Arduino Baby Project: Robotics as a Tool to Support Permanence and Success of Technical Course Students in Informatics

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***Abstract*—*This Research Fully* presents an approach to reducing the school dropout rate in Computer Technician courses, using robotics as a pedagogical tool. In a school context, the field of computer programming is considered the most important, because it contains concepts that form the basis of computing. However, few people can easily learn programming. Studies show that difficulties in assimilating programming concepts cause discouragement, and consequently lead to school dropout. In the face of this scenario, Educational Robotics has proved to be an important tool in expanding the STEM approach, in addition to presenting itself as a tool to motivate programming learning. With the goal of motivating students to stay in school, and to get a good start in learning programming, an approach called Arduino Baby was developed and employed, which uses Educational Robotics through the Arduino platform. It was structured and carried out in 4 main stages. During the execution, an integrating project was applied, the methodology of which included the creation of student teams, the distribution of bibliographic materials and kits, practice performance, and the exhibition of the developed works. At the end of the research, questionnaires were given, and semi-structured interviews were conducted for participating students, in order to find out the degree of motivation obtained. Results showed to be promising, and that they can be allies in the fight against school dropout.**

Keywords — educational robotics, school dropout, project learning

I. Introduction

We are living in the so-called "digital age" or "digital society", in which digital technologies directly influence the way we conduct our daily lives [1]. These factors are reflected in the educational environment, transforming the students' computational reasoning development, or computational thinking, into a critical factor for success in the future [2]. Although it is possible to develop these skills without directly involving the use of coding activities, computational thinking is often related to development of ability in computer programming [3].

In Computer Science related courses, programming skills have become the main standard of competence for students, as they contain guidelines that form the basis of computing [4]. However, programming involves understanding semantic and syntactic knowledge that few people can easily develop [5, 6]. Studies have shown that difficulties encountered in enhancing programming skills cause discouragement, and consequently, lead to school dropout [7, 8, 9].

Recent studies have shown the importance that Educational Robotics exerts in teaching programming to students in the computing field [10, 11, 12], and it has become an important tool in expanding the STEM approach (Science, Technology, Engineering and Mathematics) in the educational environment [13]. It also has great potential as an interdisciplinary tool, as it seeks solutions and stimulates the investigative spirit, since it allows the student to explore knowledge in each individual discipline [14]. Research also points to the Arduino platform as an Educational Robotics tool widely used in various projects and with promising results in learning [11, 15, 16].

Therefore, in order to motivate beginning students to continue in the course, avoid dropping out of school, and obtain success in a technical course in computing, an approach was produced and employed that uses Educational Robotics through the Arduino platform, with a focus on project development. The approach was called Arduino Baby. Because of dealing with a public new to programming and because it was their first contact with the Arduino platform, the Arduino Baby nomenclature represents a metaphor for initial steps, the basis for student development in their training as future Information Technology technicians.

To report about the research, this article is structured as follows: Section 2 presents the theoretical foundations of the Arduino platform, Educational Robotics, and the Project Method in education. Section 3 shows the work related to this research. Section 4 describes the methodology used in this research and in the integrator project. Section 5 displays the results and the discussions about the recorded observations, questionnaires, and interviews conducted. Finally, Section 6 gives the conclusions about this research.

II. Background

A. Arduino

It is an electronic board controlled by electrical pulses, having open code, and provides a solid base for hardware and software [16]. It allows amateur and professional developers to create devices and projects, integrating various sensors and actuators, in a simple and functional way [17].

In addition to allowing the integration of several devices and electronic components in a simple and efficient way, another factor that makes the Arduino platform extremely popular is the low cost of purchasing a kit [15]. In this way, it is possible to build prototypes and designs in a more accessible way than other systems available on the market.

B. Educational Robotics

Robotics is an area of science and engineering that includes concepts from mechanics, electronics, computing, and others [18]. When applied to education, it is called Educational Robotics, and has been gaining more and more prominence in the educational environment [15]. It can be considered as a powerful tool for having a positive influence on students, contributing to improvements in learning and interpersonal relationships [11].

It also has great potential as an interdisciplinary tool, as it seeks solutions and stimulates the investigative spirit, since allows the student to explore individual knowledge in each discipline [12]. Another important characteristic is the fact that their activities are more productive, because when performed by a group of people working together, it encourages students to seek solutions that integrate concepts and applications in other involved disciplines, such as Mathematics, Physics, Mechanics, Electronics, and Informatics [14, 18].

