institute, the student must develop skills in the handling of languages such as C ++, Java, Visual Studio which involves the development of programming logic and use of concepts such as object-oriented programming. In the same way, it is indispensable that the student is familiar with the process of modeling, designing and creating databases and dynamic web pages. To finish in the eleventh grade the student must know the basic part of the hardware that refers to basic and digital electronics where simulators are indispensable tools in the process of designing simple developments. All of these competences could be more easily obtained by the student if other strategies, tools or mechanisms in the classroom will be used, such as those described above, that motivate the student and make him/her participate in his/her own educational process.

5. Robotics Competences: Case Study

The Pascual Bravo Industrial Technical Institute of Medellin (Colombia) has been linked in recent years into research processes implemented by the Ministry of Education and public and private sector companies; which aim to provide the student with knowledge in different areas that contribute to find solutions to problems in the city or that point to innovation.

One of these initiatives is the Ondas Program, which is supported by the State [15] and has wanted to guide children, so that they learn to investigate in a simple and fun way. This program, like many others, has stages that are orientated from the beginning by the trainer of the program and that clearly obey a methodology of research own of the research projects and that are traversed step by step in each stage of formation not only of the students but of the accompanying teacher. As for this program in 2012, the Technical Institute was linked to five projects that were accompanied by the teachers of the Systems area. These projects focus basically on the environmental part, on the

reconstruction of the history of the institution and a project oriented to the recognition of free educational software.

Another of the proposals of this city, which incorporates Route N and the municipality of Medellin, is the project called "Horizontes Adventure" [16], which included several programs to encourage students to develop their ideas in robotics, new alternatives to care for and protect the environment and in general, creating innovative projects to solve city problems. The programs included in this proposal were:

1) *Innobotics*: which aimed to encourage the young people of the institutions to create and design their own robots for competitions and to solve existing problems, among other purposes. This initiative was accompanied by the company Pygmalion Robotics, which sent its advisors to teach robotics in schools, where they gave some kits with all the implements needed to tackle a simple robotics project.
2) *Engineering*^{n}: this program intended the development of projects and their prototypes to help the environment in different city problems that included a meeting every 15 days at the University EAFIT, which has excellent laboratories for the development of prototypes with 3d printers and different machines of high technology.
3) *Interchange*: this program intended to do something very similar to Engineering^n, only that it changed its headquarters since it was realized in the SENA (National Service of Learning). It also wanted to get young people to make exchanges to other countries, for their ideas and development of projects.

The participation of the Institute in this process publicly began two years ago, in a robotics event in October 2014, in the week of robotics and innovation in its second version, in Medellin. This competition is organized by the robotic company Pygmalion of this city and the organization RoboRave International which is from Albuquerque - New Mexico, United States. Before this moment, the teacher in charge of the research groups, in the Systems area of the Institute, calls on the entire community to participate in various research groups and different proposals of the Ministry of Education in different fields of knowledge.

From this moment, a great motivation arises in the students to learn about robotics and its fundamental areas. For this reason they take advantage of the training programs offered by Ruta N called Innobotica. This program was offered to many schools in Medellin, without distinction of stratum and without number of participants. Only the continuity in the process was required so that the teams could compete in the week of the robotics, where the winners had the possibility to go to compete to Albuquerque - United States to the world competition, in which teams competed from all over the world.

For this first stage the Institute participated with three teams with students of various grades and of different Techniques or Specialties (Programming, Electricity, Mechanics among others) with which the said training center has; where according to the level of exigency it was decided to compete in two challenges, one called "Line Follower and Balls" and the other "Challenge Pygmalion", where the line follower consisted of making a robot which follows a line and surpasses two intersections and carry as many balls as possible in a given time to deposit them in a tower (see Fig. 1).

In this competition the robot had to be totally autonomous, reason for which the level reached was not the best one due to the complexity of it. Obviously for being the first year of competition and because of the lack of training received so far, the performance was not the best, but did manage to motivate students so that they created links with other groups where they heard a lot of useful tips for upcoming competitions.

It is worth noting that in this competition was used a kit called Innobot that gave us the company Pygmalion by means of Route N. This package was comprised by a replica of an integrated Arduino Leonardo, which counted on 4 geared motors, 4 rims, 4 sensors (to follow the line) and an ultrasonic sensor to detect objects, among others, with a plastic structure. As far as software is concerned, the robot had to be programmed in C language through the Arduino software. The "Pygmalion Challenge" consisted of using the same robot but this time the robot had to follow an octagonal track, overcoming several intersections, where at the same time they had to recognize some totems and remove them from the track until the track was clear of obstacles (see Fig. 1).

