Programming of an Educational Robot to be Applied in STEAM areas

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Abstract

The world is increasingly digital. Countries around the world strive to attract and prepare future generations to occupy the positions, where, for the most part, they will focus on Science, Technology, Engineering, Arts and Mathematics (STEAM). An approach already consolidated in the literature is the use of robots applied in education to encourage students to develop essential skills such as critical thinking, problem-solving and computational thinking. This work, linked to the RoboSTEAM project, aims to explore educational robots that can be applied in this context, considering that most approaches use LEGO's platform, which can sometimes be difficult to access due to its high price. The robot used was the mBot in which it uses the mBlock 5 software to program it, from the MakeBlock Co. Ltd. company, being applied in two educational approaches during the execution of the project in which it is based on challenge based-learning methodology. A methodology for adding sensors to the mBot has been also explored. Finally, evaluations were made about the performance of students who participated in this project.

Keywords: Mobile Robotics, STEAM, Programming, Computational Thinking.

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Acronyms

CBL Challenge Based Learning. 3, 11, 21–23

CT Computational Thinking. 2, 35

EACEA Education, Audiovisual and Culture Executive Agency. 1

EDF Environmental Defence Fund. 33

GW Global Warming. 33

ICASE International Council of Associations for Science Education. 6

IDE Integrated Development Environment. v, viii, 2, 11, 14, 17, 18, 21, 27, 42

IPB Polytechnic Institute of Bragança. iii, v, vi, viii, 28, 32, 35

LCAR Laboratory of Control, Automation and Robotics. 28

NSF National Science Foundation. 5

PDR Physical Devices and Robotics. 2

R@FL Robot @ Factory Lite. 29

RISD Rhode Island School of Design. 7

SMET Science, Mathematics, Engineering and Technology. 5

STEAM Science, Technology, Engineering, Arts and Mathematics. iv, 1–3, 5, 7–9, 32, 41

STEM Science, Technology, Engineering and Mathematics. 1, 3, 5–9, 41

US United States. 1

WWII World War II. 1, 5

Chapter 1

Introduction

The world is becoming a complex digital society, which will require a workforce prepared to deal with the robotization of the global economy. For this workforce become valuable not only for the job market but for the whole society, they need to have a set of key skills and knowledge that will allow to design solutions for modern problems and those that even not exist. In [1] there are listed and discussed the main key skills that are essential for a person to learn and develop for living in 21st century. Many of these skills can be taught and learned through Science, Technology, Engineering and Mathematics (STEM) and STEAM education. It is in these areas where the main jobs opportunities will be expected, and several countries around the globe are striving to make the STEM and STEAM areas more appealing to the students, since these concepts started to emerge in 20Th century after the World War II (WWII) and the spatial race between the Soviet Union and the United States (US).

In the European context, there is a great importance in teaching STEM areas as stated by Education, Audiovisual and Culture Executive Agency (EACEA) in a report released in 2012, which emphasizes in tackling low achievement in reading, mathematics and science; increasing the number of mathematics, science and technology graduates; and further support in others essentials skills [2]. One effective educational approach that can foster STEM/STEAM skills and knowledge it's through applying robotics in education, a phrase used to describe the use of robotics as a learning tool due to the transdisciplinary this subject can bring [3], [4].

This work it is wholly related to ERASMUS+ Project named as RoboSTEAM - Integrating STEAM and Computational Thinking Development by using Robotics and Physical Devices [5], in which have has general purpose to increase the vocation and interest of students in pre-university formation toward in STEAM fields, by using Physical Devices and Robotics (PDR) in order to develop their Computational Thinking (CT), an essential competence that can be associated as one of the main skills needed to a future worker in society [1], [6]. The project also seek to improve teacher education, providing a framework for STEAM integration in different education contexts and giving guidelines for good practices and lessons learned adapted to different contexts.

1.1 Goals

The original objective of this work was to develop and prototype a mobile robot for robotics competitions like Line Follower of Robotic Day, and support classes in STEAM areas. The device developed could be used in teach and training in STEAM areas leading increase students interest for these fields and robotic competition. Instead of develop and built an entire robot from nothing, all the efforts have been put into finding a device that allow the student in understand the main concepts about mobile robotics, as the function of motors, sensors, microcontrollers and among others. Also find a programming tool known as IDE that can be friendly for the first lines of coding, in order to encourage the student to learn and improve the CT [6], [7]. Furthermore, supply a guideline from engineering perspective and to explore other possibilities about the use of this robot to be used as teaching tool, considering that most of educational studies in the literature uses LEGO's robot [4].

1.2 Document Structure

In chapter 2 it is presented the STEM and STEAM concepts, how these concepts were born and how it is applied in educational context using robotics. Then, the chapter 3 describes the information about the robot chosen to be used in the RoboSTEAM project and the reasons for this choice taking into account the advantages and disadvantages to other robots that are used in the literature, also it is shown a methodology for to use the mBot with other sensors and how to built its own extensions as well as describing the Challenge Based Learning (CBL) and Challenges concepts in which are the approaches used during the RoboSTEAM Project. In Chapter 4 it is reported with details the information about the RoboSTEAM project, the two activities carried out through of challenge based learning approach. After that in chapter 5 it are discussed the obtained results from previous chapter. For last, the chapter 6 it are conclusions about the work made and some ideas for future work.

Chapter 2

State of Art

In this chapter it is presented the STEM and STEAM concepts, how these concepts were born and how it is applied in educational context using robotics.

2.1 The Concept of STEM

What is this term STEM? When is searched very quickly on the internet, is usually confused with stem cell research, but it is an acronym to: Science, Technology, Engineering and Mathematics. Initially, STEM was first known as Science, Mathematics, Engineering and Technology (SMET), being a term created by National Science Foundation (NSF) in the United States in the 1990s. This concept is widely applied in educational context being acknowledged as STEM Education [8].

STEM Education is the outcome of sundry historical events. Two of the most important events that push this concept to born, was the WWII and the launch of the Soviet Union's Sputnik. During the WWII, the technologies developed and implemented were huge, this led the scientists, mathematicians and engineers to work with military force in order to produce innovative products that helped won the war and to foment the STEM Education. At the end of World War II the NSF was created, in an effort to recognize the contribution and preserve the research the documentation of commodities created during the war [9].

Since then, STEM education continued to expand and develop, and it has been applied in lot of different approaches in education, to list a few examples, is used in: competitions, classrooms, workshops, videos, summer experiences among others. D. W. White [9], suggests one purpose to STEM education, and says that it is should be available for all students to learn of how to apply their basic knowledge content and practices of the STEM disciplines into many situations of they will encounter in life. He also refers to STEM literacy to an individual's:

- Knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM related-issues;
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- Awareness of how STEM-related issues and with the ideas of science, technology, engineering, and mathematics as constructive, concerned, and reflective citizen.

In the last two decades, STEM Education has become an international topic of discussion driven by the changing global economy. Around the world, workforce will need be prepared to deal with STEM areas [10].

The International Council of Associations for Science Education (ICASE) release in 2013 in ICASE World Conference, the Kunching Declaration on Science and Technology Education, which had input from participants representing thirty-four countries, in order to recognize the need to better prepare students for their future lives as global citizens. Part of this declaration is following below:

> "Access to high quality education is a fundamental right for all. In times of global vulnerability, issues such as sustainability, health, peace, poverty alleviation, gender equity, and biodiversity conservation need to be at the forefront of thinking, planning and actions related to strengthening STEM education. While the relative balance and emphases of these disciplines varies

around the world, it is the interrelatedness and combination of these that will propel progress [11]."

This gives us an initial idea of how STEM education programs should work in general, presenting us with concepts that should be worked with students in order to develop critical thinking, problem solving, creativity, communication skills through transdisciplinary, teamwork, centralized learning, and project-based learning and challenges [3]. However, as it can be seen in the following sections, this concept is worldwide applied in programs in all grade levels, being the main focus on K-12 education and how each country in which apply this concept in your education system has your own policy and goals for his programs, regardless of the country are developed or not.

2.2 The Concept of STEAM

The main concept of STEAM it is add the subject of Art into STEM. But what does change one concept from another? According to John Maeda, president of Rhode Island School of Design (RISD), only the STEM subjects will not lead the innovations that 21st century request, and art and design education fosters creativity and innovation [12].

For B. Trilling and C. Fadel [1], there a first set of 21st century skills that are keys to learning and creative work. This set of skills is listed as:

- Critical Thinking and problem solving;
- Communication and collaboration;
- Creativity and innovation;

These skills are crucial to 21st century global economy, which is requiring higher levels of imagination, creativity, and innovation in order to improve existing products and services and also invent new ones to the global marketplace. This aligns with Maeda's thoughts and can show the importance of adding arts in STEM education, this new approach bring a new whole viewpoint seeing by arts-integration, which is know as STEAM education, this is expressed through creating an environment where students can learn through creative problem solving.

C. Liao [13] says:

> Integrated STEAM education, in this regard, is interdisciplinary education focused on transformative learning experiences whereby STEAM subjects are presented together.

Also from her viewpoint, solving problems in a creative way through art-making should be at the center of the arts-integration approach, according with problem-based learning as well, which students learn by solving problems presented in a given project. This approach encourages students to see connections amid their abilities, skills and knowledge and for these connections will eventually contribute to solutions to 21st-century problems.

In the next section, it will be show a few examples of studies/programs using robotics applied in education context in STEM/STEAM programs to set up a background to this work.

2.3 Robotics used in STEM/STEAM Education

For the first case study, as an example, an interesting case can be found in [14], which have developed a low-cost line follower robot that cost less than 25USD, using integration of free educational software and low cost electronics and mechanical devices as tool for teaching and learning, aiming to increase the students interest in engineering areas. The activity of building a line-follow robot allowed the students to have the interaction of electronic and mechanical components, requiring to learn and use the knowledge of those areas, also they had to develop skills in the manufacture of structural elements using cardboard to support all the components of the robot, and can be used as an educational tool. During the project they also have been exposed through several free educational software, by using software such as Sketchup free to 3D design and modeling, Fritzing to learn how to use electronic elements, Arduino IDE and Scratch program language to introduce microcontrollers programming and thus were presented to computational thinking and programming concepts and sentences. The number of students enrolled in this project was 28 which the average age was 17.3 years. To evaluate the appropriation of knowledge by the students, was applied one test at the begin of the activity in order to know the previous experience, knowledge and interest, and other test at the end. The results with the tests made possible to observe that the students gained greater knowledge, increasing their interest in the engineering fields as so their confidence and performance to programming microcontrollers and using electrical circuits. This work was took at University Technological of Mexico which is a developing country, and it is important because the most of the students have difficult to have access to technological tools, and this break the technological and economic barriers for then for being a project that cost less than 25 USD [14].

H. Costelha and C. Neves [7] bring a research about the database on robotics-based educational platforms for K-12 education, where gather the most used robots in the literature studies. The paper summarize in tables the information collected about the robots researched, and sort by Project, Ages, Types, Motion Type, if the robot is Open-source and among other characteristics. The author concludes there are several types of educational robotics platforms available on the market, with the associated learning resources its the using increasing, but as seen in the [4] the LEGO's robot domain with 90% in the education scenario in 2012 as the main choice for STEM/STEAM activities. The following references show the future trend where mobile robots are made by using 3D printers and being Arduino-based, to be applied in an educational context.

