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Educational Robotics Summer Camp at IPB: A Challenge based learning case study

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ABSTRACT

Robotics in education has special relevance in current digital society where students should know how to deal with technology. In this paper, it is presented an educational experiment in the mobile robotics domain. The referred experiment was part of a summer camp, which took place at the Polytechnic Institute of Bragança Portugal, being its technological aspects related with mobile robotics. Other than the technological aspects, the students participated in many different cultural and social activities, having the opportunity to know the city of Bragança and also to know different persons, mainly students, professors, researchers and laboratory technicians. The applied approach in the summer camp was a challenge based learning methodology, being involved in the experiment 3 professors, 4 monitors, working with a group of 16 secondary school students. The described experiment was planned as an activity of the RoboSTEAM - Integrating STEAM and Computational Thinking development by using robotics and physical devices ERASMUS+ Project.

KEYWORDS

Summer camp, Robotics, Challenge Based Learning, Erasmus

1 Introduction

The Polytechnic Institute of Bragança (IPB), which is a Portuguese Public Superior Education Institution, promotes and supports, every year, summer camps, in order to promote science and the Institution among potential new students, from technical and secondary schools. The Portuguese Foundation for Science and Technology (FCT) and the ERASMUS+ Spanish agency, also supported the 2019 summer camp edition, being the summer camp integrated in the RoboSTEAM - Integrating STEAM and Computational Thinking development by using robotics and physical devices - ERASMUS+ Project. This project will provide frameworks and tools to facilitate the learning actions based on robotics to teach STEAM areas [1]. The description of similar projects can be found in [2-5]. Innovative practices in the digital era by applying challenge based learning approaches to address integrating STEAM will be created. Computational thinking development using robots with physical devices is the main focus of this project. Computational Thinking capabilities in pre-university students have been studied by several authors [6-8]. At the end, exchange of experiences and challenges between schools in different socioeconomic contexts, through two pilot cycles will be applied. The project consortium is coordinated by the University of León and includes the participation of CeDRI / IPB among other 6 partners. The project will have a duration of 20 months. Having in mind the approach of Challenge Based Learning, a summer camp in the mobile robotics domain was conceived, taking advantages of the fact that mobile robotics is a multidisciplinary subject that is very appealing for different ages and different student backgrounds. Some Coding issues in pre-university studying/teaching can be found in [9-13]. The persons that participated in the summer camp were 2 professors, 4 monitors and 16 students, being the group shown in Figure 1. The authors have experience in the use of robotics in education as can be seen in [14-17].

Figure 1: Participants of the summer camp.

This work is structured as follow. After an introduction in this section, the description of Summer Camp is presented in Section 2. Then, in Section 3, the proposed challenge is stated showing the similarities and differences among all the approaches. The project results are shown in Section 4, and Section 5 points out the conclusion and future work.

2 Summer Camp

The Robotics Summer Camp at IPB has a duration of 5 days, not being only scientific, because the students have many activities that are not related with the scientific topics of the summer course, being mainly cultural and social. The summer course starts Monday morning with the welcome reception, and then students, after lunch, initiate the course with a mini challenge that is shared by all the 16 students. From Tuesday to Thursday the students will be separated in 4 groups, having each group to address a challenge. However, the development of a Challenge involves to many hours for the camp, so the idea solving something more concrete as a Mini-Challenge that can be decomposed in Nano-Challenges. Each of the groups have dealt with Nano-Challenge. [18] The summer camp ends on Thursday with a farewell dinner and on Friday it's a travelling day for them to get back to their homes. The students are from secondary schools and have an average age of nearly 15,5 years old, being present students from 14 to 17 years old, from all over the country (Portugal). The physical space that was used in the summer camp was the Laboratory of Control, Automation and Robotics of the school of technology and management of the IPB, that can be seen in Figure 2.

