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Robotics and Entrepreneurship for a Better Society. Opening Doors to Mobility

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Abstract. This article reports the development of an educational robotics project at the Basic School (2nd and 3rd cycles) André Soares in Braga, with students from 6th grade, integrated in an international cooperative partnership for innovation and good practices of the European Erasmus+ programme.

This project was initially designed to address the need to share innovative teaching practices through the development of new methodologies and multidisciplinary approach in teaching-learning processes in the 2nd and 3rd cycles of basic education combined with the stimulation of entrepreneurial skills and co-creation of knowledge. From the beginning, the project had the collaboration and support of the Hands-on Science Network Association, having given rise to the submission of an application to the 13th edition of the contest "Projeto Ciência na Escola" of the Ilídio Pinho Foundation on the topic "Science and Technology at the service of a better world". This application has been selected for the 2nd phase of the competition and obtained financial support for the development of activities which gave an added dimension to the project, attracting and further motivating students for learning science and the choice of technology areas.

Students were challenged to identify a situation/problem and find a possible solution/answer in the context of educational robotics. Thus, there was the study of the LEGO MINDSTORMS NXT programming environment for programming routines or scripts and simultaneously the work methodology hands-on was implemented using participative methodological approaches, enhancing the development of key skills and entrepreneur spirit. At first, students' creativity was stimulated through the ideas generation process called SCAMPER, channelling it to solve situations/problem where the students' task was to unlock a situation and optimize it. From a simple stick and a simulation of a path for blind people, ideas were collected to innovate this object, in order to promote a more efficient and fairer mobility. With the collection/gathering of ideas/suggestions, a guiding principle for our project was developed giving an intended metacognitive knowledge. Starting with the acquisition of this knowledge, students focus on building and programming robots LEGO MINDSTORMS NXT, developing the prototype of a smart and innovative cane for the blind people. This is an interactive process that combines the concrete and the abstract in solving a problem involving steps such as: design, implementation, construction, automation and control mechanism. In all of these steps the construction of knowledge took place, arising from different scientific fields (science, mathematics, physics, technology), as well as the acquisition of transversal skills.

The work focused mainly on the dynamics of the process rather than the products or results. Many citizenship skills were developed when creating a tool to minimize the difficulties and obstacles faced by blind people, enabling the improvement of their quality of life. It was observed, from certain experimental activities, that one can transfer new skills and knowledge acquired at school to everyday life.

Keywords. Citizenship, creativity, entrepreneurship, educational robotics, hands-on, programming robots, SCAMPER, smart walking stick.

1. Introduction

The development of this project represents, for the authors, an excellent way of application of an exploring and investigative metacognitive approach of science, Inquiry Based Science Education (IBSE). They believe this approach gives students a metacognitive understanding of procedures leading to discussion, communication and argumentation among peers. The creation of ideas and solid cognitive structures gives to this project a way of linking science to society. The methodology used allows the use of the experimental method to

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evaluate the validity of the ideas and test them, allowing the best choice of ideas and answers that may arise.

The culture of entrepreneurship in the classroom emerges as a differentiated learning, whose final proposal is to strengthen the student's personality and the development of initiative and innovative skills, creation, planning and integration in the real world of work. The stimulation of entrepreneurship skills and the use of knowledge is a process mediated by the teacher's intentional action which promotes a stimulation atmosphere of the thinking and creativity, based on principles of mutual respect, freedom of communication and expression of affection. As stated by Sá et al (2004) [1], through entrepreneurship, confidence is stimulated by the need for finding solutions to the challenge presented by this competition.

School has a role of promoter in the development of creative and decision-making skills as these are key aspects for scientific innovation which is fundamental for the labour market and to society.

The learning trigger has its start in the formulation of questions about the presented challenge, making the world better and fairer, using a programming language and a robotics kit, debating and using science teaching in an experimental, reflective and deductive approach and thereby building knowledge, connected to entrepreneurship.

