Educational Robotics in Science Teaching: A Study on The Development of a Research Project at the Federal Institute of Education Science and Technology of Rio Grande do Sul (IFRS)

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Abstract

The use of technologies such as educational software and robotics to support the teaching and learning process is increasing. Educational robotics has proven to arouse interest in students, as it allows physical handling and active participation in the learning process. In this sense, this manuscript aims to describe the Educational Robotics research project as an Incentive to the Study of Science approved in PROPPI EDITAL No. 77/2017 - INTERNAL SOURCE 2018/2019, which had as a proposal to integrate undergraduates of Licentiate Degree in Mathematics and Computer Science of IFRS - Campus Ibirubá to jointly carry out analyzes and develop procedures for teaching and learning science (mathematics/physics) using Educational Robotics resources, motivating students of the Technical Course in Computing Integrated to

High School. Thus, while this project offered an internship field for undergraduates, it promoted interest in the study of science among participants, leading them to engage and promoting greater participation.
Keywords: Educational Robotics; Science Teaching; Research Project.

1. Introduction

With technological advances and the great influence that technologies have been exerting on the daily lives of young people of school age, the low motivation that a discipline performed strictly in the traditional format can cause among students is noticeable. Therefore, educators, especially those linked to technical and undergraduate courses in the area of information technology, are always looking for tools to encourage students, with different formats for teaching and promoting learning. One of the tools that has proven effective in this regard is educational robotics. According to Silva (2009), the teaching of robotics awakens in students an interest in the study of science, including physics, mathematics and computing. In the study developed by the author, participation in educational robotics projects increased students' self-esteem and self-confidence, led to greater achievement in curriculum subjects and improved relationships between colleagues, which suggests that projects as presented by Silva (2009)) has the potential to support the permanence and success of students, increasing their engagement and consequently promoting a reduction in dropout rates in courses that adopt these practices.

One of the limitations on the use of educational robotics is the high cost of equipment, which prevents its adoption in most public schools. However, as Medeiros Filho and Gonçalves (2008) prove, with the use of free hardware – such as Arduino – and scrap of computer material, it is possible to produce equipment at a cost up to 20 times lower than that of commercial equipment. Therefore, the use of low-cost robotics was one of the central points to enable the execution of this project

In view of this, the project described in this manuscript aimed to combine the offer of technical knowledge for the construction of equipment offered by students in the Computer Science course, with the theoretical basis of undergraduate Mathematics students and the demand by high school students integrated learning in the field of science. To meet this purpose, the project promoted workshops held by undergraduate students, with the support of the coordinating professor – author of this manuscript – for students of the Technical Course in Computing Integrated to High School, in order to build innovative solutions with low-end educational robotics cost, applying concepts and contents of disciplines in the area of science.

These workshops used a construction approach based on problem situations, which were instigated from generative themes such as sustainability, environmental resources, preservation, among others. It was intended in this way to build prototypes and products that can be applied as solutions to real and supposed problems by the organizers of the workshops, which encourage the understanding of the contents of disciplines in the area of science. Such contributions can be decisive for the permanence of students in high school, since the subjects worked on in the workshops offered were mainly mathematics and physics, which are generally reported as difficult by students.

It is also noteworthy that this project encouraged the participation of the degree, as the executors will also be students of the degree course in mathematics. This is an action that is necessary nowadays, in which there is a decline in interest in the exercise of teaching, given that this is the area with the greatest dropout on the Ibirubá Campus. Undergraduate students should be encouraged to realize the importance of this area and that the figure of the teacher is fundamental, as there is no individual, social or economic development if not through education, which has the teacher as its central element.

2. Theoretical Foundation

This section discusses the relevant themes in the development of this manuscript, derived from the research project carried out in IFRS.

2.1 Education and Technology

The theory of learning styles (ALONSO; GALLEGO, 2002), which considers individual differences for learning, argues that if more than one student sense is mobilized, the easier their learning will be. Technologies in education, in this aspect, offer several pedagogical resources that favor the way of learning of each individual in its diversity, offering multiple stimuli, such as sight, hearing and touch simultaneously. The use of educational robotics is highlighted to provide an environment interconnected with new technologies, in this sense some advantages are listed: (1) Familiarization with new technologies; (2) Contextualization of the content with the real application of the proposed problem; (3) Applicability of mathematical and physical concepts and terms in practice; (4) Problem solving aimed at the student's autonomy; and (5) Resumption and analysis of results.