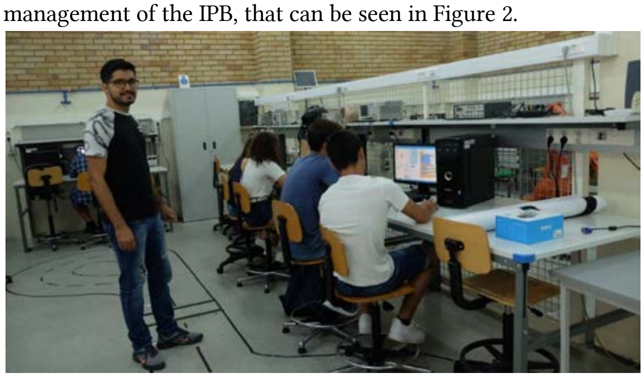

Figure 2: Laboratory of Control, Automation and Robotics of the school of technology and management of the IPB.

To teach the students, there were 3 professors coordinating the course, José Gonçalves and José Lima from the IPB and also Miguel Ángel Conde, from the University of León, being the ROBOSTEAM Project Manager. There were also 4 monitors (3 master students and a fellowship student), that played an important role, mainly in the Nano-Challenges, because each one supervised a different group that had a different Nano-Challenge.

Both the Mini-Challenge and Nano-Challenges were evaluated concerning the degree of success of each challenge, having in mind the context in which the challenges were done. The students will work with hardware only during the Nano-Challenges, having to solve previously a Mini-challenge that they have to answer a research question but they do not have to implement hardware or program any physical device.

3 Challenges Descriptions

Over the years, increasing fossil fuels as a source of energy for vehicles has generated a major impact on the environment. In this sense, a possible solution to solve this problem in controlled environments can be the use of mobile robots. However, mobile robotics requires the development of many tasks working together to solve problems that seem trivial to humans. Demonstrating some of these tasks for students can motivate future developers in the field of robotics. Thus, the challenge of transport and navigation of mobile robots is proposed to encourage students.

To reach the proposed goal, the 16 students were separated into 4 groups, as already mentioned in Section 1. By this way, each group took care of researching and developing a solution through Nano-challenges and Mini-Challenges. To define the assessment strategy and applied methods, the following subsections define each of these ramifications of the challenge of reducing the environmental impact of the use of fossil fuels.

3.1 Mobile Robots to Digital Transportation

One of the tasks involving the transport of loads by mobile robots is navigation. The ability to navigate means that the robot can move around in a certain environment without the help of a joystick. Therefore, it is necessary that the robot has the perception of the environment through sensing, and thus be guided by some orientation. In this way, it is proposed for the students the process of digitizing a factory floor with the intention of indicating to the mobile robot the region that is going through and what action should be done for each occasion. The main idea is to create small circles or squares on a factory floor, by filling them with several colors. Therefore, the robot being equipped with some color sensor can be pre-programmed to act according to the identified color. Consequently, this purpose could easily be applied in real situations, since the shop floor does not need to undergo major changes.

This process is totally connected to the line follower task since the robot still needs to be guided to move through a line. Therefore, this proposal was made in conjunction with the group of Subsection 3.2.

3.1.1 The kit and track used. After a brief description of the problem and the proposed solution, the students received a kit of a pre-assembled robot, color sensor TCS3200 RGB, and a track that simulates a shop floor. The mobile robot was pre-assembled due to the short-term of the course and also to avoid possible doubts of the students since the applied hardware has characteristics of high educational level. Figure 3 shows the mobile robot and the track used.

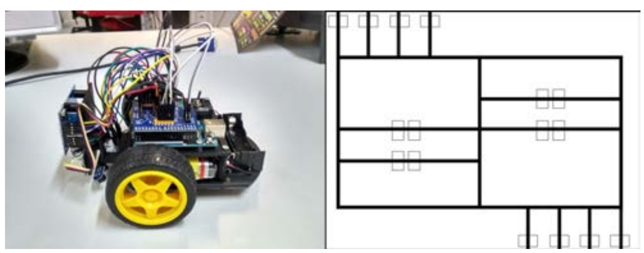

Figure 3: The robot model and the illustration of the track.