Another paper that uses the robotic in field's education is [15], the authors had developed a new platform to introduce sensoring and navigation skill to new users, using a simple approach on the use of the robot to show the problems in the field of mobile robotics. Tacking into account that the target audience for use this robot is inexperience, its was designed to be small and simple, with parts that can be acquired and replace easily. The robot was tested in the Robotic Day 2017 in Czech Republic which is a competition environment that the participating students can improve their mobile robotic skills in a real use case.

Gonçalves, José et al. [16], propose a low cost educational mobile robotics experiment: an approach based on hardware and simulation. The mobile robot it is 3D printed and the hardware used is not expensive, could be reply in other possibles scenarios. The prototyped robot was simulated in the SimTwo a realistic simulation software. The experiment was done with the objective to introduce students in the mobile robotics challenges, doing all the step until the competition that was the assessment used, they started programming the simulated robot, testing in the virtual environment and then did in the real robot. This approach in very useful and can be applied in schools of developing countries that usually have reduced budget.

Chapter 3

Materials and Methodology

This chapter describes the information about the robot chosen to be applied in the RoboSTEAM project and the reasons for this choice taking into account the advantages and disadvantages to other robots that are used in the literature. It also described the CBL concept in which is the approach used during the RoboSTEAM Project. Later it is explained the concept about Challenges.

As seen previously, there is an urgent demand for new approaches involving robots as teaching tool [3], when in 2012 the most of educational experiences/studies conducted in literature use the LEGO's robot in which some of viewpoint can be expensive [4]. H. Costelha and C. Neves [7] gather and show others robots that can be used in educational context, after making a research about each robot, it was found a robot that has an interesting potential for use due the wide of sensors embedded and for his price compared to others in this paper. The robot chosen was the mBot robot from Makeblock Co. Ltd, a and the features about the robot as well as the features about the IDE that its need to program the robot it will be described in the following sections.

3.1 mBot Robot

The mBot robot as is shown in the Figure 3.1 is an entry-level STEAM educational robot kit for beginners that makes teaching and learning robot programming easy. When a customer acquires the mBot, it does not comes ready for use, it needs to be assembled. Therefore, for many students in K-12 education, this may be their first experience with mechanical and electronic parts of a robot. In Figure 3.2 it are shown the parts that compose the mBot.

Figure 3.1: mBot Robot [17].

Concerning the technical specifications of mBot, the main control board is the microcontroller ATmega328P being the same chipset that is embedded in Arduino Uno board, and comes with a light sensor, a button, an IR receiver, an ultrasonic sensor, a line follower sensor, there is also the possibility to program other modules like a buzzer, 2x RGB LED, an IR transmitter and two motors. It can be powered with a 3.7V lithium battery or 6V (4x 1.5V) batteries. It also comes by standard, with 3 preset control modes: 1 - Obstacle avoidance mode, 2 - Line - follow mode and 3 - Manual control mode. In mode 1, the mBot moves and avoids obstacles autonomously, in mode 2 the mBot moves autonomously along the black lines on the map, and the last mode 3, the mBot is controlled by the remote controller that comes included in the package.

As can be seen in [7], the mBot comes with a large range of sensors whether compared to others, with all these sensors, it allows the students to learn about their physical concepts as an example the line follower sensor and ultrasound sensor, the schematic of mCore, the line-follower and the ultrasonic sensors can be found in appendix A. Observing

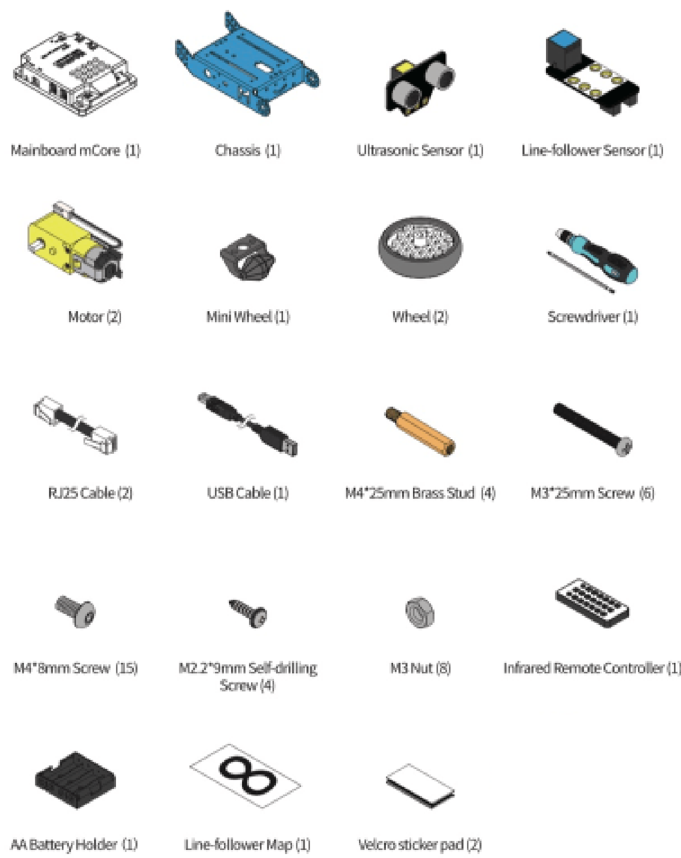

Figure 3.2: mBot Parts [17].

the price it is possible to conclude that it is much cheaper than Lego's robot, in the paper the mBot its shown the price of 99€, but making a research on the internet, it can be found even cheaper, as 63€ on the Amazon's website [18].

The mBot also allows the user to acquire some of additional hardware packages, as an instance the Talkative Pet, offering some others mechanical parts and sensors as well, showing the mBot can propose several possibilities with different approaches to learn about robotics[19].

3.2 mBlock 5 IDE

To program the mBot it is required to install the mBlock 5 IDE for the PC version, a Scratch 3.0-based software designed to support STEAM training, as shown in Figure 3.3 the initial environment of the IDE on the Windows Software. By supporting block-based programming, mBlock 5 allows users to freely program various Arduino-based devices and devices from Makeblock Co. Ltd., it is also through this software that students can program the additional hardware packages for mBot. Figure 3.4 shows a few devices available to program with mBlock 5.

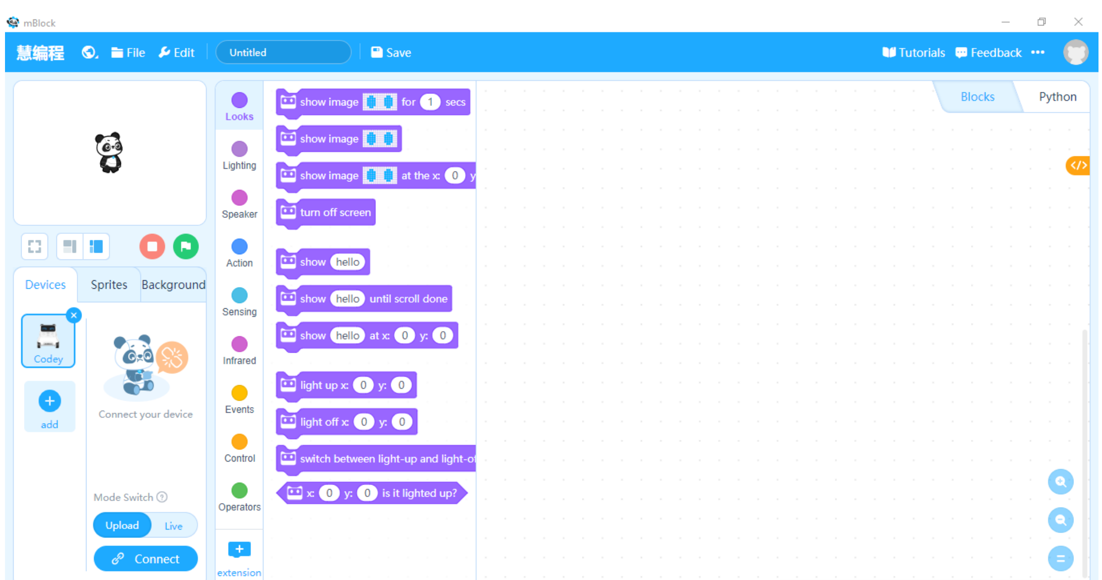

Figure 3.3: mBlock 5 IDE Environment [20].

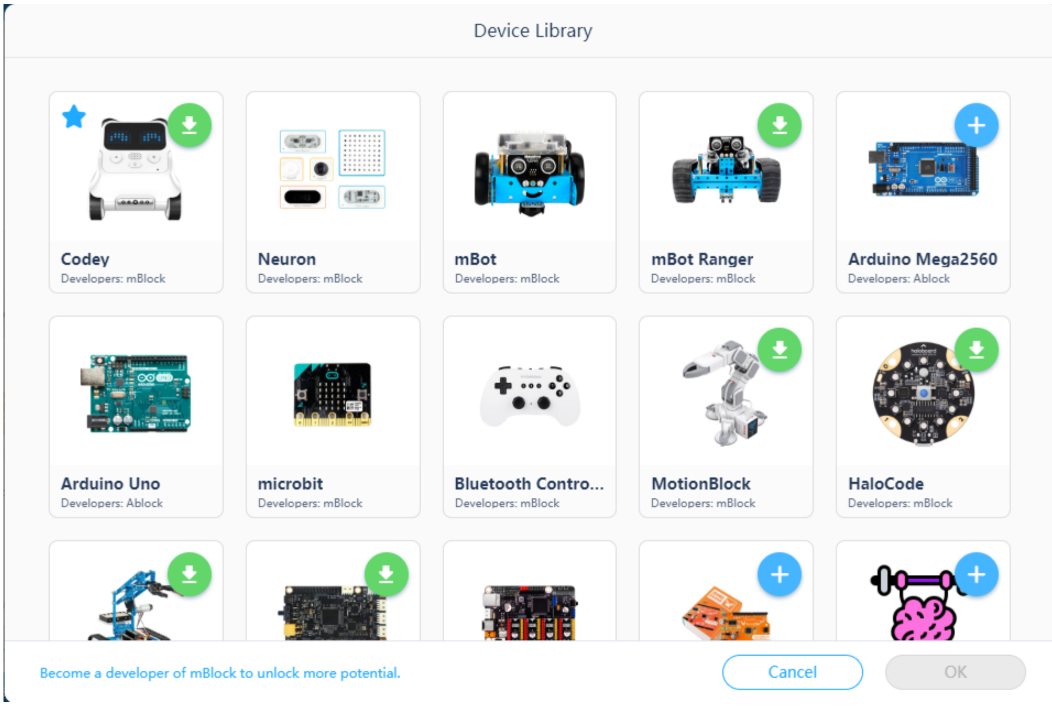

Figure 3.4: Devices for programming with mBlock 5 [20].

3.3 mBot with other Sensors

Whereby described in the section 3.1, the mBot allows the users to acquire additional hardware packages. To program these additional hardware packages the user must add the respective extensions to each type of hardware in the mBlock 5. The Figure 3.5 shows a few examples of extensions developed by Makeblock Co. Ltd. However, if the additional hardware packages and extensions are not provided by the mBot's company and not fit for the needed objectives, it is possible to create extensions blocks to use according to the sensors and devices the user is going to use.