C. Project Method

It is a learning method in which the student becomes the author of his creative, educational, and informative activities, as a result of the projects carried out [19]. It is also an activity focused on an objective, based on challenge, promoting successful cooperation and the knowledge gained by carrying out the activities [20].

This method consists of rules and phases defined and clarified between the teacher and students, to establish actions involving the project, such as the objective, team division, planning, carrying out the activities, and evaluation of results [21]. The author highlights, as advantages of this method, the educational, social, and integrative potentials, because in addition to knowledge acquisition, it enables group work, result sharing, and development of critical thinking.

There are methodologies similar to the Project Method (PM), such as Project Based Learning (PjBL), which has achieved excellent results in educational environment [22,23]. The challenges proposed in PjBL are real situations, that is, contextualization is an essential element, while in PM, the challenges can be real or fictitious situations, according to the project coordinator. As it is more flexible, PM was used in this research.

III. Related Works

This work was based on research done by Fragkakis [7], in which the author presented an approach using Educational Robotics as a tool to motivate and awaken the student's interest in school and thus avoid school drop-out and failure. The study was aimed at high school students with tendencies for failure and school drop-out, characterized by a large number of absences and behaviour problems, and which fit this profile according to teachers' opinion. LEGO Mindstorms was used, and group activities were carried out to develop simple and advanced robotic projects. It was reported that the results were encouraging and that the participants were motivated to participate in similar activities again.

The research developed by Koyuncul et al [10] is aimed at discovering how students obtain knowledge and how they learn programming with methods that involve educational robotics. It is also aimed at showing Computer Science teachers how robotics-based teaching methods affect class outcomes. The study was developed with students who were new to programming, using methodology based on projects and action research with participants divided into 2 groups, to carry out a case study. Comparing the teaching methods of traditional classes and classes with robotics, using robotics has been shown to have advantages over doing homework, such as being easier to adapt to and deal with in practice, and group discussion analysis. Students remember what they learned for a longer time, because of doing practical activities as opposed to theoretical activities. Results also showed that the use of educational robotics could improve motivation to learn, stimulate programming and favour collaborative learning.

Learning programming with robotics using Arduino was examined in research by Victal and Cândido [11]. The authors presented a report of their experience using Arduino as a strategy for teaching programming to beginning Computer Science students without knowledge of programming or of Arduino, aiming to show how programming can arouse interest when assimilating theoretical content into practice. Action research was used, and groups were created to develop activities with Arduino. In the end, the projects were presented at a public event, held within the educational institution. As reported results, we can cite the production of significant knowledge, motivation, and the interaction of the participating students

The aforementioned works support this research, aiming to deepen the knowledge presented by the referred authors.

IV. Methodology

The Arduino Baby approach was conceived and developed by a work team consisting of two Professors of Informatics and one Physics Professor, characterized as Coordinators. The team was also included the Assistant of Educational Affairs of the institution, who contributed pedagogical support, and the Informatics student monitor.

The methodological process has a qualitative, exploratory, and descriptive approach. As instruments of data collection, we used participant observation, semi-structured interviews, and the application of a multiple-choice questionnaire. Twenty-two first-year students from High School in Informatics at the Federal Institute of Amazonas, Campus Maués, were selected. The four stages of the research followed the actions described in Figure 1.

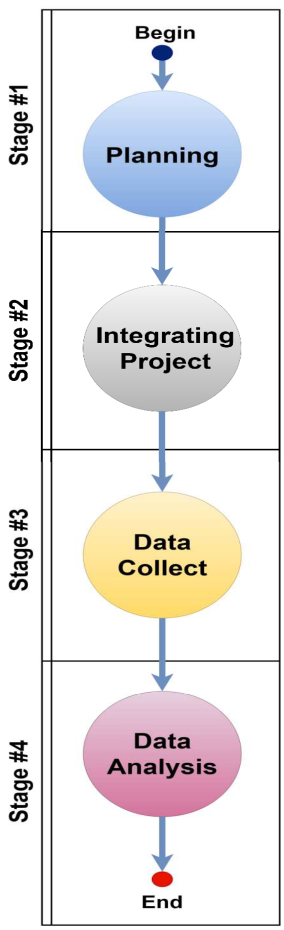

Fig. 1. Diagram of research stages.

A. Planning

This was the initial stage of the research, characterized by planning the actions to be carried out. The activities schedule was put together and the basic Arduino kits were purchased, based on activities to be performed.