The students received the same materials available for the competitors of the Robot@Factory Lite competition (R@FL), available in [19]. The robot kit contains 3D printed supports, two DC motors, one DC motor driver, a tracker sensor with 5 infrared sensors to follow the floor line, an electromagnet to attach the boxes, a touch switch, an Arduino Nano microcontroller and a demo code, also available in [20]. The robot model used in the competition does not have extra support for the application of the color sensor, so students are expected to be able to design and print a part that can fix the color sensor in the robot.

3.1.2 Evaluation method. As it is expected that students do not have much experience with robotics and microcontrollers, the expectation of evaluation lies in their understanding of the theme and also in the logistics of applying the colors on the lane to indicate the actions that the robot should perform. Another relevant point is the observation of the resourcefulness of working with 3D drawings and the adaptations of an existing project since the available model needed support for the color sensor.

To compare the evolution of learning, students are asked to report at the end of each course day. In this report done by them is described with their own words what they understood the activity, as well as the tools they found in their research to find a solution to the problem. Thus, it is possible to compare at the end of the course the students' behavior if there was or not an improvement in learning.

3.2 Follow Lines with A Mobile Robot To Facilitate Autonomous Navigation

The Nano-Challenge proposed to the students was to develop a mobile robot that could follow a line and identified intersections, based on the R@FL, the rules are shown in [17]. For that purpose, some activities should be developed first, since the students did not have previous knowledge about robotics. First, the track and the objects of the challenge were shown to the students and they were asked to do a research to find sensors that could be used to complete the challenge and learn how those devices works. After that, the students took some programming and Arduino lessons followed by some activities such as writing in the serial port and making some mathematical operations using Arduino. At least they were presented to the mobile robot they should use and, a demo code with some functions and examples of how the mobile robot works. Next, it is expected that students perform control from the following line sensors and the command to move the motors. The demo code did not have this function as shown in Figure 4.

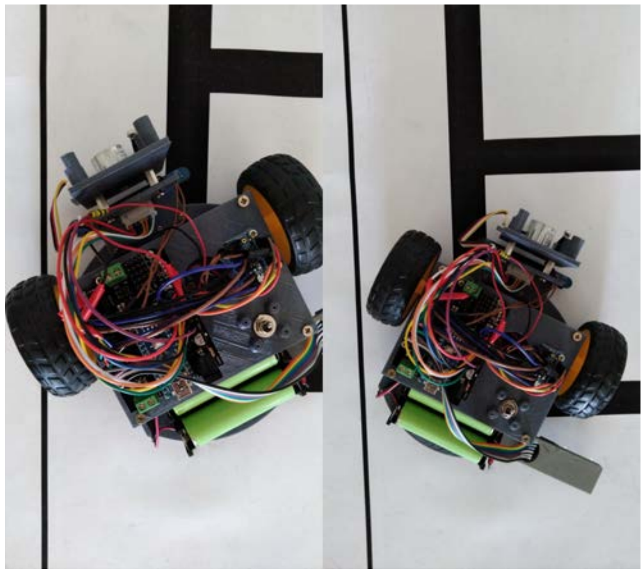

Figure 4: Mobile robot moving without system control.

3.2.1 Robot model applied. As already mentioned in the previous subsection, the robot made available to students is based on the model provided by the organizers of R@FL. The track provided was also the one provided by the proposal of the previous subsection. Similarly the other proposal, the building process of the mobile robot can be complicated, the focus of this challenge should be the control of the mobile robot. For that purpose, the robot was previously built.

3.2.2 Criteria of assessment. The first evaluation criteria was the student's perception about the STEAM areas, so the professors and the monitors could know which activities should be given for the students to achieve better results.

The criteria to evaluate the Nano-Challenge were the time employed to solve each task, the degree of success using the robot and the accuracy following the line, the degree of success in the robot detection of the crossings and the decisions it makes when it occurs.

3.3 Follow Line with Mobile Robot Using Scratch-Based Programming

In this challenge using the mBot robot, the students had to build a block program in mBlock 5 that makes the robot follow a line. They accomplish the challenge the monitor started explaining to the students how does work the line - follow sensor of mBot and how to use each block category of mBlock 5 to create block programming. Then, in the track as in Figure 5, was shown the preset mode line - follow of mBot to introduce the initial idea of how they could solve the challenge.