School plays an essential role in stimulating entrepreneurial skills, rooted in scientific knowledge consolidating the professional and personal development, future for a successful society and interested in others. Probably the project-based learning has its origins in John Dewey (1916) and Kilpatrick's ideas (1918, 1921) who defended the preparation of students for their active participation in real life and in an environment with meaning and purpose. According to Knoll (1997) [2], the project is considered a method by which students can: i) develop independence and responsibility and ii) practice social and democratic forms of behaviour. It is based on active learning where students learn to connect theory to practice and whose theory should provide examples of key aspects of professional goals [3]. Learning methodologies are strategically focused on student's involvement in carrying out activities and think about these activities, involving them in their own learning. This involvement in the project allows them to develop new skills as teamwork, critical thinking, creativity, problem solving ability, communication and project management skills [3].

2. Characterization of the award contest Science in School Project - by Ilídio Pinho Foundation

The contest "Projeto Ciência na Escola" is promoted by Ilídio Pinho Foundation jointly with the Ministry of Education and Science and the Ministry of Economy of Portugal. It established an annual award which aims to motivate all students, from Preschool Education, 1st, 2nd and 3rd cycles of Basic Education till Secondary Education. Using different ways of educating and training, to learn science and choose technological study areas, it is intended to stimulate students' interest in science, by supporting innovative projects.

The project must have an eminently practical and multidisciplinary feature, mobilizing the various curriculum areas for its development, and engage students in experiences and group work, enabling them to recognize the importance of knowledge and the scientific method and entrepreneurship skills.

The 2015/16 edition, on the contest topic "Science and technology at the service of a better world", seeks to promote the potential of science and technology as a response opportunity to the challenges and main problems of today's world, with a view to creating a better world for all. The award is made up of five levels, organized as follows:

- 1st: consisting of projects involving pre-school education children
- 2nd: consisting of projects involving students of the 1st cycle of basic education;
- 3rd: consisting of projects involving students of the 2nd cycle of basic education;
- 4th: consisting of projects involving students of the 3rd cycle of basic education;
- 5th: consisting of projects involving high school students.

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The contest is developed in two phases:

1) Ideas Competition, ideas are proposed to be supported by the foundation.
2) Development Phase, after being chosen in phase one we proceed to product development.

After phase two the 100 best projects are selected and invited to make a public presentation in the national display. In this exhibition the most relevant projects will be chosen.

The evaluation of applications has the following criteria:

i. Innovation and creativity (originality of the idea; differentiating elements to the market, enhancing competitiveness);
ii. Planning and organization (processes / procedures and products);
iii. Pedagogical relevance (opportunity to centralize the element - learning and multidisciplinary approach, involving different areas of the curriculum);
iv. Potential of social impact and institutional partnerships (forecast the consequences of project implementation, the expected effects over the target audience);
v. Viability (achieving potential/value of the idea).

The project presented in the competition is worth 70% according to the above criteria and in the national exhibition, while the public presentation is worth 30% of the final project evaluation.

After a first approach to the project and its ideas, students were challenged to discuss and present motivating ideas for the development of an object based on robotics and experimental sciences, and at the same time follow the accuracy of a structured project and respect an established schedule. At the stage of collecting ideas, inspiration material was provided for students and the meaning of entrepreneurship was discussed.

Sessions were given to make students aware of the practice of entrepreneurship and motivate them to promote entrepreneurial practices and build up entrepreneurial activity ideas to make a positive difference in their lives and stimulate thought and understanding processes. This reflective process proved to be important so that students could understand the applicability of ideas and respect the rules.

3. Characterization of the idea

It was decided to proceed with a class project in which students created a valid idea for a business and assumed the role of entrepreneurs. Thus, several steps for this application were defined:

i. Create an idea in which science and technology were at the service of a better world
ii. Develop the product and the necessary scientific expertise to support it;
iii. Define a strategy and a timetable for its development;
iv. Divide roles and responsibilities;
v. Perform different initiatives and testing to build the product;
vi. Disseminate the project to the community;
vii. Promote the product to market;
viii. Prepare an exhibition about entrepreneurship.