It is worth noting that until mid-2010, new technologies had not gained due attention in teacher training courses at large universities, which did not have in their curriculum, in most cases, a discipline aimed at familiarizing content related to computer science with application aimed at teaching in the classroom, especially in subjects in the Humanities area. However, it is quite evident the benefits that these tools can bring when used assertively by teachers, this is one of the legacies of the Covid 19 pandemic, undoubtedly one of the great tragedies of this generation, but which made the use of these tools emerge in an accelerated way. technologies, a technological revolution that might take up to a decade happened in just a year. However, the Federal Institutes were born with the mission of incorporating technology in all their areas of operation, in this sense the Federal Institute of Education, Science and Technology of Rio Grande do Sul (IFRS), on the Ibirubá Campus, in the first semester The Degree in Mathematics course highlights a discipline focused on information and communication technologies in education, which broadly addresses various educational possibilities through technology.

Based on this finding, Araújo's (2004) statement stands out: the implementation of good technological training does not only imply the implementation of a good computer lab with state-of-the-art equipment; it is necessary to review the institutionalized training model and provide for the incorporation of the digital in the teacher training curriculum. In this perspective, Valente (2005) highlights that there must be a consensus in mastering the techniques necessary to practice the use of technology and pedagogical knowledge, one must combine pedagogy, didactics and mastery of technology that is so present today. According to Paulo Freire (2002), permanent care is required to exercise a pedagogy based on ethics, respect for the dignity and autonomy of the student. Training is much more than just training the student in the performance of skills, it is reinforcing the student's critical capacity, curiosity and insubordination;

make them creative, instigating, restless, humble and persistent beings. Characteristics that can be enhanced through the application of technological education, thus exercising the ability to learn and teach, more and better, when new technologies are incorporated into practice (PERRENOUD, 2000), it is understood education as a primordial foundation and it is recognized that knowledge is built as a result of a process based on stimulating experiences that, together with the material offered to the student, generates an understanding and from this the student becomes capable of producing.

In this sense, educational robotics as a tool in the learning process exercises and instigates curiosity, imagination and intuition, central elements that favor experiences that stimulate decision and responsibility, thus autonomy is built in the experience of countless decisions that are being taken, is a process in which the subject becomes cognizant (FREIRE, 2002). For Piaget (1976), one of the main keys to development is the subject's action on the world and the way in which this becomes an internal construction process. Since the subject is in constant activity with the environment, elaborating and re-elaborating hypotheses that explain it, he goes through cognitive conflicts that lead him to seek reformulations for his hypotheses, further expanding his understanding systems, in a continuous search for the balance of his cognitive structures, a process that can be favored with the use of educational robotics.

2.2 Educational Robotics

Robotics has been causing a great impact by bringing innovations in several sectors. Whether by extinguishing jobs or creating new ones, as well as in medicine, with doctors performing delicate surgical interventions at a distance, in wars; even in domestic use and in the way we interact socially, without measuring the widespread use of robots on the industrial floor to perform repetitive and precision activities. This in itself makes it an interdisciplinary area of great possibilities in education, for Fazenda (1994), interdisciplinarity is the positive attitude towards knowledge, which implies behavioral change regarding decision-making. For her, interdisciplinarity promotes cooperation, work, dialogue between people, between disciplines and among other forms of knowledge. Educational robotics is not young, having emerged around the 1960s, when its pioneer Seymour Papert developed his theory on Constructionism and defended the use of computers in schools as a resource that stimulates children's learning. Educational robotics can be defined as a set of technological concepts applied to education, in which the learner has access to computers and software, electromechanical, electronic and digital components, such as motors, gears, sensors, wheels and a programming environment for above components may work.

In addition to involving basic knowledge of mechanics, kinematics, automation, hydraulics, information technology and artificial intelligence involved in the operation of a robot, pedagogical resources are used to establish a pleasant school work environment. In this way, a series of events is simulated, often in real life, with students and teachers interacting with each other, seeking and providing different types of knowledge, including and mainly in Science. The current global situation that promotes the eminent and incessant search for knowledge, makes it necessary to update and use means that modify teaching and learning, instigate and create provocative situations in students, so that they can create their solutions and suitability of problems that involve them daily. New technologies could not be indifferent to any teacher, as they change the ways of living, having fun, getting informed, working and thinking. Such evolution therefore affects the situations that students face and will face, in which they purportedly mobilize and mobilize what they learn at school. (PERRENOUD, 2000).