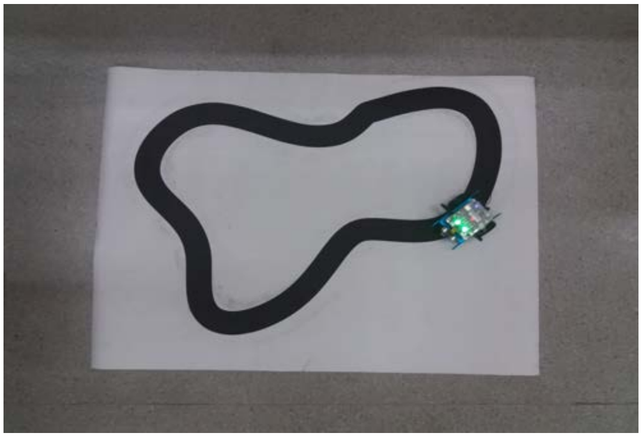

Figure 5: Track used during the challenge of follow line using Scratch-Based, with mBot.

3.3.1 The mBot and mBlock 5. The device used during the follow line challenge is the mBot robot, from Makeblock Co. Ltd., an entry-level STEAM educational robot kit for beginners, that makes teaching and learning robot programming simple. Thereby, the students involved during the challenge can learn about some of the robot machinery and electronic parts, get ideas about how works the fundamentals of block-programming, and develop their logical thinking and design skills.

The mBot already comes with 3 preset control modes: 1 - Obstacle avoidance mode, 2 - Line - follow mode and 3 - Manual control mode. About the specifications of mBot, the main control board is microcontroller ATmega328 and comes with a light sensor, button, IR receiver, ultrasonic sensor, line follower sensor, there are the possibilities to program other modules like the buzzer, 2x RGB LED, IR transmitter and two motors. Can be powered with a 3.7V lithium battery or 6V (4x 1.5V) batteries [21].

To program the robot the students used mBlock 5 PC version, a software-based on Scratch 3.0 designed to support STEAM education. By supporting block-based and text-based programming, mBlock 5 allows users to freely program the robot to solve the challenge [22].

3.3.2 The applied assessment. To evaluate this Nano-Challenge, there are some criteria to be observed as the time employed to solve the challenge, the degree of success of follow a line using the mBot and the accuracy following the line.

3.4 Maintenance and Calibration of Mobile Robots Based on a Low Cost Stroboscope Prototype

Currently, microcontrollers are present in several types of equipment that surround us and are essential for the operation of many electronic devices. One of which is the stroboscope, an optical instrument capable to generate flashes of light in different frequencies and be applied in the maintenance, calibration or speed measurement of moving bodies. The operation of this physical device is based on the stroboscope phenomenon, a visual event that occurs when a movement is represented by a series of samples and when the frequency of the movement coincides with the frequency of light pulses, the system will appear to be stationary.

The objective of this Nano-Challenge was the prototyping of a stroboscope, to be applied in the maintenance and calibration of mobile robots. The task was based on the use of microcontrollers using the Arduino platform. In the first part, the students learned the main concepts about microcontrollers, their functions, applications, Arduino platform and how to program it in Integrated Development Environment (IDE). From this, basic programming activities such as turning on and blinking LEDs, using buttons and showing messages on alphanumeric LCD display were proposed to students during the first days.

The tasks were created based on the construction of the physical stroboscope device, which was presented and demonstrated for the students in the last day, thus many concepts about microcontrollers, electronics and Arduino could be absorbed by the students and helped them understand what contents learned previously would be needed for the construction of this physical device.

Therefore, the last part consisted of students learning about the stroboscope, the importance of the microcontroller in controlling the tool developed and the applications in the real world, being one of them the maintenance and calibration of mobile robots. Then, a final challenge was proposed to them, to be developed together, in which they had to make small parts that would consist of a stroboscope, gathering activities done in previous classes, like displaying frequency information and speeds on the display according to button press and blinking an LED at selected frequencies.