To give theoretical and practical support to the students' tasks, a basic handout on Arduino was prepared. On the booklet cover was inserted the motto “I turn on, therefore I am,” used in reference to the famous phrase “I think, therefore I am,” by the French philosopher René Descartes, in order to encourage the desire for learning by practicing the activities contained in the didactic material. The handout cover can be seen in Figure 2.

Fig. 2. Handout cover designed for this research.

Afterwards, the structure and sequence of the activities in the meetings with the students were designed. After the conclusion of this stage, the participating students were enrolled.

B. Integrating Project

At this research stage, the **Integrating Project** was carried out, called the **Arduino Baby Project** in the institution for better dissemination. It was structured and implemented in 4 stages, which are described in Figure 3.

Fig. 3. Diagram of the 4 stages of the Arduino Baby integrating project.

The first stage started with the formation of the working groups. The students were free to choose their team members, the groups being composed of two or three members. This step was important for bringing about the integration of the members that make up a team, and even more for socialization among the groups.

The second stage consisted of the presentation of the Arduino platform, chosen for project development because it is simple and low cost. Each team received a basic Arduino Kit, in addition to a handout prepared by the project coordinators containing fundamental concepts and practical challenges of Arduino assembly and programming. The basic Arduino Kit is shown in Figure 4.

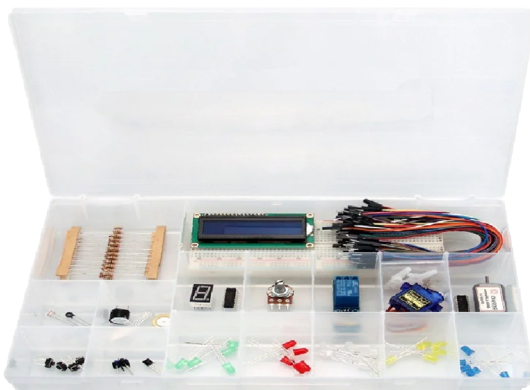

Fig. 4. Basic Arduino kit used in this research.

In the **third stage**, laboratory practices took place. During this period, the student groups received classes from one of the coordinators on how the platform, hardware, and software work, as well as an introduction to Electronics. The meetings took place in the Informatics Laboratory of the Educational Institute and provided the students' first contact with the material presented, so that they could work with it during the classes, since the focus was on the proposition of "knowing how to do it." Figures 5 and 6 show students practicing the activities proposed by the coordinators.

Fig. 5. Students practicing activities in pairs.

Fig. 6. Students practicing activities in the Computer Lab.

Once the initial stages were completed, this gave continuity in a moment when the students were already more confident to proceed with the challenges given to the groups, as arranged in the didactic support material. Each activity was classified with a difficulty level and correlated with the previous activity, thus giving a gradual aspect to the challenges.

A relevant point was the presence of the Informatics senior student in the laboratory environment, who together with the coordinating professors made possible a greater and better monitoring of the actions performed by the groups. Technical support and guidance were made available to the groups; however, the teams were directed to act as autonomously as possible. This growing ability provided the basis for the beginning of a new stage, the beginning of the research for the final product, the construction of prototypes by each team.

In the **fourth stage**, the groups that were initially pairs or trios were directed to form larger groups, with three or four members. It was necessary to have moments of dialogue among the teams and their new members, because in this stage they would need to define the project and delegate functions to each member. Once the projects were defined, the development of their initial ideas on Arduino platform began. During the meetings, the groups met in the Informatics Laboratory and even outside the school environment to assemble and program their prototypes. There was a visible communication among the teams, so that the projects came out different, and so that they could challenge themselves as programmers.

After the products were completed, the teams' projects were exhibited in an event organized by the coordinating teachers, which counted on the participation of public schools and the local community. Figures 7 and 8 show photos of the event, where the participants are exhibiting and explaining their projects.

Fig. 7. Robotics Exhibition Event.

Fig. 8. Students exhibiting "The Smart House" project.

C. Data Collection

Throughout the research, observations were recorded, with a greater emphasis being placed on the meetings with participants in the stages of the Arduino Baby integrating project. After the conclusion of the project, semi-structured interviews were carried out with the participants in order to find out their degree of satisfaction and the motivation for their actions, the positive aspects and the ones to be improved.

During the prototype exhibition, a questionnaire was given, so that the students participating in the research and the visitors would be able to give their opinions on the activities presented in the event.

At the end of the school year, the academic system of the educational institution was consulted to obtain information about how many students were retained and how many passed the course, among the participants of this research, having in mind that this was one of the objectives of this work.