At an incredible speed, the growing application of technology has been transforming the role of the teacher who must assume the role of mediator in the learning process, the role of "problematizer" who helps the student to autonomously seek the solution, as well as narrow the path between empirical knowledge and scientific knowledge. It is in this context that we propose to rethink pedagogical practice, as it should not be forgotten that students grow by incorporating technological innovations. Given these reflections, it is clear that it is necessary to search for new methodologies that enable students to incorporate reasoning, the use of logic and the analysis of situations for different problem solving. Educational robotics, if well conducted, favors the student's intellectual growth through experimentation, construction, reconstruction, observation and analysis. Students, in an attempt to solve their problems with constructions and computer programs, can manipulate different concepts in the domain of science (physics, mechanics, mathematics, computing, among others.) (ZILLI, 2004). When working in an educational robotics environment, the prototype built by students becomes a cultural artifact that students use to explore and express their own ideas.

2.3 Robotics and Science Learning

As Vygotsky (1998) defines it, learning is mainly based on people's relationships and characterizes behavior change, as it develops skills. In the case of the proposed project, these skills are developed from the interaction with robotic prototypes and the mediation of the teacher. According to the Belarusian author, in the learner's attempts to solve problems, the zone of proximal development is reached, which is the distance between real development, that which each person is capable of carrying out for himself, and the zone of potential development, one that a person can do with the help of more capable others. These interactions are established between teacher - student - robot and are very positive for the development of the domain of symbolism, bringing social, cognitive and affective advantages. The experimentation, which becomes real in this project, is a practice in which, according to Borba (1999), open problems are proposed by the teacher and in which there is a group exploration of themes related to Science. The central idea of experimentation is to work concepts modeling phenomena, nothing more excited than the teacher to launch a challenge in which students see themselves as co-authors of their learning, who can manipulate objects and real shapes in obtaining answers to what was proposed and resolve. From this perspective, robotics is a very productive tool for this type of activity.

Starting from a real "problem" stimulus that the teacher-advisor proposes, such as "developing a certain movement for the robot", the student begins to think to solve such robot activity and is motivated to seek new relationships in science and in the world. So the search for concepts takes place from this real stimulus, in which the student will compose their own concepts and identify their own science, extinguishing what Freire, (1987) calls banking knowledge, which is what happens when the student is seen by the teacher as an account in which he deposits his contribution in the form of knowledge. He himself, "the student", builds a bridge to knowledge and, after finding what is necessary for action, returns to the initial stage, now with the question answered and the possibility of applying the concepts learned. This way of thinking about the teaching process also defeats the need to follow the textbook to the letter, as reported by Echeverría (2008), most teachers were not prepared to organize both the activities and the way to evaluate, because most of the time they are limited to accompanying the textbook.

There is also the question of abstraction; in a traditional class, the student often does not make an effort to abstract mathematics to a real context, however, from a real need, he seeks essential mathematical knowledge to solve this specific task of interest, which has a motivating role. The teacher, in turn, guides the student along the mathematical path and no longer measures the contents and formulas that the student must know. A cycle is generated in which the student is the one who goes in search of knowledge by the need created in a real context, and when he finds the answers to his questions within the logical-mathematical field, he goes back to reality to apply his knowledge, now built by themselves with the help of the teacher. Each step allows the student and teacher to understand the construction of learning; In this sense, Papert's (1980) statement stands out: what is learned by doing is much more rooted in the mind.

Confirming such statements, for the construction of autonomy, according to Freire (2002), it is not enough to give freedom, it is necessary to think about the ways in which the contents taught in the classroom are worked; the more critically the ability to learn is exercised, the more epistemological curiosity is built and developed, without which knowledge of the object is not achieved. Papert (1980) says that an individual can learn, and the way he learns depends on the models he has available. This raises the question of how one learns in these models, so the laws of learning must be about how intellectual structures grow out of one another and how, in the process, they take logical and emotional form. For example: consider the challenge launched by the teacher to build a roller coaster, a very common toy model in amusement parks, therefore an object of knowledge for students. When manipulating the parts or objects of the robotic kit, they depart from abstract thinking to concrete, as there must be a conception of which mechanisms will be suitable for the construction that will enable the expected movements. This act of “playing” from the real to the imaginary creates in the student the possibility of exercising the domain of symbolism (VIGOTSKY, 1998); contextualizing the construction with the specific objective of the teacher, it establishes a connection between previous knowledge and the new ones proposed. During the construction process, there is a constant interaction between abstract and concrete thinking; this prototype construction process provides a very dynamic learning environment for the mediation process to be carried out by the teacher, who can constantly carry out interventions with new technological knowledge and will instigate new challenges.