3.4.1 Description of kits used. For this Nano-Challenge were used several devices and electronic components available by the IPB, such as Arduino boards, protoboards, LEDs, resistors, buttons, jumpers and alphanumeric LCD displays. A prototype of a stroboscope was also used and presented to students, the Figure 6 shows on the left the electronic circuit schematic and on the right the prototype. This prototype consisted of a 12V LED lamp connected to an electronic circuit mounted on a protoboard and controlled by the Arduino, in which an LCD Keypad Shield was connected, responsible to show the different frequencies and speeds in rpm on the display according to the pressing of the buttons.

For the demonstration of the stroboscopic effect, a fan with a white tape marking was used for the students could see the movement appear stopped. The fan and lamp were powered by a voltage source and the Arduino through the USB cable connected to the computer.

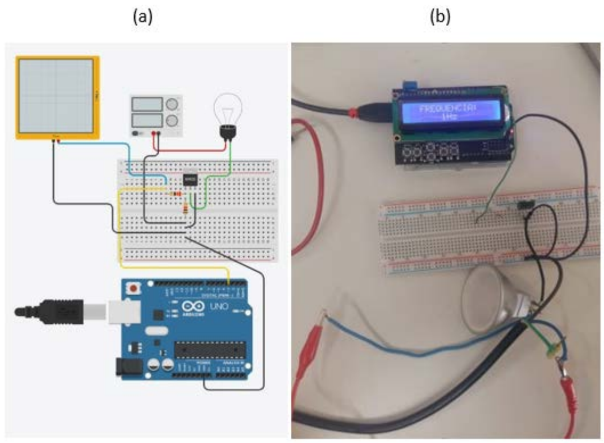

Figure 6: Electronic circuit schematic (a) and the stroboscope prototype (b).

3.4.2 Criteria of assessment. One of the first evaluation criteria used in this Nano-Challenge was the students' perception about STEAM concepts, as well as the level of knowledge they already had about microcontrollers or Arduino. Based on this information obtained at the beginning of the course it was possible to determine the number and level of the activities proposed for them.

Other criteria used as assessment were the time established to execute the tasks, as well as the time spent to complete them. In addition, at the end of each day the students wrote a summary about what they learned in class, so that it was verified if the desired knowledge was absorbed by them. The degree of success obtained using a physical device to learn microcontroller and this way create a prototype for application in mobile robots was also evaluated through the final challenge.

4 Results of the Challenge

To achieve the goal of reducing the environmental impact caused by the use of fossil fuels, it is proposed to replace vehicles with mobile robots. In view of this, the Summer Camp was used to apply the project, and some activities were carried out together and several methods were stressed. Professors and monitors developed strategies to evaluate students of the course, in which have ages between 14 and 17 years. These assessment methods are distinct because they have different purposes, so the following subsections are elaborated the results acquired during the application of this work.

4.1 The Feedback of Nano-Challenge Titled Mobile Robots to Digital Transportation

In this activity, four male students participated aged between 16 and 17 years. That on the first day they had reception in the IPB, having the first contact with the laboratories and the presentations of the professors and monitors. In addition, to the introduction of the problem of the use of fossil fuels, in which already asked to research on alternatives to solve the problem. In this first research, the students could use any means to substantiate a solution. That is, they could use the internet, ask the monitors, consult the relatives and also the IPB library. During the first day, it was possible to note the students' research capacity, who were able to finish the research in a very short time until it was possible to have an open conversation with the other 3 groups.

The following day, the students were presented with the track and the kit with the robot mounted. During the presentation, a conversation was held with the students about possible solutions to the proposal to develop a mobile theft and apply it in the industry. Then, along with the monitors, the students suggested to create a mobile autonomous robot with some sensors to take the raw material from one side to another. Still on the second day, it was necessary to search the different types of sensors and microcontrollers to apply in the robot.

The third day started with the idea of implementing a support for the color sensor in the robot kit, so the students created a 3D piece that fixed the sensor, as shown in Figure 7. The printing was done in the IPB's own laboratory and with the help of the Tinkercad software [23], and during printing the students had their first contact with Arduino.