A project based on entrepreneurship education is a fundamental type of project for the 21st century youth. According to Pereira, Miguel; Ferreira, José; Figueiredo Oliveira (2007) at school you can learn and practice skills and attitudes that promote a positive relationship with risk, learn to plan and calculate opportunities and identify threats, develop the ability to take the lead and innovate with responsibility and rationality [4, p. 5]. This project seeks to inculcate in students some of the key skills of entrepreneurship and science; built on the interests and availability of teachers and the nature of each context. Its development was integrated in the school subject “Oferta Complementar“ in a period of 45 minutes per week, with a 6th grade class (6º I) from the Basic School 2nd and 3rd cycles André Soares. There were also moments outside the school context, through the creation and promotion of meetings between teachers and parents.

It was decided to integrate this initiative into an international cooperative partnership for innovation and good practices of the Erasmus + program. The "Opening Doors to Europe" project, aims to open doors between schools and enterprises and put students in touch with

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the working world so they become aware of the skills needed to access the labour market. It assumes the main role in promoting in schools different ways to prepare students for the needs of employers, at a national and international level, highlighting the similarities and differences between the European employers.

This partnership aim is to open communication channels among young people, the education system and entrepreneurship. Students have the opportunity to cooperate and collaborate not only with their school mates but also with students from different countries in Europe. It will also be an opportunity to disseminate all the work in an entrepreneurship exhibition to be held from 6th to 11th March 2017.

Initially it was necessary to create an idea in which science and technology would be at the service of a better world and to achieve this goal the potential of robotics to improve society was discussed. At the very beginning the mobility problems of blind people in our city emerged. After an initial contact with the sensors of Mindstrom Lego kit provided by the Hands-on Science Network, they quickly suggested the creation of a smart stick with the help of these sensors. The first notes were taken and then the first programming approach for the use of the sensors appeared to help solving the problems pointed out by the students. The educational potential of this tool in the teaching / learning process was clear, linking different fields of knowledge, with emphasis on Mathematics, Physical and Natural Sciences and Technological Education.

The result was a very motivating learning process for students and teachers, with an undeniable enthusiasm of all in this phase of the project, as they were able to create, test, make mistakes and learn actively and consistently with the hands-on approach and all the IBSE cognitive processes. At this stage students have acquired self-confidence, which led to an effective and responsible group work.

4. Project implementation

After exploring the computer programming language and its sensors, collaborative work was carried out with school mates, supported by teachers. The process of generating ideas begins. Generating ideas is one of the most important stages of the process, since it is the starting point to make any project successful.

4.1. Generating ideas

It has been established to recreate the walking stick with SCAMPER methodology, developed by Bob Eberlee [5], whose name comes from the acronym created by the initials of the seven steps that make up this technique: Replace, Combine, Adapt, Modify, Find other uses, Delete and Revert. These steps work as possible generic solutions leading to think about specific solutions. This is a very effective method when we need to improve or create new objects, systems or processes based on something already existing. Its application aims to stimulate creative thinking in a targeted way, by exploring different ways to reinvent and solve a problem. The technique also uses a set of questions directed to a problem in order to generate new ideas that normally would not occur, making it possible to guide and organize the discussion of a group and achieve a more productive outcome.

Figure 1. Students explore different possibilities

4.2. Debate and reflection

Questions were put to stimulate reflection and solve this specific problem of mobility. It was possible to explore different possibilities and alternatives with the answers given and the moments of debate that followed it. Students felt the world differently and concluded that the human being not only see with their eyes, but also with all their senses. The debate ended in a set of valuable information source for all participants. The exchange of points of view was a way to encourage new ideas, launching

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new paths and challenges, urging the progression and bringing them closer to solutions (Figure1).

4.3. Testing

The development phase of the project went through a test of "Orientation and Mobility" for the blind people carried out by students, by walking through a path to assess the physical barriers. After the accessibility diagnosis, a further study of the sensors and possible materials to be used in the development of the prototype was initiated (Figure 2).

Figure 2. Test of "Orientation and Mobility"

This step was extremely important because it gave a more concrete knowledge on this issue, allowing the idealization of a possible and feasible product. The learning by doing means that the student is the main actor of his own apprenticeship, and to do so he has to adopt a research methodology around his own process of learning / teaching (Pereira et al., 2007) [4, p. 16].