Activities like this encourage students to learn and learn about new elements, with a closer relationship with the theme and prior knowledge, which balance with new skills and challenges. Students think about how things work, experiment, observe, analyze and correct possible errors. When they finish building the prototype, many concepts can be analyzed in practice, such as physics principles - the transformation of potential energy into kinetic energy, in addition to the concepts of friction, acceleration - and mathematics - measurements, angle measurements, the study of second-degree equations, in other words a multitude of themes and contents that can be inserted, working with robotics in science teaching and learning.

3. Methodology

The purpose of this manuscript is to describe the research project carried out in 2018 entitled: Educational Robotics as an Incentive to the Study of Science. This project had as its main focus to promote the research of procedures for the improvement of Science teaching, using Educational Robotics and, in this way, also to promote the integration between the Licentiate Degree in Mathematics and Computer Science, as well as with students from Computer Technician Integrated in High School, encouraging the study of science through low-cost educational robotics. The project was developed through action research, in which the project coordinator and the fellows got involved in a cooperative and participatory way, in this way, in addition to developing techniques and procedures for teaching Science through Educational Robotics, also validated them through the application, in the format of workshops. The project methodology was carried out through well-defined phases: installation; planning; execution; and closing, described in Table 1.

Table 1. Project Development Stages

PHASE	DESCRIPTION
Project installation phase	1. Selection of scholarship holders; 2. Purchase of essential equipment.
Planning phase	1. Survey of the possibilities for the application of educational robotics (types of equipment available from other projects already developed); 2. Development of a systematic literature review to select the main works carried out in the area; 3. Selection of the contents that will be covered; 4. Development of techniques and procedures based on contents and also on educational robotics; 5. Selection of the application audience; 6. Preparation of the action plan.
Execution phase	1. Development of robot projects: projects will be executed including the complete life cycle, from planning, distribution of roles, monitoring, correction of failures during the process; 2. Development of Workshops including Integrated High School students; 3. Post-mortem testing and analysis.
Closing Phase	1. Systematization of lessons learned and dissemination of results, including through public exposure, and in particular by publishing the results achieved.

Source: Authors.

As for the installation phase of the project, due to budget adjustments, it was possible to have only one fellow and one volunteer, the fellow was a Computer Science student and a volunteer from the Licentiate Degree in Mathematics was chosen. The purchase of equipment was quite costly, as there were some problems with budgets, practical elements that delayed the project's execution a little, but all the equipment plus the Arduino boards needed to assemble the robotics kits used by the students during the workshops. As for the Arduino, it is important to emphasize its relevance in the great growth in recent years of free educational robotics. Arduino is a free hardware electronic prototyping platform that is very easy to program; therefore, many components and devices have been developed to work together with Arduino. As an example we can mention: audio and video devices, color sensors, image, temperature, luminosity, GPS, buttons, wireless, wi-fi, ethernet, GSM, motors, among many others, with a low acquisition cost. One of the main goals of Arduino is to allow the creation of robots and other programmable devices at a low cost, especially for those that would not be able to reach the most sophisticated controllers and more complex programming tools. In this sense, it is clear that it is possible to create robotics projects with low-cost technologies or even with parts from the disposal of electronic equipment.

Regarding the planning phase, this was very fruitful, in which a lot of knowledge was generated, especially regarding the search for methodologies to improve science teaching with the use of robotics, as well as the main contents that could be worked with this practice. After that, the target audience of the study was selected, which were the first-year students of the Technician course in Computing Integrated to High School, Campus Ibirubá - freshman class in 2018, with 30 students - after this selection, the students answered a questionnaire in which they indicated from a total of 10 available contents (5 from the physics area and 5 from the mathematics area) which they would like to be the subject of the educational robotics workshops. Thus, selected by majority vote: in mathematics, the content of Metrics – which addresses geometric and also measurement transformations; and in physics, the content of Kinematics – which is the branch of physics that deals with the description of the movements of points, bodies or systems of bodies, without worrying about the analysis of their cause. Furthermore, after these definitions, the action plan was drawn up at this stage, which was basically composed of the planning of each workshop that would be held, which had the following elements; a) Name of the Workshop; c) Workshop objectives: at least 3 objectives, clear, evaluable, measurable, achievable by the group; d) Dynamic: script, which specified the challenge proposed to the students, within the selected contents and possibilities of solutions previously elaborated by the scholarship holder and the volunteer; e) Materials needed; and f) Bibliographic references.