In this test there were also some difficulties. In this case with the electronic part, specifically with the sensors of the robot, this meant that they could only compete once in the 5 days of the competition. Finally the winners of the three challenges (Line follower, Pygmalion challenge and Fire challenge) were a team from Las Cruces (New Mexico, United States), the San Ignacio de Loyola and an institution of Envigado. In spite of not having obtained the first positions, great links were obtained between the institution of the United States and the students of Pascual Bravo that strengthened the academic process and where information and electronic devices were exchanged for a later competition.

Thanks to the US team, who gave Pascual Bravo a "Track Base", which in turn was counted on an H-bridge (circuit that allows a DC motor to rotate in both directions, forwards and backwards) for better engine performance in terms of power and spinning capacity, a new project could be started with better electrical and electronic devices that would improve the performance of the robot (see Fig. 2). So from this moment, a new challenge begins to represent better the institution and Medellin in those competences.

Fig. 1 Pygmalion Challenge Mounting

Fig. 2 Crawler base provided by the US team

6. Proposed Solution

Before starting the project it is explained in detail to the students by the trainers of the project, tracing a process route for the completion of the final product. Below there are some of the steps taken in this process for the participation of competitive events.

6.1. Training in the use of electronic elements

In this phase a teacher, belonging to the program sponsored by Route N and Pygmalion, attended 2 hours a week to schools where there were equipment to teach students what is referred to robotics fundamentals, Arduino programming environment, robot mechanical parts such as gears and pulleys, as well as training in the handling of electronic parts such as batteries, resistors, sensors, motors, among others.

These robots had to comply with the three conditions that make it a robot: to be totally autonomous (not having physical connections with other devices), to be programmable (different codes can be loaded for each function), and to have a controller to make decisions (according to the variables obtained from the environment). Also a robot has a fundamental basic structure with sensors, actuators, tools and a control unit, and a power source that is in charge of feeding all the electronic circuits that make them perform all their functions (can be long battery life, solar panels[3] among others).

For example, the sensors are the ones that allow the robot to detect the environment conditions (such as temperature, humidity, proximity of objects, lighting, etc.) so that the control unit (a micro controller[4], a DSP[5] or a PLC[6]) takes this information, makes calculations and makes the best decision in order to define which actuator must manipulate to give the correct operation of this. On the other hand the motors are part of the actuators of the robot that are the responsible of the movement of it. Possible types of motors are DC[7] motors, step by step[8] and servomotors[9].

No less important is the structure or skeleton, which makes it possible to support all the parts, mentioned above. It is possible to say that each competition has associated a weight and dimensions of robots to be able to compete and the programming language to be used.

6.2. Recognition of the Arduino device

This was necessary for the trainer to give some guidance on the advantages and disadvantages of

[3] Solar panels are those technological devices of the latest generation that can take advantage of solar energy by converting it into electricity.

[4] A microcontroller is a programmable integrated circuit, which can execute commands stored in its memory. It is composed of several functional blocks, which fulfill a specific task such as analogue digital or digital analogue converters, input and output ports, serial port among others.

[5] A digital signal processor is a processor-based system that has a set of instructions. These are used in applications that require numerical operations at very high speed.

[6] A programmable logic controller or programmable automaton is a computer used in the automation of electromechanical processes, such as the control of factory machinery in assembly lines or mechanical attractions.

[7] The current motor is a machine that converts electrical energy into mechanical, causing a rotational movement, thanks to the action that is generated from the magnetic field.

[8] This motor converts a series of electrical impulses into discrete angular displacements, which means it is capable of advancing a series of degrees depending on its control inputs.

[9] A servomotor is a rotary actuator or linear actuator that allows precise control of angular or linear position, speed and acceleration.

using Arduino devices or specifically Arduino Mega which is a board of micro controllers based on the ATmega1280 that has 54 pins for its operation, (see Fig. 3). Some of these advantages are the fact of having an Open Platform (which their Cards are manually manufactured), it is ease of programming and it can store a great amount of information in the network. In the case of the Mega Arduino, it has important features such as the number of input and output pins for the use of different sensors and motors for robot rotation control or manipulation of objects.

In addition it has a good storage capacity to generate predictive algorithms that make it more effective for any test. Also the size of the chip is ideal for this type of projects as well as its low energy consumption. Other features of this device is that it has 15 pins that can be used as PWM (pulse width modulation) outputs for motor control, 16 analog inputs, 4 UART (serial ports), a 16 MHz crystal oscillator which is responsible for synchronizing the device, a USB connection, a power connector, an ICSP header and a reset button [12].