In the case for this project and due to the theme of the challenges as will be seen in the section 4.2, the mBot robot needed to be adapted so that the challenges could be solved, adding a flame sensor as shown in Figure 3.6a). To unite the sensor to the robot it was designed a support using the free software OpenSCAD and prototyped using a 3D printer, the support can be observed in Figure 3.6b). The final result of mBot is shown in Figure 3.7.

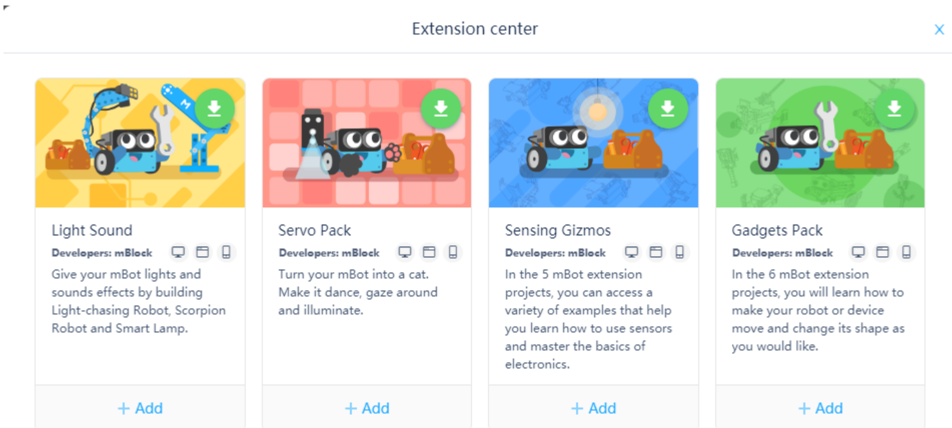

Figure 3.5: Standard extensions for mBot [20].

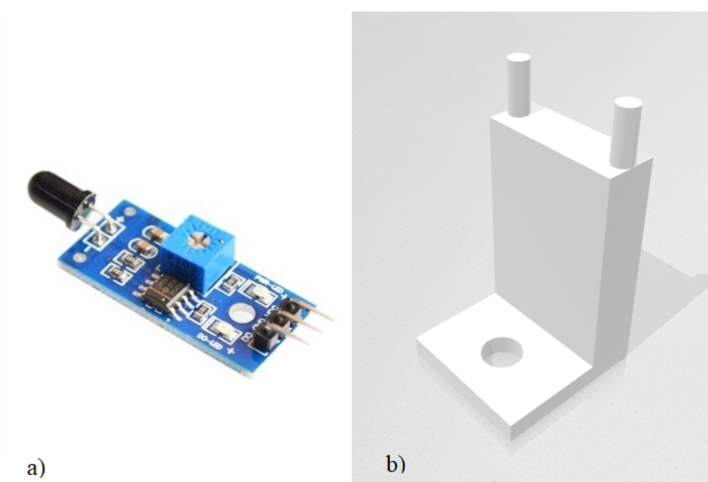

Figure 3.6: Flame Sensor and its support [21].

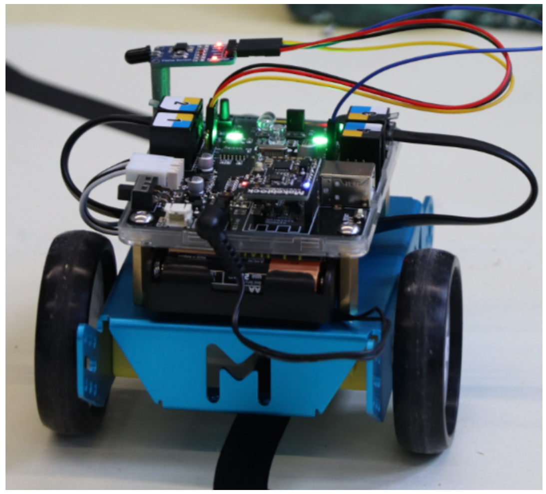

Figure 3.7: The mBot adapted [21].

With the mBot already adapted, it was necessary to create an extension for the mBlock 5 so that the analog or digital values of the flame sensor could be obtained and read by the mBot. In order to do this, the MakeBlock Co. Ltd provide a platform for makers and stakeholders and it is available on [22]. The whole process to create a new extension it is described in the subsection below, using as example the flame sensor.

3.3.1 Creating an extension for mBlock 5

Before begin to create an extension for any sensor, we must know how it does work the sensor by reading its data sheets, the flame sensor scheme and user manual it is found in the appendix A and its the data sheet on [23]. An instance it is shown in the appendix B, using the Arduino IDE.

With this structure in mind, it is will be applied in the Extension Builder web-based IDE, in which its appearance is shown in the Figure 3.8.

To start create the new extension, just click in the "Add extension" button as can be seen in the previous picture, then choose the "Universal Template" option and will appear the box to the user fill the basic information about the extension, being mandatory the user complete the "ID", "Version" and "Name" fields, for the "Support device/sprite" field the user must select the "mcore" option, because it is the name of mBot's board, like

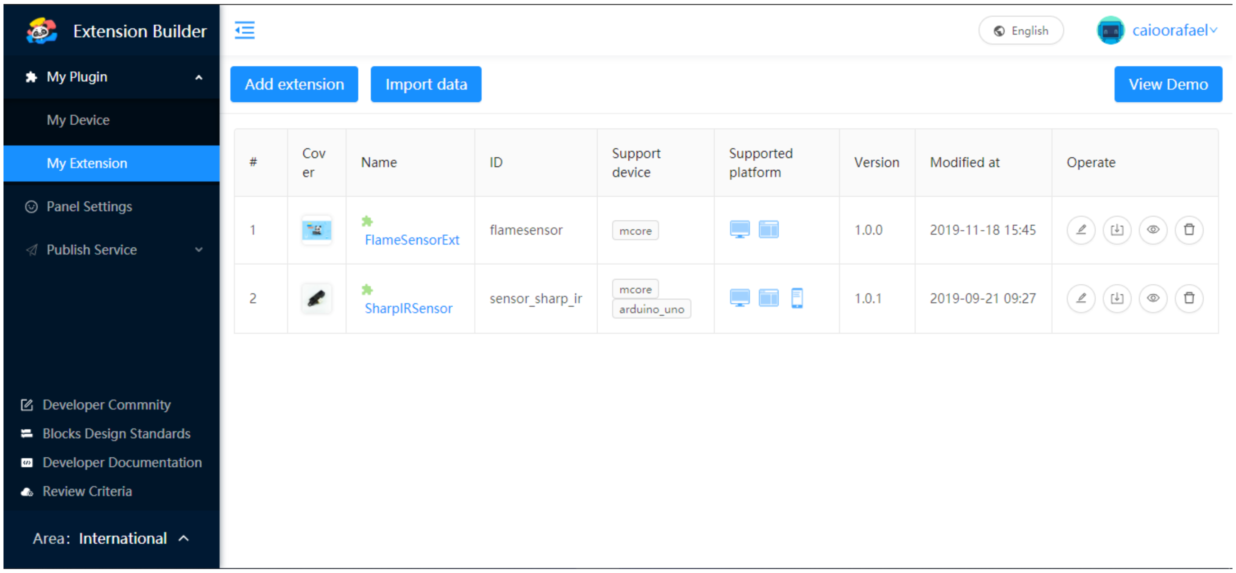

Figure 3.8: Extension Builder IDE [22].

shown in the Figure 3.9.

After this step, the extension created it will be listed in the Extension Builder IDE, and now its required to configure the block of the extension. In order to this, the user has to select in the "Operate" column the option "Edit". The next step it is add a category of block in the "Blocks Settings", then choose the name and color to the block's category. In the case of the flame sensor, the block category's name is "Sensors", and the analog value is read and this value that will return from the block is a integer number as presented in the structure on the appendix B, so the block category to chose it must to be the "Number" option, this whole step can be see in the Figure 3.10.

For the last and the most important step before we generate and import the extension to the mBlock 5, the user needs to set and save in the tab "Transcode Settings" the code language that the block will to use, in the flame sensor is the "Arduino C" option, that means the block's codification will to be C-language-based. Thus, in the tab "Upload Transcode", as can be seen in the Figure 3.10, it is the place where the main coding of the sensor going stay. The flame sensor example it is shown the Figure 3.11.

Therefore, the extension and the block it ready to be downloaded and imported to the mBlock 5 IDE, the file downloaded it has the "ID" name and the ".mext" format.

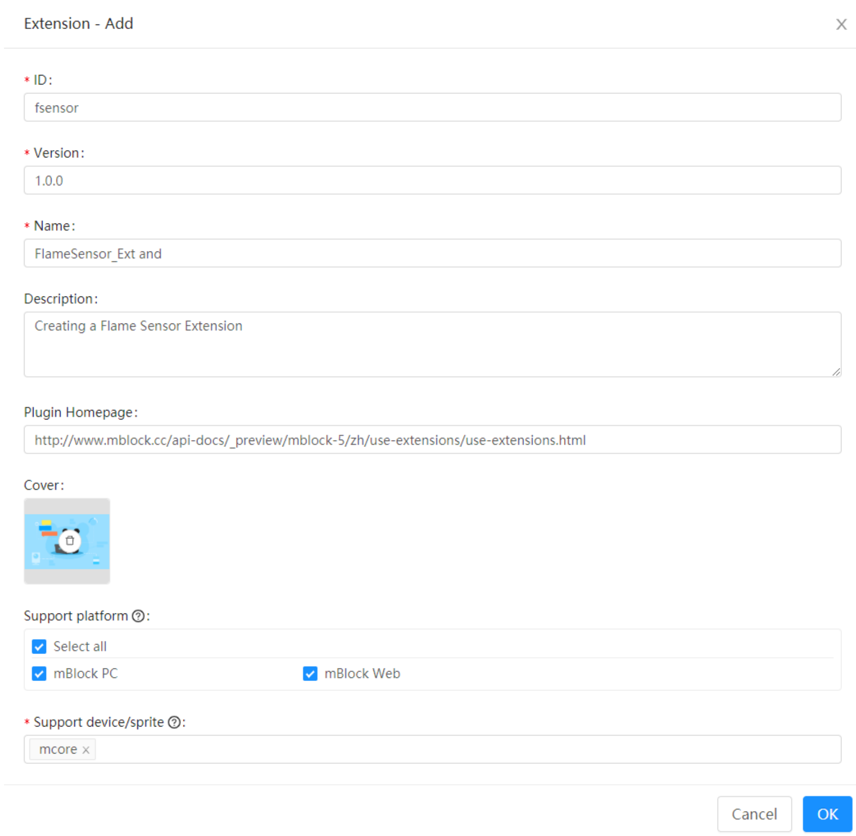

Figure 3.9: Creating the Flame sensor extension [22].