D. Data Analysis

After grouping together all the research material collected, the data were tabulated in an electronic spreadsheet. Then, a description was made for analysis and discussion of the results.

V. Results and Discussions

A. Recorded Observations during the Integrating Project

During the stages of the project, the 22 participating students were motivated and willing to receive instructions about developing the activity. Initially, when forming the groups, they maintained a natural behaviour in choosing those with whom they had more affinity, which was an important factor for them to be more confident when answering questions with their colleagues or with the coordinating teacher. From that moment on, a fundamental element for the success of the activities began, which was maintained throughout the project: the socialization among the groups, which contributed in a legitimate way to meeting the schedule and the using the available time.

The second stage proved to be beneficial due to the dynamic nature of the meetings, which kept the group always focused on some prepared activity based on theory and practice. These moments were important in order to identify the students who had some difficulty in meeting a challenge, or in understanding a concept or reasoning presented. As one of the solutions, we oriented the students who felt more capable of collaborating with the students who had more difficulty. As a result, the interaction and collaboration among the participants, even outside the school environment, contributed to the success of the practical activities.

In the third stage, students were able to work more autonomously, since having become more familiar with the Arduino platform, they were instructed to work out challenges contained in the support material in a more independent way, that is, asking less and less help from the teachers or the senior student. We also noticed that in some moments, they no longer wanted to receive help, because they wanted to feel the satisfaction of completing the proposed challenges by themselves. We also observed development of the students as programmers because each time they completed a proposed activity, they moved on to the next one with an increasing level of complexity, bringing personal satisfaction and fostering teamwork.

In the fourth stage, new teams were formed, this time with a larger number of participants, three or four members. Because the groups kept in communication during the previous stages, there were no problems in changing the structure of the initial groups. However, choosing their final prototypes was a longer process, as they needed to make a list of materials and define the role of each team member. An interesting point was the constant communication between groups due to members' concerns about not choosing the same project.

We noticed that some teams had difficulty in coming up with an idea for the final project, and during the construction, noticing the non-feasibility, they had to redesign the whole prototype. This process was very significant, as the students were aware of the importance of the project being presented, and were anxious and motivated to present a good work. This concern was reflected positively in the exhibition because everyone showed the artefacts functioning and in an organized manner.

B. Robotics Exhibition Event

During the exhibition of the projects developed by the students, there was great participation by teachers and students of the institution and members of the community. A questionnaire was given, and it was answered voluntarily by 175 of the people present, in which “1” represented the worst case, “3” was an average situation and “5” the best case. The responses about the general evaluation of the event are in Figure 9.

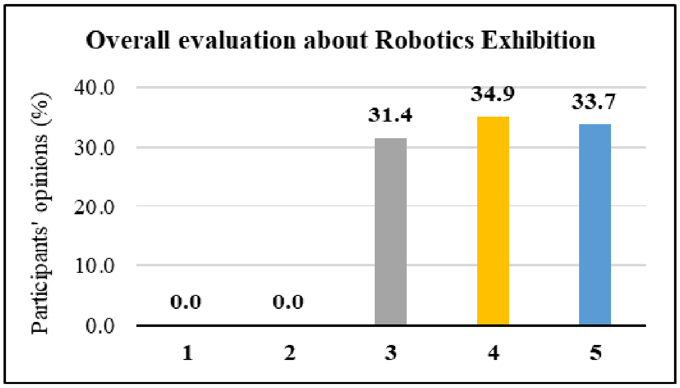

Fig. 9. Overall assessment of the participants in the Robotics Exhibition.

The participants evaluated the event in a positive way, because as we can see in Figure 9, the percentages of the opinions vary between the average value and the best case. These numbers represent the satisfaction of the participants about the event, which encompasses not only the exhibition itself, but the entire organization and logistics necessary for the success of the event, in addition to bringing a teaching approach based on technological tools to the local community.

The Robotics Exhibition was the first event involving this technology in the city. This generated some expectations in the community and the result can be seen in Figure 10.