6.3. Training in robot programming

To create a project of this type we must know the development environment that Arduino offers us and the advantages of each one. Within the possibilities that exist for this type of hardware are: Scratch for Arduino, Eclipse, and Visual Studio, among others. Scratch is a visual programming environment, structured by blocks that define the behavior of the board while Eclipse and Visual Studio integrates by means of powerful plugins assistants to help the programmer in the development of the code.

In this case, the training was carried out in the environment provided by the Arduino project, which basically is a very light IDE that provides the basic tools to program the board (see Fig. 4). Then, small tests were made such as spin of engines, advance and retreat, recognition of obstacles, among others. For this, first we must install the drivers, then open the application and select the Arduino with which it is going to work. Then we proceed to program and download the code on the chip. For this, Arduino has predefined functions, based on C, that allow an intuitive programming. For example, in the code that is shown in Fig.5 is easy to see that there are two functions. The first one refers to the configuration of the device (setup) and the second implement what the integrated (loop) should do. In this case the led must be turned on and off with 1 second pauses.

As shown in the code in Fig. 5, the programming of this device is very simple. The really interesting thing is to achieve the harmony between software and hardware to achieve that the processes are carried out with the greater speed and accuracy.

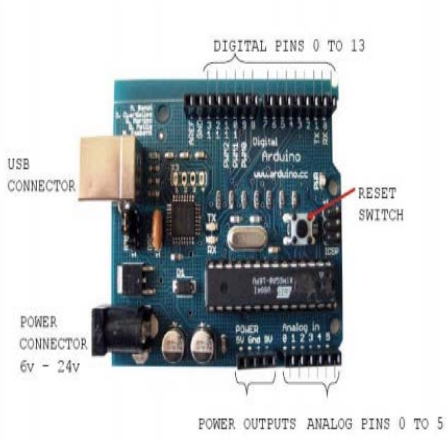

Fig. 3 Arduino Mega Platform Card

Fig. 4 Programming Environment

```
int ledPin = 13;
void setup (){
pinMode(ledPin, OUTPUT); }
void loop(){
digitalWrite(ledPin, HIGH);
delay(1000);
digitalWrite(ledPin, LOW);
delay(1000); }
```

Fig. 5 Code example for the Arduino project

6.4. Project analysis

Regarding the use of educational robotics in the acquisition of competences and the development of computational thinking, we can say that great success is observed in students who continue the process in the robotics club, especially in the acquisition of knowledge in the electrical and electronic parts, as well as in the mechanical part and programming, evidenced in the language used and the own development of the project. With which it can be affirmed that also students developed competences like the following ones:

- Intellectuals: since skills in decision-making and creativity for the solution of this project were developed.
- Personal and Interpersonal: it is summarized in the competences achieved in the citizen competences.
- Organizational: in the management of the plans and information collected as photographs and measures, orientation to the construction of the animation.
- Business and entrepreneurship: with the realization of this project the students verified that they can realize different types of projects in the field of robotics.

The motivation of students for the development of the project was really good. At all times, there was a willingness to participate in all phases of the project and teamwork, which has led them to have support from different public and private entities to compete in the first half of 2016 in the United States.

The development of the project has allowed them to participate in the competition of this year. Also they have already represented the institute in different events achieving great results that have allowed tuning up this machine.

As for teacher/student, teacher/advisor and student/student relations, several behavioral changes were observed, among which a more cordial, respectful communication and a more technical vocabulary. These competences refer to the citizens and communicative in terms of basic competences. On the other hand, it is possible to observe that with this project transversal competences are developed in other areas, as is the case of the area of mathematics, electronics, mechanics and programming.

6.5. Future Work

Since 2015 and the CACIC congress where this work was presented [9], we work on three drones (unmanned aerial vehicles) for different purposes. One drone is used for research supported by the University Institution Pascual Bravo, where they are part of several projects that has to do with support in rescuing people in environmental disasters. The other two drones are for competition at national and international level where the lowest time of flight is sought in an established circuit. . To speak of the built drones, it is necessary to mention the parts by which they are constituted which basically is a skeleton or support, engines, propellers and electronic speed controllers, radio receivers, GPS[10], cameras, stabilizers, among others and like competitive robots, energy sources must have a good weight/capacity ratio to maximize multirotor flight autonomy.