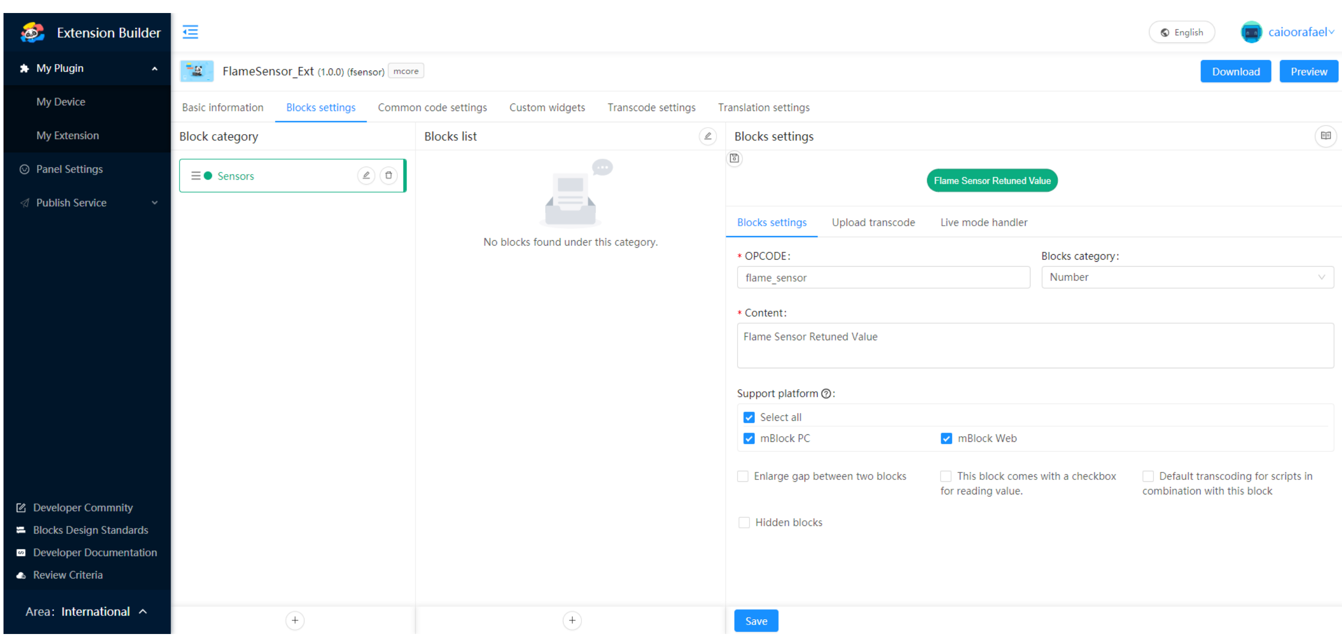

Figure 3.10: Creating the Flame sensor Block [22].

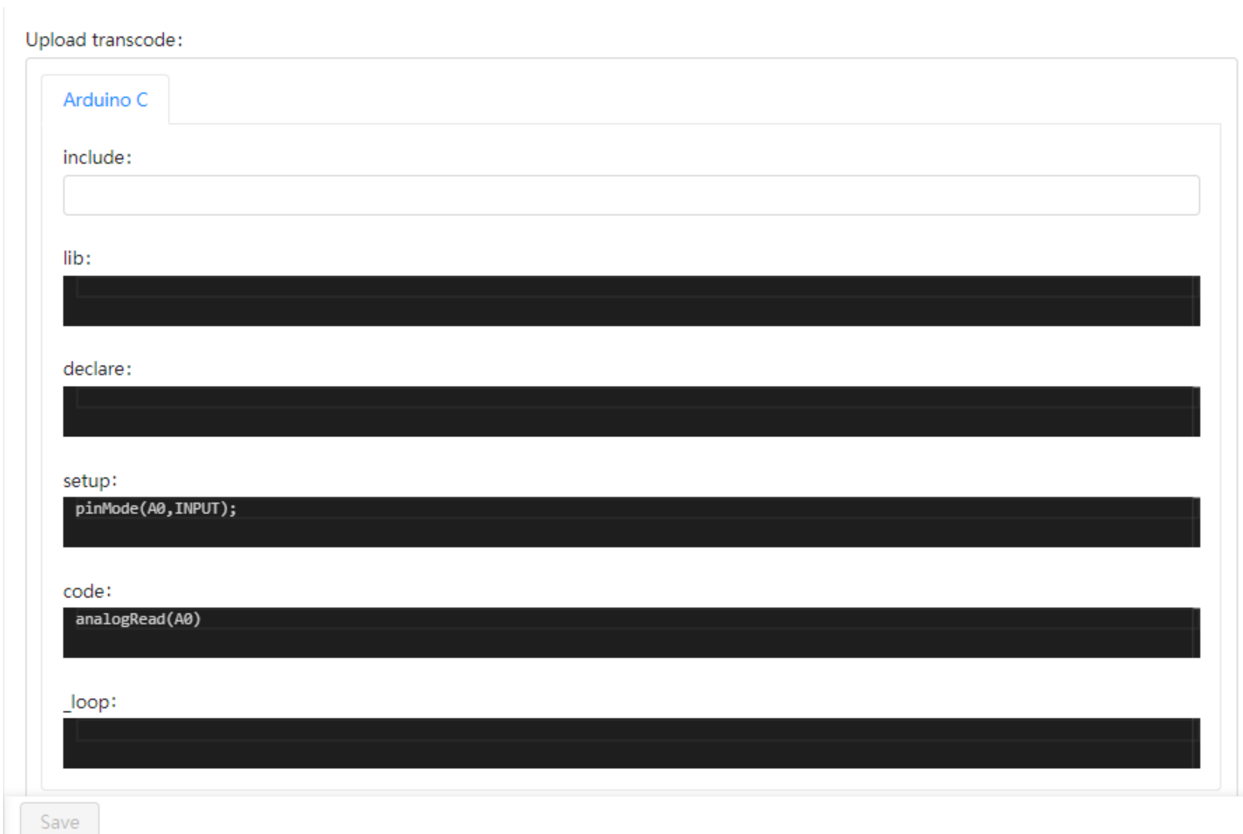

Figure 3.11: Fields to Program the Sensor [22].

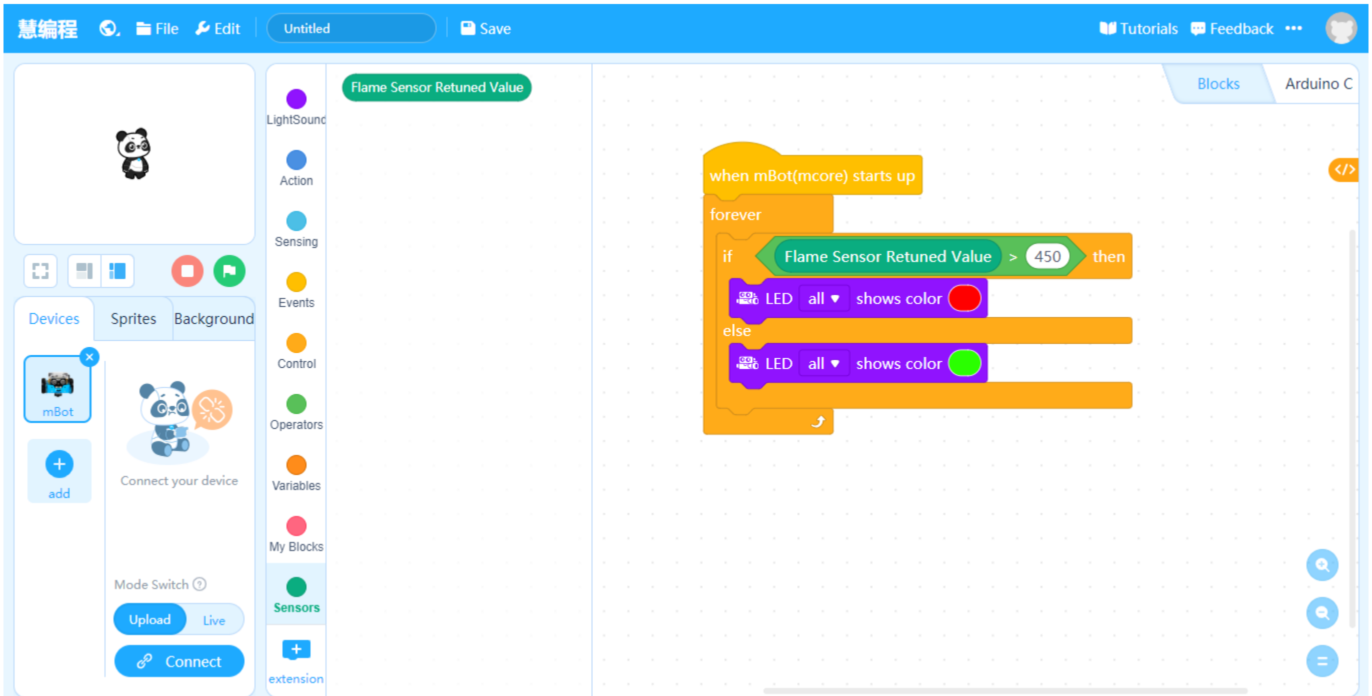

Figure 3.12: Flame Sensor in an example [22].

To import this file to Scratch Environment just drag into mBlock's work's space and the extension will be added successfully. The Figure 3.12 demonstrate the example made to the flame sensor with a little application in the mBlock's IDE.

This method used in this section shows that can be possible to adapt it to several types of sensors to the mBot robot in order to be applied in many situations or challenges for STEAM teaching, being the important part of this work.

3.4 Challenge Based Learning

As pointed out by Camargo et at.[21], CBL is a flexible methodology that encourages students to leverage the technology they use in their daily lives to solve real-world problems [24]. CBL is a collaborative methodology. It is going to involve the student's groups, but also other peers, teachers, experts, parents, etc. in order to solve a real problem. A CBL approach requires to propose to the students a big idea, this idea will be discussed in order to find some main questions. The students analyze the questions and define a challenge. The challenge is addressed by the students in a collaborative way and involving people from their educational contexts and from the outside [24]. Some authors identify 3 phases in a CBL methodology [25]:

- Engage. Through a process of Essential Questioning the Learners move from an abstract Big Idea to a concrete and actionable Challenge.
- Investigate. All Learners plan and participate in a journey that builds the foundation for Solutions and addresses academic requirements.
- Act. Evidence-based Solutions are developed, implemented with an authentic audience, and then evaluated based on their results.

Some samples of the application of CBL could be [24]–[32]. From these experiments and other it is possible to describe some advantages of this methodologies [33]:

- CBL provide to the students a deeper understanding of different topics and the possibility to learn how to analyze the problems in order to pose the better solutions.
- CBL involve learners both in the definition and solution of a problem.
- CBL promotes collaborative working between students from different disciplines in order to solve a problem. This collaboration goes beyond their classmates, but includes also parents, teachers, researchers, experts, etc. This collaboration could help them in their professional development.
- CBL connects the student with the real world in order to address the challenges.
- CBL promotes the development of communication skills by using social and media tools.

However also previous works have shown some drawbacks in the methodology:

- Global projects are often away from the specific contents of academic subjects [29].

- Traditional assessment systems can be a problem for students, because they may be more focused on assessments than on learning [26].
- Most of the CBL experiments cannot be easily associated to a specific subject in academic contexts. They used to be applied to CBL specific designed subjects or to master projects [31].
- Students' perception about this approach is not clear because not all the experiments have indicators to evaluate this [32].
- The participation of people with different roles may cause difficulties for students that should adapt their way to work to this situation [29].
- The results of the global projects are typically obtained when the academic year has finished [28].
- There is wide choice of tools to use in CBL experiences so evaluation is not easy [33].