4.4. Sketches

Sketches of what students think the walking stick can be appeared as a result of this experience. Through the ideas and features existing in the drawings we can clearly see a world vision closely connected to the Internet. The scanning of this concept quickly set off (Figure 3).

The Internet of Things (IoT) is a technological revolution that connects electronic objects of our daily lives, such as electrical appliances, means of transport and, in this case, the walking stick, to the Internet and interacts with the surroundings. With the active work methodologies that have been applied, students actively participate in the construction of their own knowledge. Young people have to face new situations to prepare themselves to be useful in our society. We must put them in front of challenges and let them find the answers and build solutions. This process promotes learning by trial and error and self-correction. Mistakes serve as source for new experiences that, by this means, reinforce learning.

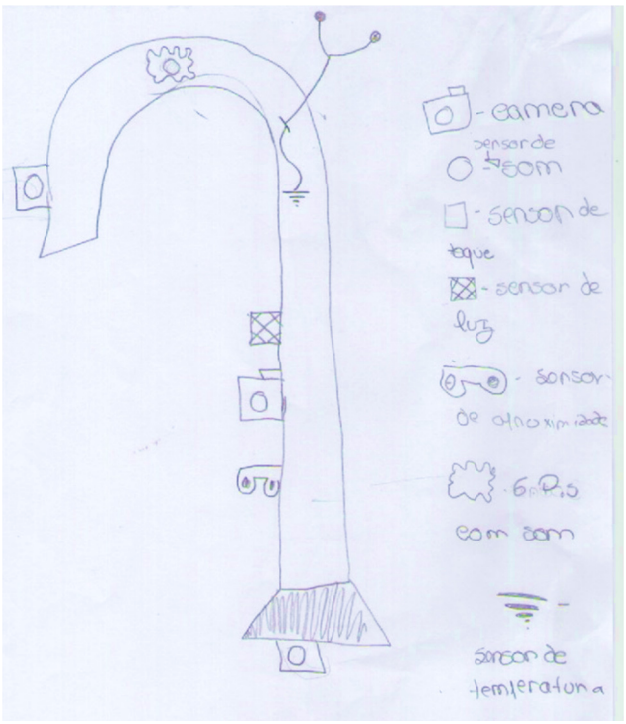

Figure 3. Sketches of the walking stick

5. Communication

The communication process and the dissemination of results, findings and steps is a key aspect for the project's success. The verbalization and discussion of ideas is a tool that enhances the building and sharing of knowledge.

During the process, a group of four students and a school teacher from “Sydvestjyllands Efterskole” school, in Denmark, visited our school to be acquainted with all the work developed based on robot programming. This meeting has reinforced the importance of a clear and accurate communication of the different stages of the project. When facing this situation, students felt the need of a more formal and efficient language to convey the scientific knowledge acquired. The challenge

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was difficult, since all the dialogue was in English (Figure 4).

Figure 4. Students and a school teacher from "Sydvestjyllands Efterskole" school

Most of the obstacles were overcome and the whole experience was a time of learning and fundamental progress. On the one hand, they realized that sending a message in an efficient and accurate way is very important, especially if we are being observed by people from outside of the school community. On the other hand, this was a unique opportunity to communicate in English and be aware of its usefulness in a real communication context.

Students will have the opportunity to speak foreign languages again, mainly English, during the presentation of this project in an exhibition about entrepreneurship, which will take place in 2017, in Portugal, within the European Erasmus + partners' mobility.

6. The development of the robotic walking stick creation

The implementation of the plan is the time when the class group interacts effectively with the environment, in order to change it, adding value to a fairer society project. Quoting Pereira, Miguel; Ferreira, José; Figueiredo Oliveira (2007) [4, p.49] this is the most motivating activity for students, but also the most demanding, since they will confront all their energy and desires with a complex reality and will learn to cross these two worlds; theirs and the others. It is an extraordinary opportunity to learn and practice their skills productively.

