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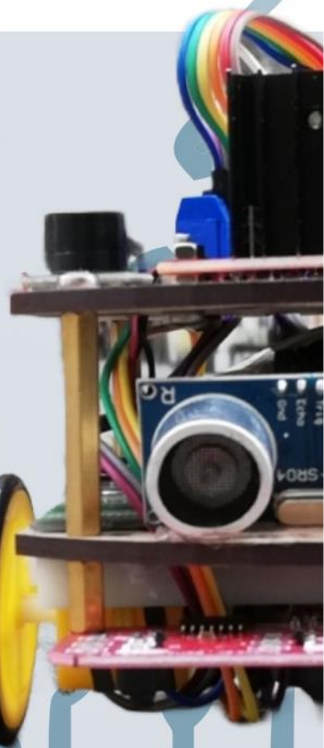

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Using educational robotics as a springboard to developing young children's computational thinking

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Introduction

In recent years, efforts have been made to introduce computational thinking into educational practice and curricula in several countries around the world (Bocconi et al., 2016). Computational thinking is a term used in education to refer to the cognitive processes underlying the application of computer science concepts and problem-solving strategies. Educational robotics has been used to introduce computational thinking to young children. As tangible artefacts, robots have been proposed as developmentally appropriate for early youth, promoting engagement and allowing young students to represent abstract ideas in concrete settings.

Educational robotics is a great way to promote active learning. Students can work on projects using or building robots or even other technological devices, allowing them the opportunity to be the creators and producers of their knowledge (Brennan & Resnick, 2012; Wing, 2008). In addition, active methodologies, can make learning attractive and fun for students.

One of the main advantages of using educational robotics for computational thinking is that it allows children to simultaneously develop essential skills for the 21st century, such as problem-solving, collaborative work, creativity and critical thinking. In addition, educational robotics can also contribute to training more vital and conscious citizens, as it teaches students the importance of social and environmental responsibility. With technological advances increasingly present in everyone's daily life, the challenges posed by human beings also occur at an accelerated pace. They can even be instantly affirmed, requiring a critical awareness of your role.

The exponential advance in the use of technology in education, mainly linked with robots or programming, has led to changes in pedagogical practices, curricular organization and the development and creation of teaching materials. In Primary Education schools, educational robotics has been integrated into curricula as an interdisciplinary activity or even being part of it, and some teacher training courses already incorporate it as part of them, Coelho *et al.* (2016).

Curiosity and the taste for technology have dramatically influenced educators to mobilize in the performance of activities involving educational robotics, integrating concepts of engineering, science, and technology, emphasizing the relationships between knowledge and the possibilities of students to produce interdisciplinary knowledge. Thus, tasks such as performing the design of robots, building them, programming them, and perfecting them appear as creative and motivating learning activities, which favour students' cognitive processes, Bers (2010).

Robots are mechanical devices, which perform tasks automatically, through direct human supervision or through a predefined program, following a set of rules and standards through artificial intelligence.

Educational Robotics

In recent years, educational robotics has arisen as one of the emerging educational tools with significant potential. Its introduction into classroom practices is adequate, particularly in learning based on the resolution of concrete problems, "whose challenges created promote reasoning and critical thinking in an active way, also raising the levels of interest and enthusiasm of students by sometimes complex subjects", Coelho *et al.* (2016).

Planning practical tasks using robots can help students establish relationships and experience the concepts learned during the classes of mathematics, science or other areas of knowledge in various contexts and to face them from different perspectives, enabling the development of their ability.

In educational robotics environments, students develop an abstraction capacity by having to plan their goals to dye and design the programs thinking as if they were the robot itself. By projecting itself into the robot in the way it learns and judges, the child feels about thought (metacognition). The programming process is carried out based on a symbolic and visual language, which the student will have to be able to map in the physical behaviour of the robot. This implies the ability to predict the robot's behaviour from the abstract symbols included in the programming, D`Abreu *et al.* (2012).

During learning with robots, students recognize the importance of reflecting on the decisions made, learning from mistakes, and thus trying to avoid repeating them. In this process of reflection, students will commit themselves to their correction as they strive to understand the origin of a particular error and understand the difficulties in which they are to be resolving it. Using a moving robot is a valid enough reason for students to engage in greater exploration and understanding of what they must learn to solve a particular problem, Monteiro *et al.* (2019).

The experiences with the students demonstrated that the work of peers or groups allowed moments of communication, both of reasoning, mathematical ideas, and scientific concepts, orally and in writing, of self-confidence, creativity, work routines and persistence. In all the students involved, there were moments of sharing and agreement of information that contributed to effective programming and coexisted with an apparent attempt to combine the orders to be placed in the programming for the robot to perform the routes correctly, Bers (2010).

In the groups of students, it was possible to verify that they did not only seek specific answers but sought to understand the problems with which they were confronted. In this sense, the whole process of the students, that is, all the attempts they made, was intended to establish an understanding because, as already mentioned, the fact that, at the beginning of each problematic situation, they did not know or did not understand which programming is correct, this was not a reason why the programming could not be known and understood.