On the other hand, the radio receiver is responsible for receiving the radio signal sent from the Remote Control, so that the Flight Controller executes the necessary instructions so that its movement is as coordinated as possible. The Camera is used to take advantage of the flight and capture photos or videos from the air.

Finally, Motors, Propellers and ESC[11] are the fundamental components to keep the multirotor in the air, which in turn are manipulated by the Flight Controller that is the brain of the machine as seen in Figure 6. For these new Projects we used an APM 2.6 flight controller that provides us with, among other things, the possibility of 14 modes of flight, modes for kinematic shots, acrobatic mode, modes assisted by GPS, modes to fly it as if it were an airplane, modes for scanning structures or terrains (photogrammetry), auto-landing and take-off modes, follow mode, 4 vehicle types supported (rover, boat, airplane and multi-rotor), automatic flight mode with memory for more than 100 waypoints, possibility to program code, ground station and application for smartphone.

One of the advantages of using this APM based on Atmel ATMEGA2560 and ATMEGA32U-2 processors is that it is compatible with Arduino. It includes a 3-axis gyroscope and magnetometer together with a high performance barometer, as well as a Flash memory of 4MB and an additional uBlox NEO-6M GPS Card with digital compass. Finally, this controller is one of the first Open Source autopilot systems to use the Accelerometer/ Gyroscope 6 DOF MPU-6000 of Invensense, and barometric pressure sensor updated to the MS5611-01BA03 model of Measurement Specialties.

On the other hand, for these new projects we also had the same training, where begins with the parts of the dron, its operation and the different applications that it may have. It was a basic training that continued with autonomous work by the students achieving performance tests in which take-off and landing, speed tests and GPS positioning, back home and tracking of interest points or waypoints.

To conclude we will talk about the new competitions and recognitions that this group of students has had. They participated in the 2016 Technology Expo, held at the Pascual Bravo University Institution, where the winners competed with university students and where they had the goal to participate in 2017 implementing artificial vision. In addition, there is the possibility of participating in

[10] Components that connect to the Flight Controller allow it to know the exact location, altitude, and speed of the multirotor.

[11] The Electronic Speed Controllers regulate the electrical power to control the rotation of the motors with agility and efficiency.

two international competitions of Roborave, which has been conducting competitions around the world for more than 15 years, where it intends to participate in Mexico in mid-May and Japan in the end of the year. As for the awards, student *Dalid Duque* of the tenth grade, participated in the *City of Medellin Award for Quality Education*, as a student highlighted by the Robotics group of the Institute, where he was deserving of an exchange program for improvement and deepening of the English language, in Canada from the 12 to 27 August of this year, and there is also the possibility of a university scholarship when finishing eleventh grade.

Fig. 6 Winner Drone Cutout

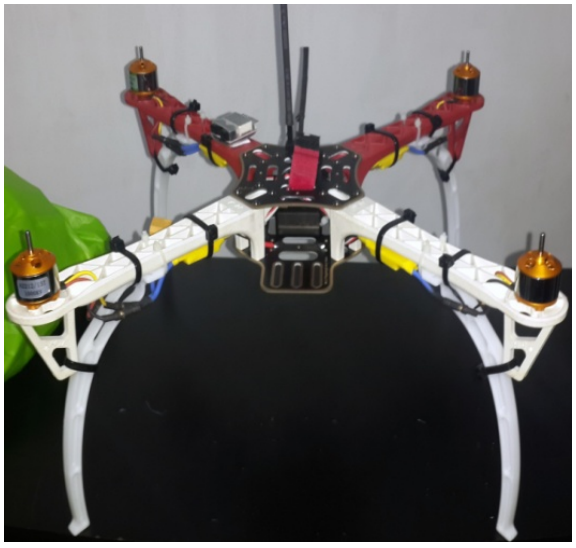

Fig. 7 Winner Drone at Expo Universidad

7. Conclusions

In this research was observed a great motivation not only of students and teachers, but also of the educational community, who were impressed with the quality and the difficulty of the project. In the same way, precedents are generated so that through these science or research clubs, students and teachers think about participating, so that through these group-type projects they can promote autonomous and multidisciplinary work.

Finally, what is intended with these types of clubs is to encourage, through various strategies, that the student is motivated towards the acquisition of knowledge in a fun, practical, simple and different way that leads to generate a solid and transversal learning in different areas of knowledge. We are currently working on research into the possibility of using free software in teaching and learning in the area of technology and information technology and in the use of programs such as Scratch for the development of logic in students of programming.

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