Some of these drawbacks are also present in the RoboSTEAM project. RoboSTEAM aims to carry out two pilot stages. The first phase includes piloting in 5 schools with students from 12 to 16 applying the methodology and later to carry a pilot stage exchanging challenges and tools. In order to check if the same solutions and challenges can be applied in different socioeconomic context. At this moment, this piloting is being designed and one of the most relevant issue found is to understand what a Challenge is, and how to define challenges to be applied in different schools, with time and students background constraints.

3.5 Challenge Concept

Camargo et al. also shown the Challenge concept. Being necessary to describe the challenge concept with different granularity levels, so it can be adapted to the specific needs of each institution,in the case for the RoboSTEAM project team decides to apply the concept of Challenge, Mini-Challenge and Nano-Challenge proposed by Nichols et al. [25]. In the next subsections these concepts will be commented.

3.5.1 Challenge

It works posing to students a big idea, they should discuss about it and define some main questions about this idea, from these questions a challenge is proposed. Students should address the challenge looking for a collaborative solution that involves their peers, teachers, experts, etc. After this, the solution, will be assessed [25]. “Standard Challenges are longer (one month and longer) and allows considerable latitude for the Learners. Working together, the Learners identify and investigate Big Ideas, develop Challenges, do extensive investigation across multiple disciplines and take full ownership of the process. The Framework is used from start to finish, including implementation and evaluation of the Solution in an authentic setting.” Although in the literature there is not a clear description about how many hours the students employ to these types of challenges per day the authors consider 4 hours per day, 5 days per week and 4 weeks per month. This means that it should comprise 80 working hours, from which around 40-60 should be at class and 20-40 is personal work of the student.

Examples of standard challenges [34]:

- Big Idea: Gender Equality
- Main question: How it is achieved gender equality?
- Challenge: Build a culture of gender equity!
- Later the authors will have some guiding questions, research, act and reflect.

3.5.2 Mini-challenge

The Mini-challenges are not so big as a standard challenge and increase the level of choice and responsibility of a nano-challenge, typical duration is around 2-4 weeks. These challenges allow learners "to start with a Big Idea and work through the entire framework. The research depth and the reach of their Solutions increases and the focus can be content specific or multidisciplinary. Taking a "show me what you can do" perspective, Mini Challenges are good for intense learning experiences that stretch the Learners and prepare them for longer Challenges" [25]. Regarding duration with 4 hours per day, 5 days per week model we can talk about a minimum of 40 hours per mini challenges, which 20-30 should be at class and 10-20 are devoted to students' personal work. Several mini-challenges could be the base for a standard challenge.

3.5.3 Nano-challenge

> "Nano Challenges are shorter in length, focus on a particular content area or skill, have tight boundaries and are more teacher directed. The Learners typically start with the Challenge without identifying a Big Idea or Essential Question. The process includes the Investigation and Act phases, but at a significantly lower level of intensity and often stop short of implementation with an external audience. Typically, Nano Challenges are used as scaffolding leading to more significant Challenges or during longer Challenges to address specific concepts"[32].

That is, nano-challenge will be our minimum unit to build challenges, it is more oriented to a Project based learning approach, it could involve external people but it is not necessary. Regarding the number of hours required by it we are talking between 6-10 hours of classes and 4-6 of students work. Several nano-challenges can be used to address a mini-challenge.

Chapter 4

RoboSTEAM Erasmus+ Project Activities

The RoboSTEAM ERASMUS+ Project, which is an European project co-funded by Erasmus+ KA2-Cooperation and Innovation for Good Practices and Strategic Partnerships for school education, has as goal to provide frameworks and tools to facilitate the learning actions based on robotics to teach STEAM areas. In order to accomplish this goal the project has eight partners which are: the Karlsruher Institut Fuer Technologie from Germany, ITA-Soumen Yliopisto from Filand, IES Eras De Renueva, Salamanca University and León University from Spain, Polytechnic Institute of Bragança, Carvalhos Boarding School and Emídio Garcia School, the last three are from Portugal. During this project had occurred exchanges between partner's students in order to understand if the same tools and methods can be applied in different socioeconomic context[5]. The Logo of the RoboSTEAM project it is shown in the Figure 4.1.

In the following sections it are depicted two exchanges in which mBot and mBlock 5 IDE were used as the tools that helped the students thinking through the proposed challenges, each one with a central theme with a challenge based learning case study.

Figure 4.1: RoboSTEAM Project Logo [21].

4.1 Educational Robotics Summer Camp at IPB

The summer camp at IPB happens every year. It has as objective to promote science to technical and secondary schools, in July of 2019 the summer camp took place in the Laboratory of Control, Automation and Robotics (LCAR), and took 5 days to be done. The number of persons involved in this project was 22, being 16 students, 4 monitors and 2 professors, the whole group can be seen in the Figure 4.2. The students were from secondary schools from all over of Portugal with average ages nearly 15,5 years old, however the ages range goes from 14 to 17.

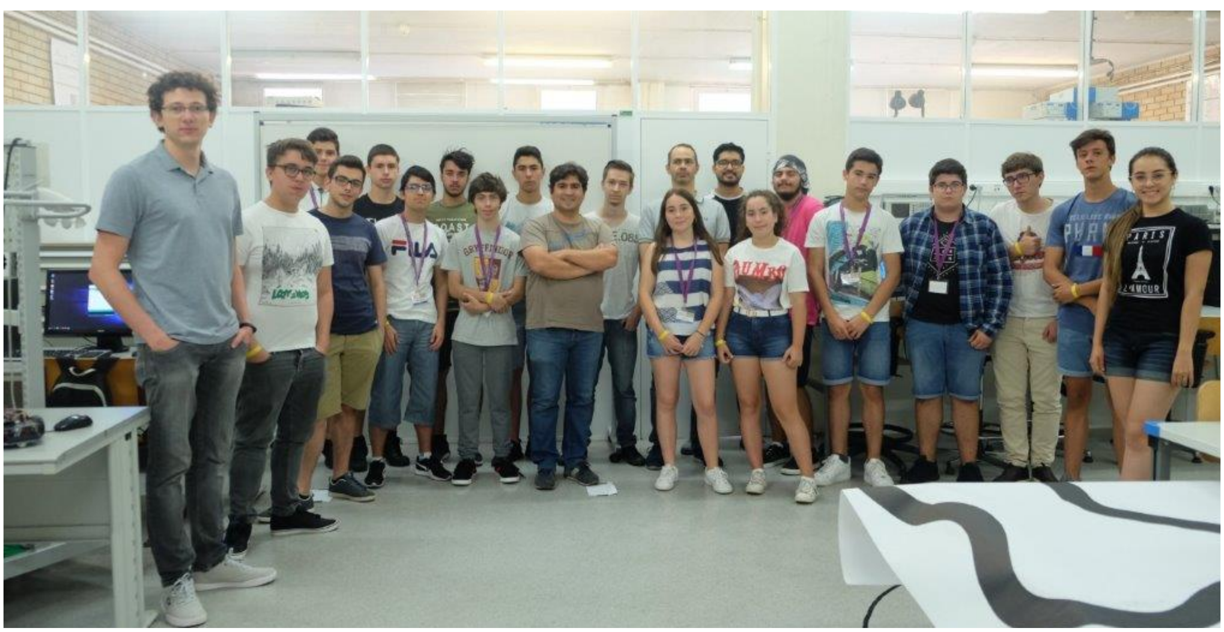

Figure 4.2: Group of IPB Summer Camp [35].

For the Summer Camp being a challenge based learning case study, it needed to have a central challenge for the students to think and study about and solve, however in [25] the development of a challenge involves too many hours whether compared with the hours available for the camp, so based on theme, the challenge was turn into something more concrete as Mini-Challenges and this was separated in 4 Nano-Challenges being one of them the one that use the mBot and mBlock 5 as tools to solve it.

4.1.1 Challenges Descriptions

The main theme of the summer camp was Transportation and Navigation of Mobile Robotics and all the 4 Nano-Challenges were based on this topic. This was proposed to encourage the students to reason about the increasing using of fossil fuels as a source of energy over the years, and how the vehicles based on this source of energy impacts the environment. They had to develop the tasks to work together that makes the mobile robots solve problems that seems simple to humans, in order to think in to reduce the environmental impact caused by the use of fossil fuels.

The students were separated in 4 groups, 2 groups had 4 students, one group with 3 students and the last one with 5 students, in this way, each group had to solve a different Nano-Challenge to develop a solution. A brief description upon the 3 Nano-Challenges is given below, and the one uses the mBot and mBlock 5 is described with details in the next subsection.

The first nano-challenge to be described involves the transportation of loads by mobile robots through a controlled environment, the robot should move along the track without any help of a joystick. Thus, it was proposed to the students the process of digitizing a factory floor, so the robot can indicate which region it is moving through and decide to take an action for the possibles occasions it may have. The main idea here was that on the factory floor there would be circles or squares with different colors, and with the color sensor, the robot would take a pre-programmed action according to the color identified.

The second nano-challenge given to students was to learn and develop a mobile robot that identify an intersection while follow a line based on the rules of Robot @ Factory

Lite (R@FL) competition as can be seen in [36]. This task it is linked with the first nano-challenge and these 2 groups work together to solve these 2 problems, the Figure 4.3 shows the robot and the track used during these 2 first nano-challenges.

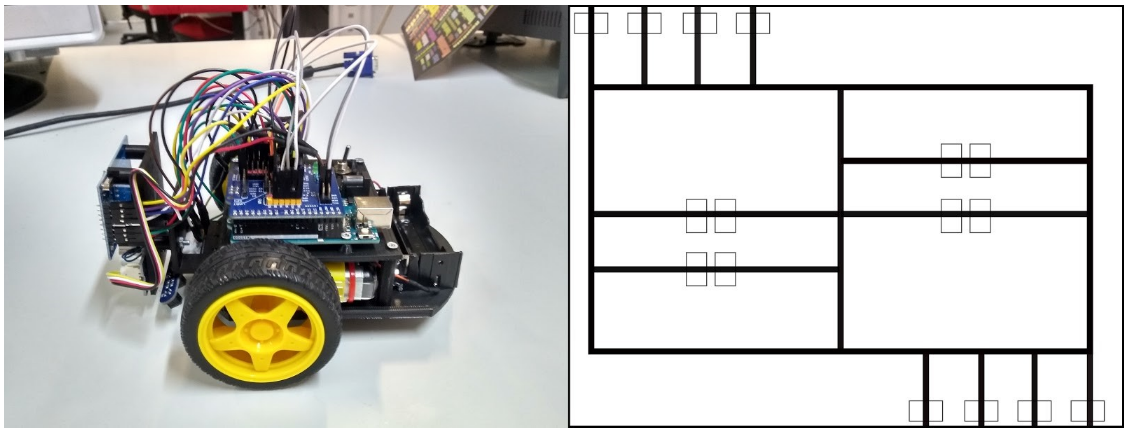

Figure 4.3: Robot and the track used during the 2 Nano-Challenges [35].