Educational robotics is a technological resource that can be used in education with a view to the development of projects that aim to gain learning about:

> robotics itself (computational thinking, programming, technology);
> a variety of knowledge and content (Mathematics, Science, Portuguese, Environmental Studies, Visual Arts, Music, among others)
> implementing the integration and interaction between these two presented categories.

concepts that involve the aspects of robotics themselves. In this context, students develop projects to learn how to program and build robots, working with basic programming concepts, technology and even artificial intelligence.

In the second category, robotics is used in developing projects highlighting the learning of diverse concepts related to Mathematics, Portuguese, Science, Visual Arts and Music.

Therefore, this use allows the creation of differentiated and diversified learning environments in which, through creating and programming robotic artefacts, students can learn concepts from other areas of knowledge.

The last category involves integrating the first 2, where the projects carried out encompasses both the learning of robotics concepts and issues directly related to specific areas or disciplinary content, Kafai *et al.* (2014).

Educational robotics, because it is a differentiated technological resource, being incorporated into the learning teaching process allows creating more motivating, more creative and scientific environments with the students involved.

Computational Thinking

As Wing (2017) says, computational thinking can be understood with the ability to formulate problems so that it allows the use of computers and other tools in their resolution; the ability to organize and analyse data logically; the ability to represent data through abstractions such as models and simulations; the ability to automate problem-solving solutions through sequential thinking; the ability to identify, analyse and implement possible and diverse solutions to achieve the most effective and efficient combination of spaces and resources and the ability to generalize and transfer the entire resolution process to a variety of problems.

Computational thinking can be worked on in various contexts, for example, in Science, Mathematics, Visual Arts and even Music (Wing (2008).

Based on the assumption that computational thinking should be integrated across curricula, we choose to develop integrated activities in the different areas of knowledge such as Mathematics, Portuguese, Study of the Environment and Arts. Therefore, we cared to provide the students with the opportunity to use spatial visualization and reasoning in the analysis of situations and problem-solving and to formulate arguments through observations, descriptions and representations of objects, configurations, and paths, Barr and Stephenson (2011).

Incorporating educational robotics into children's curricula in Primary School Education allows the development of numerous skills, including computational thinking, Barr and Stephenson, (2011).

The choice of tasks of position and location, counting, and creation of narratives adhere to the need for students to act, predict, see, and explain what goes on in the space they perceive, progressively developing the ability to reason based on mental representations. To this end, the resolution of problem situations as a facilitator of multiple potentialities was used when associated with other aspects of transversal capabilities, provides the use of different representations, and encourages communication; collaborative work; critical spirit; creativity; and fosters reasoning and the presentation of solutions, Pedro et al. (2017).

The problematic situations presented to the students comprised more than a way to reach the final solution and more than a correct answer, corresponding to open problems. It was intended that students use differentiated and diversified explorations to discover regularities and formulate conjectures, appealing to the development of reasoning, critical spirit, collaborative learning, creativity and the capacity for reflection.

With the creation of challenging and motivated activities, we want all students to be able to participate frequently in various experiences that allow them to: (i) develop habits of computational thinking; (ii) be encouraged to exploit, make attempts and err; (iii) to formulate predictions, to test them and to construct arguments about their validity and (iv) to question, discussing their reasoning and that of others, Brennan and Resnick (2012).

The students of Primary Education should explore the formulation hypotheses about mathematical relationships, investigate these hypotheses and elaborate mathematical arguments based on their experiences, Diago et al. (2018).

Reasoning directs us to calculate and use reason to judge, understand, examine, evaluate, justify and conclude, which leads to the fact that, in Mathematics, we do not reason only when we prove something. We also assert when presenting reasons that justify statements or positions.

The development of computational thinking is promoted by raising the explanation of ideas and processes, the justification of results and the formulation and testing of simple hypotheses by students, also stressing the importance of the experiences that are offered to students so that they can express themselves, develop ideas and clarify and organize their thoughts, without forgetting the moments of sharing that are challenged by the activities and challenges proposed, Sullivan and Bers (2017).

The introduction of robotics in teaching other areas of knowledge, such as Portuguese or Study of the Environment, allows the students to develop the ability to think about real daily problems and, in a collaborative way, working in pairs or groups, find the sums for these same problems thus developing their capabilities reflexives and critical spirits by discussing the solutions encountered with their peers or through error trial, Rodrigues and Felício (2019).

By confronting students with challenging tasks that stimulate their attention, commitment and involvement, we provide students with greater joy and enjoyment of learning and a more significant commitment to achieving the proposed challenges.

Methodology

During this school year, the AlfaROBOT Robotics Club (available at https://padlet.com/celestino_magalhaes/alfarobot-clube-de-rob-tica-alfa-5-0-fg0dqtajtkz2a44x) was created at Alfacoop School. This club develops interdisciplinarity, collaborative work, and the application of knowledge in new situations through the development of technical work and real-life experiments where students research and present solutions to the proposed challenges. The club's creation was intended to stimulate the students' interest and facilitate the development of competencies in current scientific and technological areas; also, to achieve some of the objectives of the School's Educational Project: i.e., to guarantee the continuous improvement of academic success; promote appropriate behaviour for the exercise of responsible citizenship; ensure the diversification of teaching models, methodologies and practices; provide curriculum coverage in the dimensions: scientific, humanistic, technical, technological, artistic and sports.