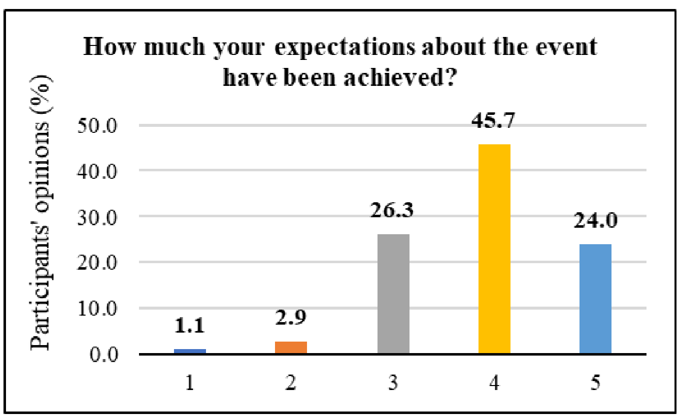

Fig. 10. How much the participants' expectations have been achieved.

We consider the evaluation to be very good, since the expectations of the majority of the audience that attended the event were met. The percentages presented show an excellent degree of acceptance, because when the best cases are added up, in positions 4 and 5, the total is 69.7%, that is, the vast majority of opinions. However, this mixture of opinions signals, as mentioned earlier, that working with people must come with awareness that we are interacting with different personalities, goals, and preferences, which becomes an even greater challenge in planning each activity.

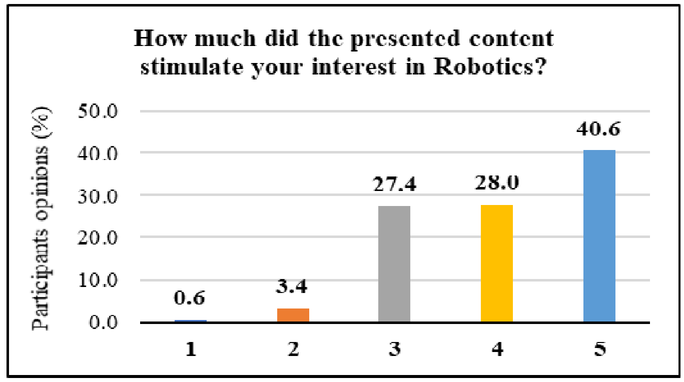

Fig. 11. How much the content presented stimulated interest in robotics.

Participants were asked about gaining interest in robotics and their opinions are described in Figure 11. From the experience they had during the event, the participants pointed out a significant increase due to their interest in robotics. Even though there were opinions that represented the worst cases, the percentages presented for the best cases show that inserting robotics into education is an assertive strategy for teaching, and for the learning process of students in all modalities.

It is important to remember that in a large group of participants, each individual has different interests, multiple aspects of intelligence, and different skills that may or may not converge in the area of technology. Theme dissemination went beyond just stimulating the students. A few months after the event, two participants joined the institution that organized the event, reporting that their interests in the area of Informatics, and more specifically in robotics, emerged during their visit to the exhibition of the projects built by the students.

As mentioned at the beginning of this paper, robotics has been shown to be a great promoter of the STEM approach, that is, it has contributed to integrating learning in Sciences, Technology, Engineering and Mathematics. In order to measure the participants' perception about this interdisciplinary capacity, it was asked how much robotics can be used as a tool to support other areas of education. The results are shown in Figure 12.

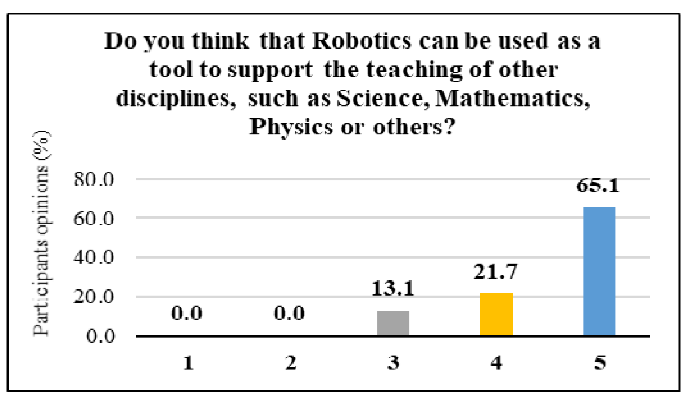

Fig. 12. Participants' opinion on how robotics can be used as a support tool for other disciplines, such as Science, Mathematics, Physics or others.

The data presented show a favorable scenario for the use of robotics in an educational environment. Among the answers, the vast majority opted for the best scenario, which tells us that appropriation of the fundamentals of this educational tool can work together to promote an interdisciplinary teaching that is so important for student development as a citizen. During the project development process, the interdisciplinary element was present since the first stage. Each challenge called for concepts of Physics—more specifically in the areas of Electricity and Waves, which permeated the activities—s well as Mathematics, Programming Language, and Electronics.