For the last nano-challenge before we discuss about the challenge that uses the mBot and mBlock 5, the students had to develop a low cost stroboscope prototype, which is a optical instrument that generate flashes of light with frequencies that can be chosen for the user and be applied in the maintenance, calibration or do the measurement of bodies in a movement.

4.1.2 Nano-Challenge using mBot and mBlock 5

This subsection it is focus on describing all the activities made by the 5 students that realized this nano-challenge. The main goal was to build a program based on Scracth language that makes the mBot follow a line. The monitor started showing the functioning of the 3 preset modes as is described in the Chapter 3, following with the explanation in how it does work the line-follow sensor of mBot and the logic behind the functioning of the sensor, as can be seen in the Figure 4.4, in which allows the students associates the infrared light used in the sensor with the physics subject, moreover explaining and showing how to use and create their own block programming. After this, the monitor proposed to students the main goal of this challenge.

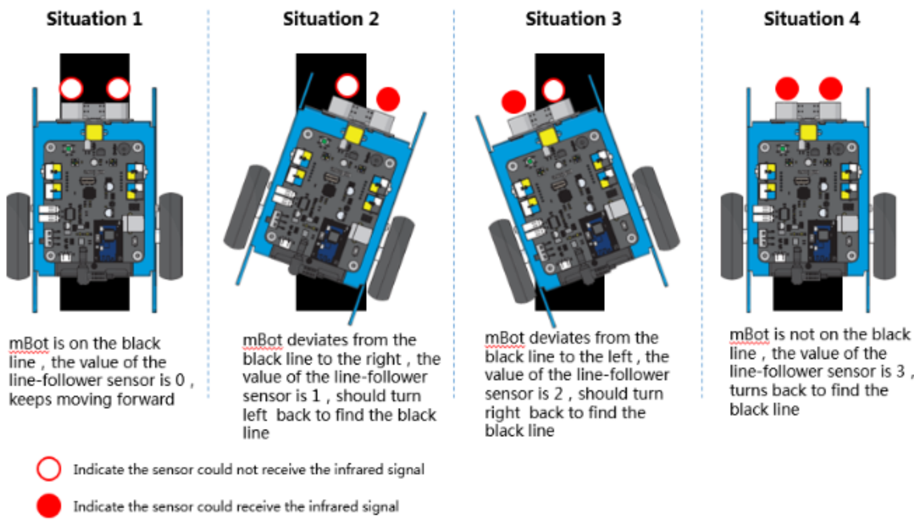

Figure 4.4: The functioning of the line-follower sensor [37].

In that way, the line - follow challenge was set, using the mBot the student had to build a block program in mBlock 5 that makes the robot follow a line similar presented in the preset mode. When the students finishes the program they upload the code to the mBot and test their logical think in the track shown in the Figure 4.5.

The main objectives of this activity was:

- Study mobile robots;
- Study navigation issues in mobile robots;
- Study possible ways facilitate that a mobile robot follow a line;
- Explore the scenarios were mobile robots can be applied.

And the points to evaluate the students after to conclude the challenge was:

- Time employed to solve the challenge;
- Degree of success using the mBot robot to follow the line;
- Robot accuracy following the line.

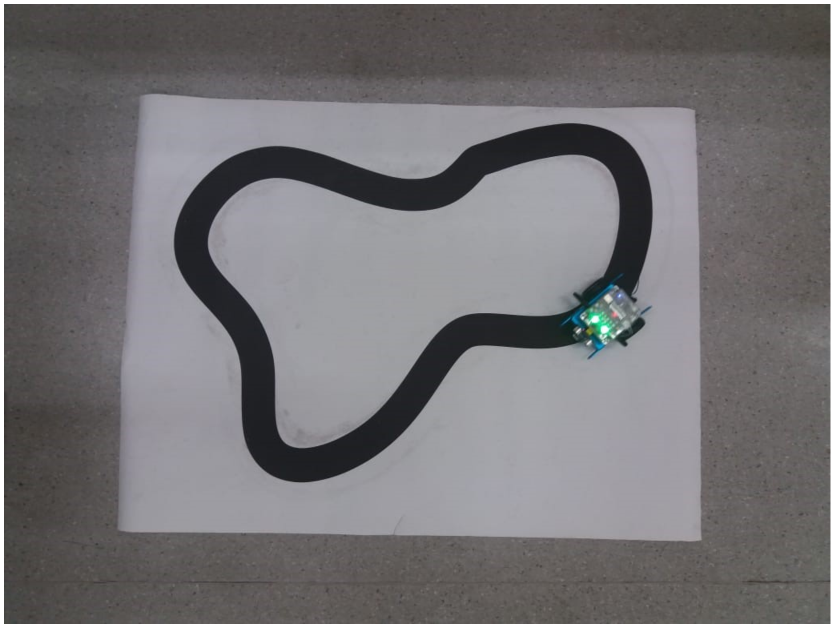

Figure 4.5: Track used during the challenge [35].

The complete description and results about the others nano-challenges previous commented can be found in [35]. The results of the evaluation realized with the students it is discuss and presented in the Chapter 5.

4.2 Emídio Garcia School Pilot A RoboSTEAM Erasmus+ Project Activity based on a Challenge Based Learning Approach

Another exchange of students from the RoboSTEAM Erasmus+ project, occurred at the Emídio Garcia School from Bragança in Portugal, this pilot was done with the collaboration of the IPB, the University of León and IES ERAS DE RENUEVA School also from León in Spain. This STEAM activity took 5 days to be done and uses the challenge based learning approach to promote technological knowledge being related with mobile robotics, using as physical device the mBot robot and the mBlock 5 to program it. In the following subsections it is described the challenge theme as well as the mini-challenge and the four nano-challenges done by the students, and also is depicted the procedure realized to adapt the mBot to be used in this project.

4.2.1 Challenges Descriptions

A worldwide issue that concern all of us it is the wildfires. This problem has annually double in the American west according to Environmental Defence Fund (EDF). In Europe this problem must be similar about the numbers and facts. Setting in this way, the main theme of this challenge, aiming the use of robotics the project sought to improve the environment and to look for successful strategies to prevent fires reducing the Global Warming (GW). An artwork also was made by the art students, contributing in a meaningful way to provide the context for the scientific challenge based on team work. The Figure 4.6 shows the complete artwork, highlighting the damage caused by fires in our community and lives.

Figure 4.6: Monitors and teacher observing the scenario model made by students [21].

With this global issue as background, the students had to work in four nano-challenges using the mBot, in order to perceive the problem and think about it. The first nano-challenge was to make the mBot following a line, the second one was to use the detector flame sensor, thus they could understand the functioning by detecting a flame, then the next nano-challenge was to gather the first and the second nano-challenges to run into mBot, the last one was to make the robot avoid obstacles, add posteriorly this block in the third nano-challenge code.

Once complete all the nano-challenges, the mBot navigated in the scenario of the Figure 4.6, was giving the idea to students that using mobile robots we can prevent early ignition and also using it for surveillance tasks and among others examples.

So that mBot could be used in the challenges it was necessary an adaptation to use the flame sensor, this is described in the next section. And the discussion about the obtained results of this challenge based learning project it is presented in the chapter 5.

Chapter 5

Results and Discussion

In this chapter it are discussed the results obtained from the two RoboSTEAM activities based on the challenge based learning approach that involved the use of mBot robot and the mBlock 5, each one with different central themes, leading the students to think through the proposed problems and developing their CT.

5.1 Results obtained from Educational Robotics Summer Camp at IPB

As seen the subsection 4.1.2 the assessment of the students was made by observing the time employed, the degree of success and the accuracy to follow the line using the mBot. To solve the proposed challenge, the students had to understand the operation of the line-follow sensor, understanding the decimal values that return from sensor in order to structure the block-code, thinking in what the robot should do in the each situation as shown in the Figure 4.4. The mBot's line sensor have two infrared sensors as can be observed in the Figure 3.2, being 1, the left sensor and 2, the right sensor, these sensor can represent values in bit as well as in decimal, to better comprehend this its shown in the Table 5.1.

The group that had 5 students participated in this challenge, being 3 males and 2

Situations	Sensor Values in Bits	Sensor Values in Decimal
Situation 1	00	0
Situation 2	01	1
Situation 3	10	2
Situation 4	11	3

Table 5.1: Response Values of Line-follow Sensor.

females and the average of their ages was 15.2 years. Three of them said they were the first experience in programming a mobile robot, one said already had experience in programming in another platform using scratch, and the last one informed already had programmed LEGO's robot and shown facility in structuring the blocks to solve the problem.

After a few hours working, the students were able to understand and code in block language the logic according the Table 5.1 to make the mBot follow the line, in which performed efficiently for 3 first cases where the response value of the line sensor was 0, 1 and 2. For the last case, the students had some performance problems, because when the robot reach this case, it changed the direction going the reverse path. Took while to they thought of a way to solve it, in which was when the robot was doing the curves, it did with lower speed in the motors, therefore, the robot would never reach the case where the response value is 3.

Viewing the general context, the students were efficient to solve the challenge around 3 hours, taking in count that 60% of the team never had previous experiences with the programming of mobile robots. The degree of success of the program was considered good, but they tested the robot several times without think better if the code was going to make the robot run the whole track or not before to test.

5.2 Results obtained from Emídio Garcia School Pilot

During the described Pilot there were seventeen students involved in total, being eight Spanish and nine Portuguese. They were divided into four groups, three groups of four students and one group with five students, as presented in the Table 5.2. The students were distributed regarding their backgrounds, each group had as many students of Arts as of Sciences and Technology. They were all from regular educations secondary schools, that is part of the consortium of the RoboSTEAM project.

In the first group, there were two Spanish students from the fourth year of High School and two Portuguese students, one from Sciences and another from Arts, with an age average of fifteen years old. The second group was composed of two Spanish students from fourth year of High School and three Portuguese students, two from Arts and one from Sciences and Technology, all of them were fifteen years old. The third group consisted of two Spanish students from the third year of High School and two Portuguese students, one from Arts and another from Sciences, with their age around fourteen years. In the last and fourth group, there were two Spanish students, one from the third year and one from the fourth year of High School, two Portuguese students, one from Sciences and Technology and another from Arts, being the average age around of fifteen years old.

It were applied four nano challenges for the all groups, as seen in the subsection 4.2.1, in the nano challenge 1 the students had to write a program in scratch that makes mBot follow a line. In the nano challenge 2 they had to use the flame sensor to detect a flame and the nano challenge 3 consisted to merge both functions for the mBot follow a line, detect a flame, stop, play a buzzer during three seconds and then continue the navigation. In the last nano challenge, the students had to make the robot avoid obstacles, using an ultrasonic sensor, and then to present the four nano-challenges together running in the mBot. On Table 5.3 it are presented the groups performance, the total time to complete the nano challenge, the respective grades, as well as, the final grade calculated for all the groups, through the average grade of each nano challenge. The evaluation and the grades

Groups	Students	Nationality	Age	Course
Group 1	Student 1	Portugal	15	Sciences
	Student 2	Spain	15	4º ESO
	Student 3	Spain	14	4º ESO
	Student 4	Portugal	16	Arts
Group 2	Student 5	Spain	15	4º ESO
	Student 6	Spain	15	4º ESO
	Student 7	Portugal	15	Sciences and Technology
	Student 8	Portugal	15	Arts
	Student 9	Portugal	15	Arts
Group 3	Student 10	Spain	14	3º ESO
	Student 11	Portugal	14	Sciences
	Student 12	Spain	14	3º ESO
	Student 13	Portugal	15	Arts
Group 4	Student 14	Portugal	15	Sciences and Technology
	Student 15	Spain	14	4º ESO
	Student 16	Spain	14	3º ESO
	Student 17	Portugal	16	Arts

Table 5.2: Groups description table [21].

were based on the time that the groups spent to complete the nano challenge, as well as the effort and cooperation between the students evaluation. Besides that, the groups that thought more before testing got better grades than those who just tested.