In the execution phase, before the workshops start, the scholarship holder, the volunteer and the coordinator were responsible for testing the feasibility of the solutions to the proposed problems, already developing prototypes, it was possible to test the plans, and correct process failures so that no unforeseen events occurred during the workshops. In addition, it was at this stage that the workshops were actually held, in this sense, 6 workshops were developed that lasted around 4 hours each, held at the IFRS Hardware Laboratory, Campus Ibirubá, in the second half of 2018. The first workshop was just to teach students how to handle robotics kits, both the physical assembly and the programming environment, the other workshops had the following format: (1) Presentation of the theme and content of the workshop, with expository explanations; (2) Identification of the problem and its context; (3) Definition of time and resources for students to try to solve the problem; and (4) Presentation of Results by all. As there were 15 robotics kits and the class consisted of 30 students, the activities were carried out in pairs.

Due to the space limitations of this manuscript, only one of the workshops held, considered to be of greater use, will be detailed: This workshop had as its main theme the calculation of speed and acceleration, by measuring the time and distance covered by carts made with the kits of robotics and was called “Nobody Takes My Cart”. Firstly, the kinematics contents related to the velocity and acceleration of bodies were worked on. Then, the following problem was defined: "With a cart made from the robotics kit, what would be the speed value that should be assigned to it so that the time to walk the laboratory corridor would be 3 minutes, and what would it be the acceleration caused by this movement, would it be constant?”. After that, the students were encouraged to build their carts and it was pointed out that whoever could find the answer to the problem first could take the built cart home to show family members, which left all students even more motivated to finish quickly and with more. whim your constructions. One of the built carts can be seen in Figure 1.

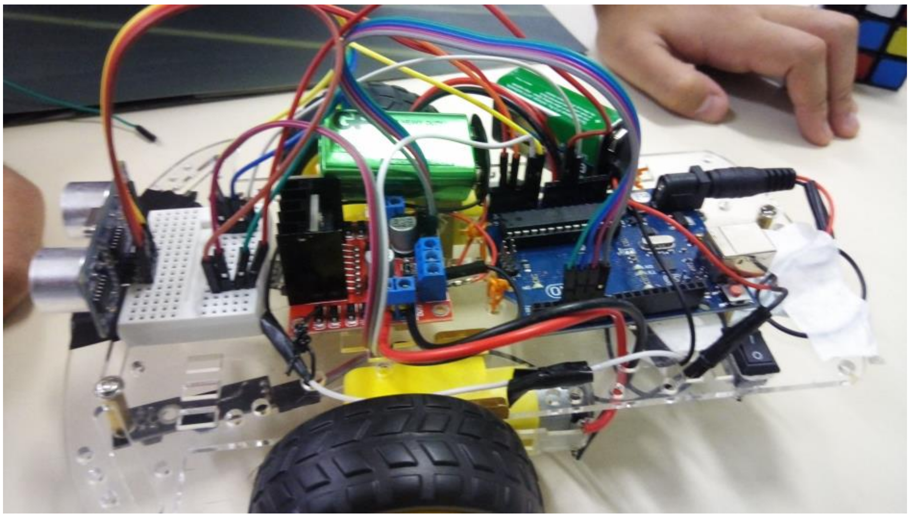

Figure 1. Cart assembled with robotics kit.
Source: Authors.

After construction, students could use cell phones to calculate the time spent by carts to complete the corridor route, if they spent more or less time than 3 minutes, students had to go back, plug the carts back into the computer to adjust the schedule of speed. After a while, everyone had the speed adjusted to make the route in 3 minutes, then they could calculate the acceleration of the carts, with the formulas demonstrated by the scholarship holders at the beginning of the workshop. All completed the activity satisfactorily and a winner was defined who managed to adapt the speed to the time in just one adjustment, however at the end of the activity it was said that everyone could take their carts to show their families (taking turns because it was a cart for pairs of students) and should bring it to the next workshop that would use the same car structure already assembled. No doubt there was great enthusiasm from the students at this time.

To finalize the considerations about the execution phase, at the end of each workshop the project team would meet to carry out a post-mortem analysis of what was done. This analysis works as an information system of lessons learned, which provide valuable insights into a project and the possibilities of obtaining the best returns, this project specifically analyzed the factors that worked, and factors that did not work, with a record being made per workshop. As for example the workshop described above, a factor that worked very well was the reward at the end of the activity, however, using the corridor as a "runway" for the carts ended up generating a lot of noise that bothered other teachers, making it necessary to draw the students' attention several times . Thus, factors with positive results should be replicated while those with negative results should be avoided.