Even though many participants did not act as teachers, students and other participants were able to identify fundamentals of arithmetic, geometry, and electrical circuits in the exhibited prototypes. Thus, the event can contribute to digital inclusion inside and outside of the classroom, using new technologies in the teaching-learning process.

C. Student Opinion about the Arduino Baby Project

In order to know the students' opinion about this research, semi-structured interviews with 4 questions were conducted, which are shown in Table I.

TABLE I. QUESTIONS DIRECTED TO STUDENTS PARTICIPATING.

#	Question
1	In your opinion, did the Arduino Baby Integrator Project motivate you to continue your studies at the institution?
2	Do you consider that the participation of your project contributed to your academic studies?
3	In your opinion, regarding this research, what are the positive points?
4	Also, about this research, what are the points that need to be improved?

Among the collected responses, we noticed that the opinions converge toward common points. Thus, in Table II we highlight some of the responses obtained.

TABLE II. SOME RESPONSES FROM PARTICIPANTS COLLECTED IN INTERVIEW.

Question	Answers
#1	"Yes, because it contributed to my learning and aroused even more interest in technology and robotics.".
	"Certainly. It was extremely important for my good performance, both in the technical course, as in specific subjects, such as Physics."
	"Yes, because it improved interest in learning more about Programming Language, Mathematics, and Physics."
#2	"Certainly, because through the project, I got to know new areas of Informatics."
	"Certainly, considering that my course completion project was based on what I had learned in the Arduino Baby integrating project. And it was extremely relevant also for me to find my professional vocation. Through the Arduino Baby Project, I acquired the certainty that I intended to follow the Information Technology area."
	"Certainly! Through it I learned more about Arduino, and later on did my Course Completion Project on the subject."
#3	"It enabled new knowledge in technology and robotics areas."
	"I highlight project realization in the institution, expanding the knowledge horizon of the students, and innovative teaching and learning processes through practical experiences."
	"To present Arduino in a simple and direct way, to teach the material many times for free, scholarships, and others."
#4	"Some students lacked some Arduino assembly components. Also had incorrect assembly codes in the instruction guides".
	"I highlight the possibility of reaching out to more students with the project, offering them the opportunity to take advantage of such a useful tool, which, for sure, will be relevant to their good academic performance ."
	"Difficulty to obtaining more advanced materials. As it is an electrical material, there is the risk of components to be destroyed. Try to reach out a larger number of students".

We perceived the students' satisfaction in having participated in this research, and the contribution to both their remaining in the institution, as well as to their continuation in their academic and professional studies.

We noticed that there are points to be improved, such as obtaining components that are more current, updating the support material, and increasing the number of participants.

D. Student Retention and Success

The retention of students and their success were the central focus of this research. At the end of the academic year, the academic system recorded that all 22 participants in this research remained at the institution, which made a retention rate of 100%.

Regarding the students' success, 21 received a passing grade in all disciplines, graduating to the next series, totalling 95.45% of participants. Only 1 (4.55%) was unsuccessful, having to repeat the same school year. However, it was found that socioeconomic factors directly influenced the student's failure, and not the student's lack of academic commitment.

In face of these results, we concluded that the objectives of this research were achieved, and that this approach brought benefits and motivation to those involved in this work.

VI. CONCLUSIONS

The research showed that Educational Robotics is an important teaching tool, which, together with planning of actions, can motivate and stimulate retention and success for students in their educational institution. This is possible if the work is directed at constructing a teaching environment in which the student is the central element, strengthening a more dynamic teaching-learning process, promoting autonomy, and providing opportunities for new discoveries for all the people involved.

With the practices carried out during the project, students were able to develop specific technical training skills and to build social relationships with other members of the group. Among these skills, we highlight the ability to solve problems, an important skill for the current job market. Abilities to develop autonomous and group work were favoured.

During the project, the students had the opportunity to comprehend the relationship between robotics and other areas of knowledge, such as Physics, Electronics, Mathematics, Foreign Language, in which each challenge required interdisciplinary knowledge, showing that knowledge is connected and interrelated, which favours the understanding of worldview and still collaborates with the STEM approach.

Some difficulties were detected during the research, such as access to more diversified and updated components, and infrastructure limitations where the practices occurred, which also limited the number of participants. We intend to continue carrying out other similar interventions, overcoming difficulties and correcting points that need to be improved.

This study serves as a basis for future research, and for encouraging the application of robotics and collaborative learning in the educational environment.

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