Group 2 obtained the highest grade and group 4 the lowest. The group 3 spent much time to finish the nano challenge 1, it was observed that they had more difficulty to understand the scratch program language, because two Portuguese students already had knowledge about high-level programming, therefore they felt confused to work with simpler programming and thus they took more time to reach the goal.

In the nano challenge 4, groups 1 and 2 had more difficulty to develop the avoid obstacles task, because this challenge was the most complex, being necessary to spend more time to reach a good and reliable solution. However, groups 3 and 4 were faster, this happened because they already knew what adjustments were needed. In general, all groups presented a good performance and managed to finish the nano challenges.

Groups	Group 1	Group 2	Group3	Group 4
Time nano challenge 1	35 min	25 min	52 min	40 min
Grade	6	8	2	4
Time nano challenge 2	20 min	8 min	13 min	28 min
Grade	8	10	7	7
Time nano challenge 3	24 min	38 min	19 min	47 min
Grade	10	10	9	5
Time nano challenge 4	50 min	56 min	28 min	26 min
Grade	8	8	8	8
Final grade	8	9	6.5	6

Table 5.3: Groups performance table [21].

Chapter 6

Conclusions and Future Works

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 as critical thinking, problem solving techniques, work distribution, etc. In may case this is achieved through STEM/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 initiatives as the Summer Camp and the pilot exchange described through the chapter 4. These kind of approaches 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 two experiments accomplished in this work, it was possible to obtain several conclusions: 1) Students are easily engaged with technology and programming, being the themes robotics related very appealing to them; 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, because the challenge based learning approach inserts the students into the challenge theme, making them research about the topics approached; 4) It is not necessary a deep knowledge on programming or robotics to complete Nano-Challenges using the mBot and the mBlock

5; 5) Students perception about STEAM improves after the experiments.

Taking this into account, it is clear that Challenge Based Learning approaches work 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.

6.1 Future Works

This work explores the potential of the mBot robot and its mBlock 5 IDE an educational tool, applied during the RoboSTEAM project in two different programs with challenge based learning approach. There is a few considerations to do about the mBot as well as the mBlock 5 to relate as future works.

The first point to discuss about it is the importance of the mBlock 5 IDE, this is a powerful tool that it is supported by several devices, from smartphones to personal computers, this software can be implemented in the early stages of K-12 education, allowing the students to create their own histories and games just using the standards sprites of the program, may using Scratch language for beginners or Python language for those more interested in coding. Its all in order to improve the critical and computational thinking of the students, being also a great education tool to start teaching programming microcontrollers.

Another aspect to highlight is about the hardware of mBot it is too simple, its impose limits in the number of activities that could be used for, a instance for this affirmation it is the adaptation realized in the 3.3 and the mBot could have coupled an accelerometer and a 3-axis gyroscope sensors to enable the possibility of the robot could measure its speed, distance and directions. With these sensors the robot can be used in physics subject to teach for example kinetics, and using the method as in the subsection 3.3.1.

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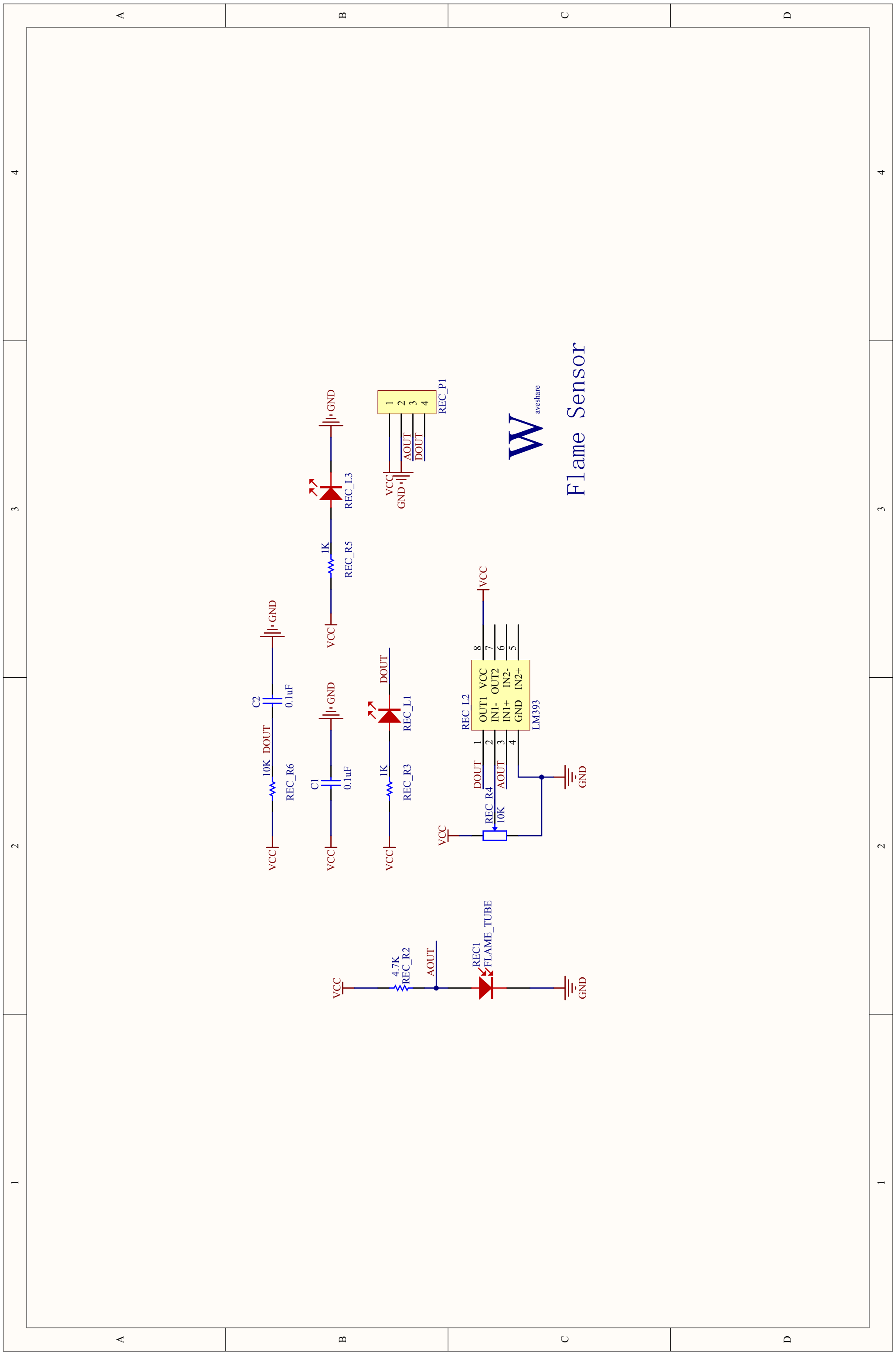
Appendix A

Schematics


Flame Sensor
aveshare
REC_P1
VCC
GND
AOUT
DOUT
REC_L3
REC_R5
1K
C2
0.1uF
REC_R6
10K
C1
REC_L1
REC_R3
REC_L2
OUT1
IN1-
IN1+
VCC
OUT2
IN2-
IN2+
LM393
REC_R4
REC1
FLAME_TUBE
4.7K
REC_R2

A2

Flame Sensor User Manual

1. Features

Voltage comparator chip	LM393 (wide voltage range)
Detection wavelength	760nm-1100nm
Operating voltage	3.3V-5.3V
Detection angle	0 degree-60 degree
Operating temp.	-25℃-85℃
Dimensions	29.2mm*11.2mm
Fixing hole size	2.0mm

2. Applications

This module can be applied to fire detection system, fire-fighting robot, fire alarm system, etc.

3. Interfaces

Pin No.	Symbol	Descriptions
1	DOUT	Digital output
2	AOUT	Analog output
3	GND	Power ground
4	VCC	Positive power supply (3.3V-5.3V)

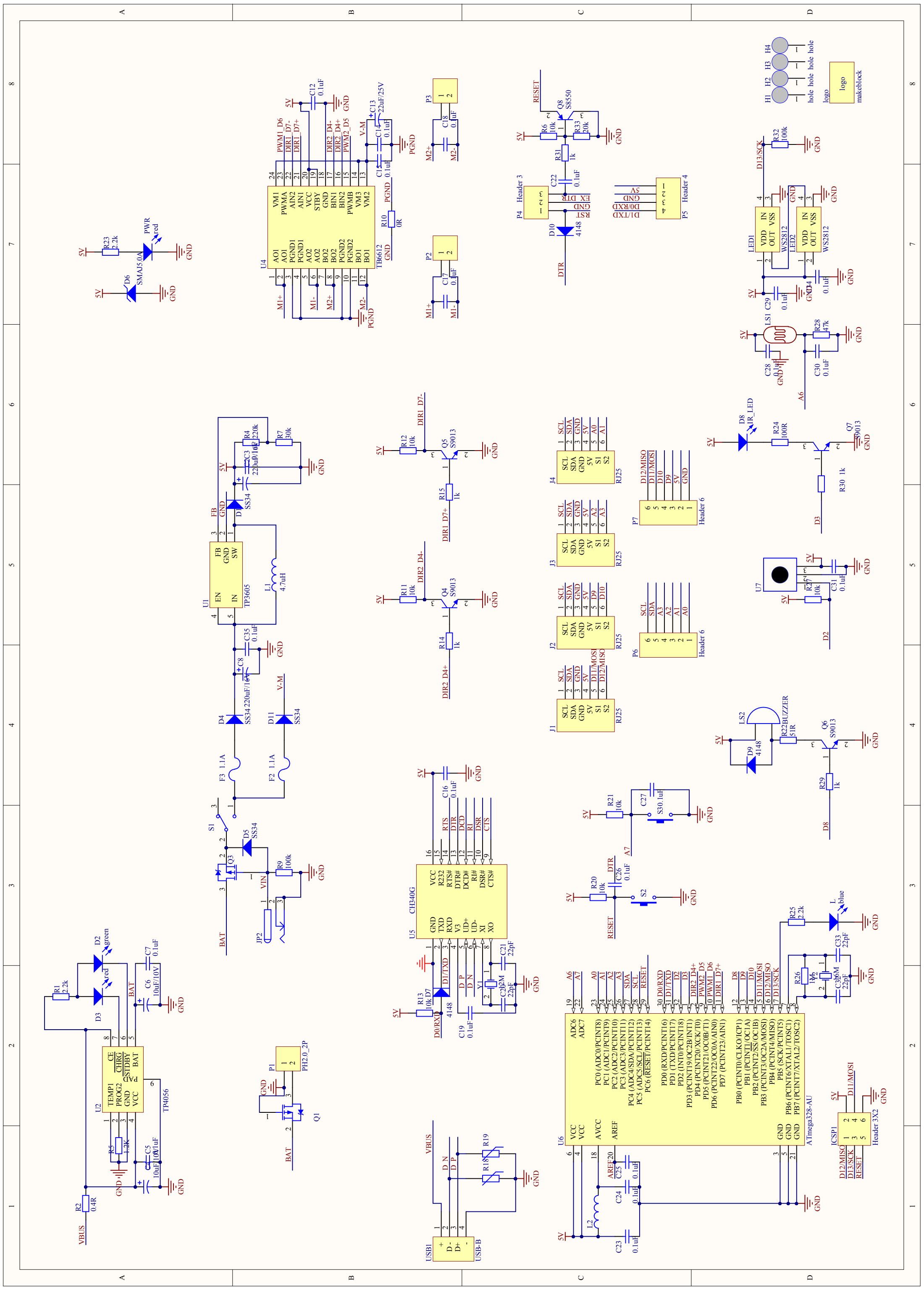
4. How to use

We will illustrate the usage of the module with an example of fire detection by connecting a development board.