Finally the first version of the smart walking stick is created which seeks to provide society with an affordable prototype, easy to use, and functional model that helps the mobility of the visually impaired. The prototype recognizes the environment and points out possible obstacles and threats to mobility (Figure 5).

Figure 5. First version of smart walking stick

The smart walking stick, for the blind people, helps the user to detect objects, people, and stairs or holes. This stick is composed by a NXT Smart Brick module, which processes all the students' program code. It has a RCX processing block (Robotic Commander Explorer), based on an ARM7 microprocessor. The new RCX processing block is compatible with Bluetooth communication and It has a 32-bit ARM7 microprocessor with 256 KB of memory; USB 2.0 port; 4 RJ12 input; 3 RJ12 output; 1 LCD monitor; 1 speaker and a rechargeable 9V battery (or six 1V5 AAA batteries). This device also has a bag to make it easier to transport.

Two ultrasound sensors are at the bottom of the stick to make the path scanning. They are connected to the smart brick module by RJ12 cables which pass through a PVC tube. These sensors are designed to "see" their surroundings, sending RF signals and waiting for its feedback in order to process the data. The best signal reception is detected when the object is in front of the sensor and it also measures the distance. However it loses efficiency when the object is in a side perimeter. This is why the stick needs to be handled in a pendulum like movement. The sensorial communication is carried out by the servomotor and reinforced by the emission of a sound warning that there is no longer any obstacle set in the program code. This is programmed in a Visual Basic language, based on blocks. This way, students can easily build

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and test all decision and repetition structure blocks. The NXT Smart Brick module controls the servomotor by the RJ12 outputs. This communication is established when the system detects any object on its way. When the servomotor is operated it creates a counter-clockwise rotation that is felt in the user's hand (Figure 6).

Figure 6. The smart walking stick

These cables are connected to the ports numbered from 1 to 4 of the smart brick. Ports A, B or C there is another RJ12 cable connected to the servo motor responsible for communicating with the user.

This prototype can be a starting point for future and more advanced prototypes for blind people, who can benefit from an easy-to-use walking stick that interacts with the environment. One of the biggest potentialities of this smart stick is the ability to communicate via wireless with the environment, such as traffic lights, shop windows, signs, GPS, etc. and become part of the list of Internet of Things' objects. Students have referred several times that the intelligence of each object could increase the power of the network to return the processed information to different parts of the city, making it an object that interacts with other city objects (Internet of Things).

7. Evaluation

The project evaluation is made on the basis of targets and dates that the group/ class proposes as well as, in case of changes, through the corrective actions undertaken throughout the project development. The evaluation and validation of the idea is based on external organizations that interact with the project.

This project was worthy of a financial support for the implementation of the first phase and was selected for the 13th edition contest "Science in School Project", promoted by Ilídio Pinho´s Foundation, entitled Science and Technology at the service of a better world.

The project is among the eight best projects of the 3rd level, selected to attend the national exhibition, chosen by: i) A representative of Ilídio Pinho's Foundation; ii) A representative of the General Supervision for Schools (DGEstE); iii) A representative of the General Direction of Education (DGE); iii) A representative of the Ministry of Economy; iiii) A scientific expert invited by Ilídio Pinho´s Foundation; iv) A representative of each of the Regional Education Boards of the Autonomous Regions; v) A representative of the National Confederation of Parents' Associations (CONFAP). This selection provides an external evaluation of our working group and the validation of the quality of work done by students.

As a result of the international cooperation partnership for innovation and good practices of the European Erasmus + program, the final product will be presented to a group of foreign students and teachers in March 2017, inserted in an innovative exhibition of products, during an entrepreneurship contest called "IDEAS", as agreed with the "Opening Doors to Europe" project team.

8. Project result

The strategic planning for the development of cultural, social and educational changes involved in the free and unconstrained environment by rigid educational programs and contents make these initiatives a single and promoting tool of autonomy.