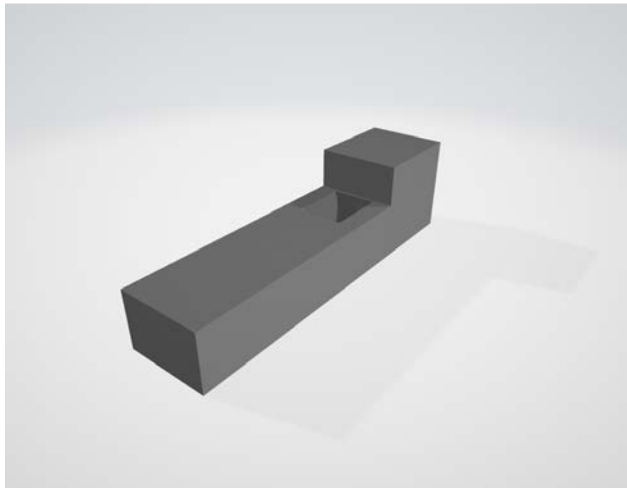

Figure 7: The support developed by students.

On the last day of the course, the color sensor support was mounted on the mobile robot and evaluated which sectors of the track are crucial for the robot to read the information of what should be done. The Figure 8 shows the scan of the track with the colors to be identified by the sensor. All color and caption settings were taken from the reports the students made at the end of each day. According to student development, each colored circle in Figure 8 means:

- Red goes forward 15cm;
- Blue turns left;
- Green turns right;
- Orange stops and one turn 180 degrees left;
- Pink turns right, and turn 180 degrees to the right.

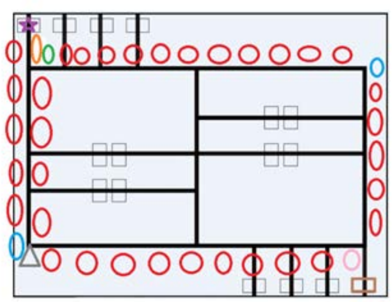

Figure 8: The digitalization of the shopfloor developed by students.

Then the support was applied to the mobile robot, as shown in Figure 9.

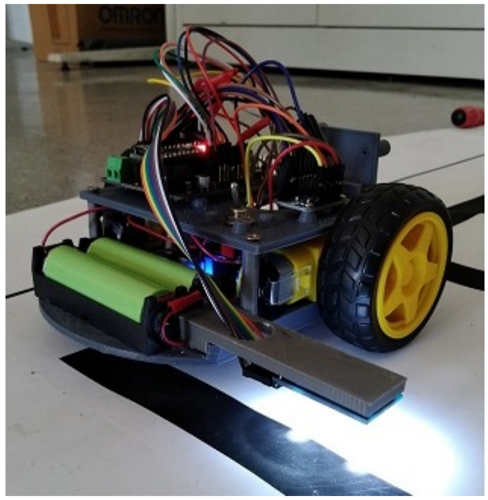

Figure 9: The support applied on the mobile robot.

Throughout the four days of the course, it was possible to notice the learning curve of the students. Although they did not carry out the application in real situations, the students were able to perceive the difficulty of implementing mobile robotics on an industrial scale. Another point to be analyzed is the initialization of students with robotics and tools that involve the sector, for example, students had never used Arduino and made prototypes with 3D parts. One possible explanation for not having performed the activity in real situations is the daily time of course, since the class had a period of 3 hours.

4.2 Challenge Assessment of Nano-Challenge Titled as Follow Lines With a Mobile Robot to Facilitate Autonomous Navigation

There were 4 students, working in pairs, in this challenge, all boys aged between 16 and 17. On the second day of the summer school, the students began the Nano-Challenge activities showing some fast results. The students completed the research, cited in Section 3.2, within 30 minutes and started to do simple activities with Arduino.

On the third and fourth day the students worked with the mobile robot, having access to the demo code and taught about how the functions work. The students first loaded the demo code in the robot to see how it acts and saw that it did not followed the line appropriately. From there, the students changed the demo code and tested in the robot to see how the change affected the robot and what else should be changed. After approximately one hour the students solved the follow line problem, the robot was following the line in the center of it. After that, the students started working in the decisions and actions of the robot after crossing an intersection. This last task wasn’t totally completed, but they made a great improvement in the robot actions compared with the demo code.