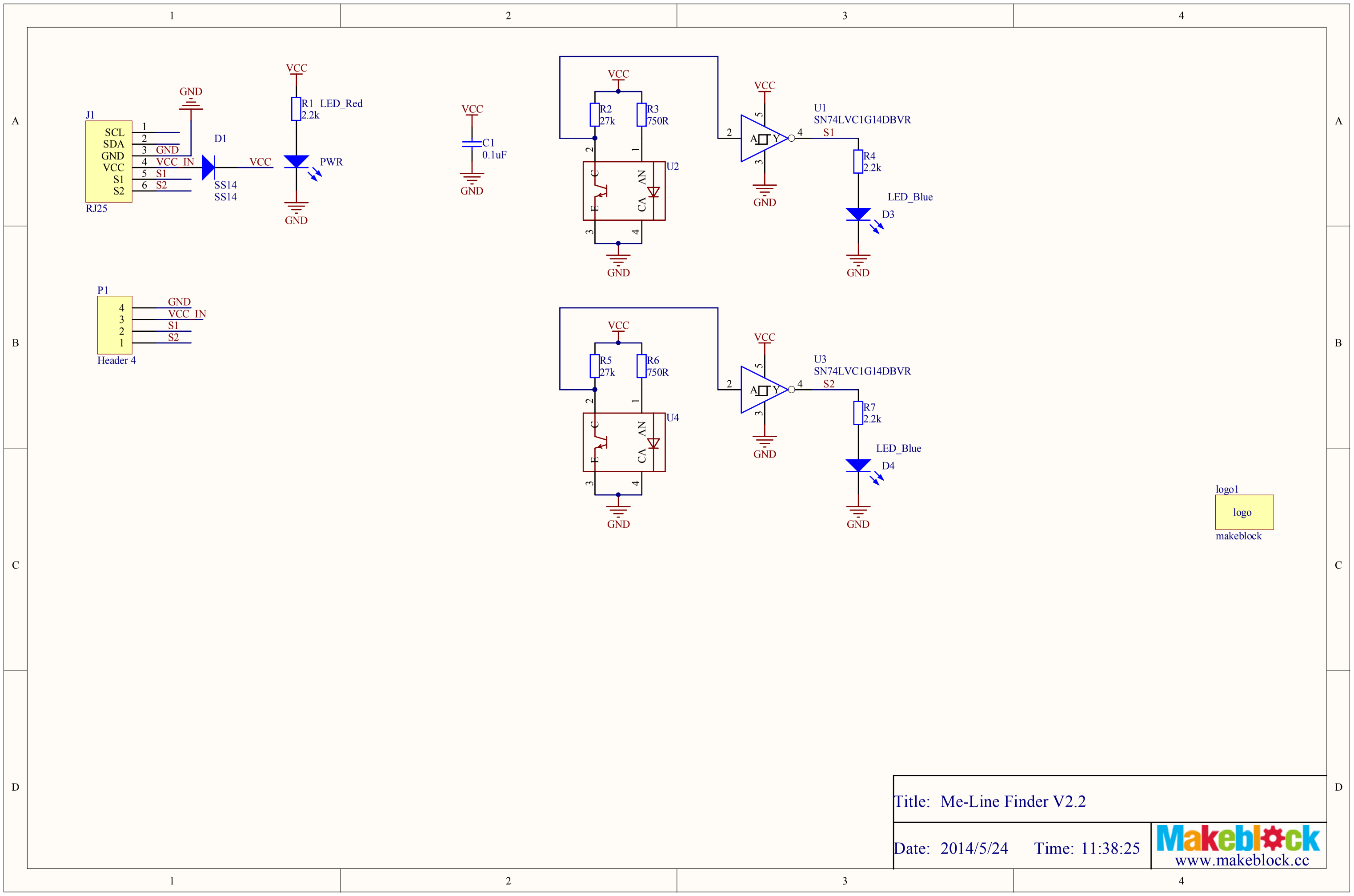
① Download the relative codes to the development board.

② Connect the development board to a PC via a serial wire and the module to the development board. Then, power up the development board and start the serial debugging software.
Here is the configuration of the connection between the module and the development board.

Port	STM32 MUC pin
DOUT	GPIOA.4
AOUT	GPIOA.6
GND	GND
VCC	3.3V

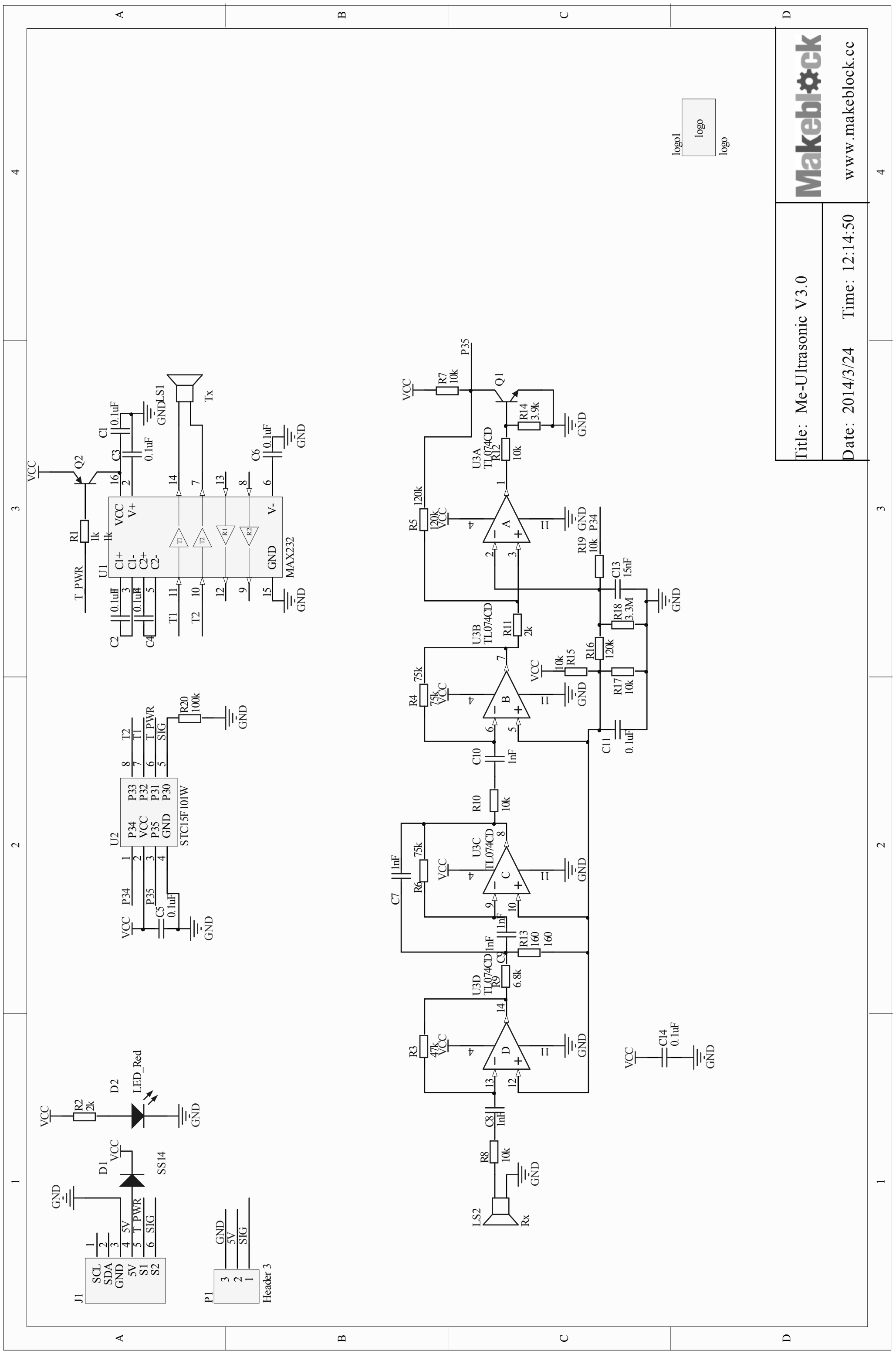

ATmega328-AU
CH340G
TB6612
TP4056
TP3605
WS2812
Header 6
makeblock

A4



J1
SCL
SDA
GND
VCC
S1
S2
RJ25
GND
VCC_IN
S1
S2
D1
SS14
SS14
VCC
R1 LED_Red
2.2k
PWR
GND
C1
0.1uF
P1
Header 4
R2
27k
R3
750R
U2
R5
27k
R6
750R
U4
U1
SN74LVC1G14DBVR
U3
SN74LVC1G14DBVR
R4
2.2k
R7
2.2k
LED_Blue
D3
D4
logo1
logo
makeblock
Title: Me-Line Finder V2.2
Date: 2014/5/24 Time: 11:38:25
www.makeblock.cc

A5


Title: Me-Ultrasonic V3.0
Date: 2014/3/24
Time: 12:14:50
Makeblock
www.makeblock.cc

Appendix B

Codes

```
// lowest and highest sensor readings:
const int sensorMin = 0;     // sensor minimum
const int sensorMax = 1024;  // sensor maximum

void setup() {
  // initialize serial communication @ 9600 baud:
  Serial.begin(9600);
}
void loop() {
  // read the sensor on analog A0:
  int sensorReading = analogRead(A0);
  // map the sensor range (four options):
  // ex: 'long int map(long int, long int, long int, long int, long int)'
  int range = map(sensorReading, sensorMin, sensorMax, 0, 3);

  // range value:
  switch (range) {
  case 0:    // A fire closer than 1.5 feet away.
    Serial.println("** Close Fire **");
    break;
  case 1:    // A fire between 1-3 feet away.
    Serial.println("** Distant Fire **");
```

```
      break;
    case 2:     // No fire detected.
      Serial.println("No Fire");
      break;
  }
  delay(1);  // delay between reads
}
```

Listing B.1: Arduino Flame Sensor Example.