Finally, the last closing phase was carried out by the project team, in which the main results were systematized and disclosed at the IFRS Research, Extension and Teaching Exhibition and also at the Teaching, Research and Extension Exhibition of the Ibirubá Campus.

4. Results and Discussions

The three main contributions generated by the development of this project were: (1) Scientific – generated from the analysis of the impact of the practice of educational robotics on the interest in the study of science among high school students; (2) Development of techniques and procedures; and (4) Technological – with the systematization of knowledge for the development of low-cost robotic products, using free hardware combined with scrap computer material, initiatives such as this one aimed at lowering the cost of products allow more public school students have access to educational robotics equipment.

Due to the theme addressed in this manuscript, the impact of the practice of educational robotics on the engagement of integrated high school students is discussed, supporting the interest in the study of science; it is believed that this contribution was one of the most noticeable of the project, because at the end of each workshop, a conversation was held with the students, in which they were asked about what they were feeling with the workshops and the answers were always that they provided more. of knowledge, motivation. Corroborating this statement at the end of the project, a questionnaire was applied to the students so that they could respond to the improvement in the learning process in the subjects of mathematics and physics, which was practically unanimous in the sum of the responses, stating that the project collaborated, this being believed to If that this project can be a positive example of actions that encourage the permanence and success in IFRS.

It is considered that educational robotics has great potential as an interdisciplinary tool, since the construction of prototypes, in general, makes the student question and be able to relate different knowledge and skills in order to solve a problem. The search for solutions stimulates an investigative spirit, motivated by curiosity, and allows students to extrapolate individual knowledge of each discipline. The use of educational robotics allowed participating students to articulate the theoretical field with the practical field and, therefore, experience knowledge in a more concrete way and attribute meaning to learning. In this sense, Papert (2008) highlights that anything is simple if a person manages to incorporate it into their arsenal of models; otherwise everything can be extremely difficult. One of the main keys to development, according to Piaget (1976), is the subject's action on the world and the way in which this becomes an internal construction process. Thus, learning results from the interaction of the subject with the object of knowledge, affirming the importance of concrete operations in the construction of knowledge.

It can also be said that this project helped students to think, favoring a creative learning environment. By being challenged to build and program robots, the student is teaching the computer to think and is able, at the end of its assembly, to associate the theoretical content with what they have learned in practice, coordinating different actions, and, by manipulating the object, they understand the process programming in general, as well as the concepts of mathematics and physics covered. It is worth mentioning the strong interaction appeal provided by the didactic proposal of the low-cost robotics kit, making students learn to work collaboratively and develop skills such as cooperation.

Other results that could be identified were: (1) Greater interest in the degree on the part of university students: there is not always an interest in teaching; (2) Greater preparation for the exercise of teaching by undergraduate students: the practice, allied to the theory seen in the classroom, contributed to the formation of the future teacher; (3) Greater interest in higher education on the part of high school students: participation in the project tends to motivate the student to enter higher education to pursue a career in some area involved in the project; (5) Development of technology for the construction of low-cost educational robotics kits: the projects developed, with the use of free hardware and software, are available to be used again; (6) Greater integration between the Computer Science and Licentiate Degree in Mathematics courses.

5. Conclusions

The use of educational robotics in science teaching is not a simple task, as it requires a multidisciplinary team, especially with knowledge in computer programming and electronics, as well as teachers who have theoretical knowledge about the contents being worked on. However, educational robotics is a tool that is much more accessible due to the emergence of cheaper and easier-to-program free hardware. Furthermore, with educational robotics it is possible to demonstrate in practice many of the theoretical concepts, sometimes difficult to understand, motivating both the teacher and especially the student.

In this sense, with the development of this project, it was possible to identify a greater engagement of high school students integrated in disciplines in the science area, which can promote an increase in the permanence and success of students. In addition, the developed workshops demonstrated the potential of robotics in science education, with emphasis on the ease of viewing physical and mathematical phenomena whose parameters are informed to the robotic device by students. The described activity proposal clearly demonstrates the didactic applicability of this resource in education. Furthermore, with the use of low-cost educational robotics, there is the possibility that more students can use it, which is a very promising tool.

6. Acknowledgement

This study was supported by the Federal Institute of Education, Science and Technology of Rio Grande do Sul (IFRS).

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