The older pair of students showed more interest in the activities and finished the tasks first, but none of the students showed to much difficult on solving the tasks that were proposed to them.

4.3 Challenge Assessment of Nano-Challenge titled As Follow - Line With Mobile Robot Using Scratch-Based Programming.

The number of students involved in this challenge was 5, 3 males and 2 females, the average of their ages is 15.2 years. To solve this challenge students had to understand the operation of the line sensor and how to use the sensor response values to structure the logic in the block program. The mBot's line sensor consists of two infrared sensors, being sensor 1 on the left and sensor 2 on the right, so we have four possible response values to identify the black line path in contrast to a white surface, as shown in figure 3, the response value is 0 when both sensors are on the black line, value 1 when the sensor 2 is on the white surface and sensor 1 is on the line, the value of the line sensor is 2 when the sensor 1 is on the white surface and sensor 2 on the path in black and last it is 3 when the response of both sensors is on the white surface.

Of the group of students, three of them reported being the first contact with programming of a mobile robot, one said already that it had experience in programming in Scratch platforms and the other one informed already to have programmed robots in platforms LEGO®, being the one that demonstrated more facility in structuring the blocks in order to solve the problem.

After a few hours, the students were able to code in block language the logic to follow the line, making mBot perform it efficiently for cases where the response value of the line sensor was 0, 1 and 2. For the case where the response value of the sensor is 3, the students had some performance problems, because when the robot was in that case it changed the direction of the course, and then they thought of a way to solve it, which was when performing the curves with lower speed in the motors, this would never reach the case where the response value is 3.

In a general context, the students were efficient in solving the Nano-Challenge around 3 hours, considering that most of them never had previous experiences with the programming of mobile robots, the degree of success of the program was considered good since they tested the robot several times in the course worked correctly.

4.4 Challenge Assessment of Nanochallenge Titled as Maintenance and Calibration off Mobile Robots Based on a Low Cost Stroboscope Prototype

The group was composed of only three students, all boys, with an average age of 16 and from secondary schools, in which two were in the tenth grade and already had programming knowledge, but they didn't know about microcontrollers and had never programmed an Arduino. The other student was in eleventh grade and hadn't any knowledge about the concepts.

These two students who knew how to program in C language performed better compared to each other. This performance was as much in relation to the time to develop the activities as in the absorption of knowledge. However, in the final challenge, it was remarkable how easy this student understood the necessary calculations for the stroboscope creation, standing out more than the other two at that point.

All the activities proposed to the students were completed successfully within the time limit of approximately 3 hours per day, with the exception of the final challenge. It was observed that more time would be needed to develop it, because the students failed to finish, but were doing a good job. Analyzing the summaries made by them and the overall performance, it can be concluded that the students were able to understand the expected concepts.

5 Conclusions and Future Work

The preparation of future students for our current Digital Society is not an easy task. The students are used to the use of technologies; however this is not enough. They should develop skills critical thinking, problem solving techniques, work distribution, etc. In may case this is achieved through STEAM related subjects or the development of Computational Thinking. But integrating this in our current educational landscape is really hard.

A possible way is during educational inititives as the Summer Camp described in this work. Summer camps allows to work with a reduced number of students, in groups and with advanced technology as are Robotics and Physical Devices. In this case, with the support of RoboSTEAM project also methodological innovations as Challenge Based Learning Approaches were also applied.

From the experiment it was possible to obtain several conclusions: 1) Students are easily engaged with technology and programming; 2) The use of challenges give them more freedom to address their tasks and the possibility to involved not only their peers but teachers, experts, parents, etc; 3) The use of Challenges provides students of a wider perspective of problems that not only solving problems or projects; 4) It is not necessary a deep knowledge on programming or robotics to complete Nano-Challenges; 5) Students perception about STEAM improves after the experiments.

Taking this into account, it is clear that Challenge Based Learning approaches works properly in controlled environments and the use of Robotics and Physical devices can be positive to develop skills related to those demanded by the digital society.

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