The proposed activities and challenges in the Club intend to involve students in carrying out small projects that allow them to understand the fundaments of programming, combined with electronics and robotics.

The main objectives of the Club are:

- To Foster interest in programming and robotics by articulating with different areas of knowledge, such as Portuguese, Mathematics, English, History, Environmental Studies, Science and Arts;
- To Encourage students to look for answers to different problems proposed through programming and robotics;
- To Foster a taste for technology and science.

To do this, we used kits composed of pre-built robots where students had to do their programming using the directional keys that the robots have. These kits include Sphero, KIBO and mBot robots. These are presented on the following pages:

The **Sphero** robot is a spherical, advanced robot that can be controlled using a smartphone or tablet. They can be used for a variety of purposes, including racing challenges, programming challenges, and even art projects.

Figure 1. Use of the Sphero robot to explore a student racing challenge (control of speed and orientation)

KIBO is composed of a kit developed by researchers at Tufts University to be used by children from 4 to 7 years. It is a set that allows students of this age group to program an autonomous robot. Programming does not require a computer since it is done by reading barcodes fixed in wood blocks, Bers (2010).

Figure 2. Use of KIBO robot in the exploration of orientation activities

mBot is an educative robot for beginners, which makes teaching and learning programming robots simple and fun. Building the robot from scratch only necessary a screwdriver and starting programming learning, and the proposal of mBot is block-based programming.

Figure 3. Use of the mBot robot in the exploration of programming and speed control activities

We use the Project-Based Learning methodology, which according to Krajcik and Blumenfeld (2006), allows the development of understanding as a continuous process that requires students to build and rebuild what they know from new experiences, ideas, knowledge, and previous experiences. In this method, the teachers and artefacts used do not reveal knowledge to students; instead, students actively build understanding as they explore the surrounding world, observe and interact with phenomena, absorb new ideas, make connections between new and old ideas, and discuss and interact with peers. In project-based learning, students actively build their knowledge by participating in real-world activities like those that experts perform to solve problems and develop artefacts.

Activities were created with programming, robotics, the creation of digital narratives, the creation of games, the use of mathematical simulations and even those that do not use technologies themselves since we can use various panels to explore this computational thinking with the help of robots in proposed activities and built for the exploration of panels.

These panels were built and produced by the students within the various areas of knowledge to explore their creativity and the motricity for developing the "soft skills" where they had the freedom to use their imagination and creativity.

In the exploration of panels with robots, scripts were created with various activities and challenges proposed to students to be performed and executed in groups or pairs in a collaborative way where students were able to debate and exchange opinions on how to solve the different problematic situations with which they stopped, how to explain and realize their thoughts in a way objective with the use of robots, explore their way of communicating and expressing, experimenting with solutions and stifling and verifying the results obtained and refining the solution if it did not work.

Goals

Some of the goals we had with our approach are:

Active learning: Robotics promotes active learning, as students are encouraged to test their solutions, which can increase their interest in education;

Development of technical skills: Robotics involves the assembly and programming of robots, which allows students to develop essential technical and logic skills;

Stimulation of creativity through problem-solving: Robotics requires students to think outside the box when solving complex problems; this can be a great way to develop creativity;

Self-confidence: Robotics can help students develop confidence in their abilities as they see their projects come true;

Collaboration: Robotics usually involves collaborative work, which allows students to learn to work together to achieve a common goal; its use can be an excellent opportunity to develop communication, sharing and collaboration skills;

Encourage inclusion: Robotics is an excellent way to include students with different skills and interests, i.e., students who have difficulty learning more traditionally can benefit from their learning process through robotics.

Results

The use of robotics in education can allow the development of technical and scientific skills and even creativity and problem-solving.

The use of educational robotics in a school context showed that students intervene more actively in the whole process and, thus, in the connection with errors through problem-solving and the critical reflections they make about new ways of learning.

The classes presented different dynamics due to interactivity, the interrelations created, the sharing between students and the exchange of knowledge and experiences.

The students became more alert to what was happening around them, more committed to the performance of the proposed tasks, and the production and creation of substantially better-elaborated results.

By being offered students tasks where they were challenged to work collaboratively, their critical natures and creativity led them to get involved in the activities and use robots to meet the proposed challenges.

These activities allowed students to extrapolate to everyday life solutions in solving the problems presented in the distributed scripts since these were projected onto the robots during the performance of the proposed tasks and challenges.

Learning by doing plays a mental and primordial role in the learning of these students since, when they are the creators, to have the freedom to explore their creativity, they produce and realize more objective and lasting knowledge in their school paths, Papert (1993).

In general, educational robotics and the use of active methodologies have proven to be effective ways to promote students' engagement, as well as to make learning more meaningful.

In addition, the introduction of educational robotics has proven to be a means of promoting inclusion and diversity in education. By working on robotics projects, students learned to respect differences and work collaboratively, regardless of gender or ability. This helped create a more inclusive environment in the classroom.

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