The encouragement of collective creativity, widely promoted by international, national and local initiatives, for instance the "Science in School" prize – of Ilídio Pinho's Foundation and Erasmus + program, is an opportunity for teachers to choose for the implementation of activities focused on the reflective teaching of

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science and its applicability to a more entrepreneurial society.

In this project the entrepreneur or entrepreneurial spirit has been introduced in order to be combined with what is learned at school. As a result, the class faced the need to manage, budget and present the project in an official and formal way towards the scrutiny of the school community and other actors in the world of entrepreneurship.

In the EU2020 Strategy document it is said that “the emphasis should be placed on priority areas such as (...) conditions for R&D, innovation and entrepreneurship, including social innovation". It also adds that to create value by basing growth on knowledge one should "integrate creativity, innovation and entrepreneurship concerns from basic school" [6; p. 5].

Entrepreneurship involves a new way to look around us, to deal with problems and needs and take advantage of the changes and opportunities. Since this is a dynamic process, students have assumed this role by planning actions, putting into practice strategies, proposing solutions and overcoming some of the obstacles in a true teamwork environment. The awareness of the cost of labour is a significant impact on the viability of it, promoting a reflection on the business part, and another variable is added: the financial sustainability of what has been worked and developed (Figure 7).

According to Sá (2007) learning becomes a metacognitive experience when students are encouraged to develop a clear intentionality in their actions, becoming reflexive in planning activities and in its implementation and evaluation [1]. And Piaget (1972) states that children develop their way of thinking based on their interaction with the world around them. Consequently, the effect of hands-on during the process brings added value to the discussed concepts, as well as a clear representation thereof [7].

This teaching experience had a significant training benefit to the understanding of science and programming from the experimentation, design and internalization of all processes. The self-reflexive character was challenging and promoted the critical and reflexive skills, providing the means for a mobilizing and facilitator thought of the dynamics of construction of their own knowledge. It is clearly an entry into an important cognitive phase for the group/ class. There is a degree of self-esteem that allows the group to start developing assumptions and seek to support them.

Figure 7. Students programing

The involvement of different areas allowed the development of educational, communication and technological skills proving to be an advantage for the creation of new knowledge and the promotion of more enduring skills. It was also possible to instil in our students an entrepreneurial culture, which certainly will prepare them to be active and socially integrated citizens.

9. Conclusions

We conclude that, in the initial phase of construction of knowledge, autonomy and the use of language as a metacognitive tool has been predominant for the project discussion, organization, planning and correction. Another important aspect is that one can tell when a student starts a formative learning process through observation, even if it is initially inaccurate. Papert (1980) supports the idea that human beings learn in a more sustainable way when involved in the planning and construction of objects or artefacts they considered significant, sharing them with the surrounding community [8].The external construction process of the object is followed by inner knowledge development that gives a level of metacognitive learning to this experience. There is a degree of self-esteem that allows them to start developing

assumptions and seek to support them with valid arguments, exemplifications and verbalizations. It is through the questioning process that students have the possibility to check and test what really learned and validate what they accomplished.

They just did not result in concrete products due to technical limitations of the hardware. Through "hands-on" approach, combined with entrepreneurship education, it is possible to develop in students different technical and soft skills. Some students' ideas were unique and with potential, but they did not give rise to concrete products due to technical limitation of the hardware. The use of programming at school is an educational tool with great potential that stimulates collaborative work, as well as an excellent vehicle to develop project's work methodology. It is considered that to be an added value if these students have the opportunity to keep exploring these pedagogical approaches. The school has to evolve and to experience educational strategies for entrepreneurship, in order to interact with the real world. This project tries to explore the current challenges, although at a reduced scale and at an experimental level. The project here described is a contribution to show the importance of developing entrepreneurship skills, and demonstrates the need for their integration in our educational system. This is a way it brings our young people´s learning closer to what is expected in the real labour market.

On the other hand, it promotes the formation of responsible young people able to have an active and critical role on their own future, with civic and interventional awareness and a key role in building a fairer society for all.

It is with an entrepreneurial Europe that school must proceed, without concealing responsibilities in this process, and also without wasting what all have to give for the construction of an entrepreneur country and a Europe able to recognize these skills.

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