WIP: Educational Robotics Through Interdisciplinary Project-Based Learning in the Training of Teachers and Students in Professional and Technological Education

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***Abstract*—This WIP research-to-practice paper describes a training project in Educational Robotics (ER) for teachers and students of Professional and Technological Education (PTE) through Interdisciplinary Project-Based Learning (IPBL) carried out at the Federal Institute of Amazonas Campus Manaus Distrito Industrial (IFAM-CMDI), Brazil. Such training is due to the fact that currently, several High School students do not have the opportunity to have contact with contexts that promote and stimulate professional and technological skills. When they enter technical schools, in courses focused (mostly) on technological areas, they seek these skills. Among the actions to carry out this training was the acquisition and use of LEGO® and Arduino Robotics kits. This training was applied to teachers of different subjects and students belonging to the Integrated Technical Courses in Electronics and Mechatronics in High School at IFAM-CMDI. Students interacted with teachers and together they developed interdisciplinary projects. Each group made up of teachers and students were exposed to the proposed methodology, during the first semester of 2024. It is expected for the second semester of 2024 that encouraging the development of professional skills in participants will bring a change in academic stance with positive results, both in teaching and in student training, as the IPBL active methodology promotes the construction of skills for both, such as logical reasoning, critical thinking, decision making, work in groups with collaboration and negotiation of arguments, actively participation in the formulation of hypotheses, in addition to reflecting and evaluating the different stages and procedures of resolution problems.**

Keywords—Project-Based Learning; High School; Professional Skills.

I. Introduction

The traditional role of the school characterized by lesson planning, content transfer to students, assessments and attribution of grades is gradually transforming [1]. This transformation consists of the adoption of new teaching and learning methodologies that propose the decentralization of the teacher as a teaching agent and the possibility of the student being the protagonist of their knowledge [2]. Currently, many students in Brazil who come from Elementary School (in Brazil, called *Ensino Fundamental*) do not have the opportunity to have contact with contexts that promote and stimulate professional and technological skills. When they enter technical schools, in courses focused on technological areas, they seek comprehensive training, which encourages research, cultural production, entrepreneurship, and cooperativism, in addition to scientific and technological development. In this sense, the Federal Institute of Amazonas Campus Manaus Distrito Industrial (IFAM-CMDI), as it is located close to the Manaus Industrial Pole, seeks to guarantee its students the right to acquire professional skills that will provide their aptitude for admission and remaining satisfactorily in professional sectors, where there is the use and development of technologies.

Furthermore, in the current scenario of transformation in the way of thinking about teaching practices, the proposal of this paper focuses on teachers and students training for the use of Educational Robotics (ER), through Interdisciplinary Project-Based Learning (IPBL), in dynamic environments of maker culture, so that these projects enable students to acquire the elements necessary for their technical and comprehensive training.

Given this concern, this paper presents a training for teachers and students in ER, where they made use of IBPL. This approach sought to unify knowledge common to two or more disciplines, in an interdisciplinary way, and in this case, associated with the construction of an ER project, integrating knowledge and concepts from technical and basic disciplines, providing the students and teachers involved with a training not only for the world of work, but essentially for life, that is, integral human training. The choice of the theme of this project is justified by the growing importance of using ER as a tool that has been gaining prominence, especially with regard to Professional and Technological Education (PTE), that is in accordance with the normative documents of Brazilian Education [10] [11], with the aim of encouraging teachers to carry out interdisciplinary practices, through projects, aiming to improve the teaching-learning process, leading students to fully understand academic concepts and their applicability to the real life. In this way, the continued training of teachers is a relevant topic, in terms of knowledge and teaching praxis, above all, from a theoretical-practical perspective, necessary for their preparation, in order to work in the most diverse educational contexts.

Among the actions defined to carry out this work was the acquisition and use of LEGO® Robot Inventor/Spike kits, in addition to Arduino, considered reference kits in ER. This training was applied in the first semester of 2024, for teachers and students of Integrated High School in Electronics and Mechatronics at IFAM-CMDI, to also improve the level of knowledge and maturity acquired by students during their academic training. Each group were exposed to the proposed methodology, so that they have enough time to create, develop, and finalize projects, since their projects will finalize in the second semester of 2024.

Thus, this work aims to promote teacher and student training in ER and maker culture, through IPBL, where teachers guided their students to apply school concepts in solving problems commonly found in people's real everyday lives, through practices associated with the application of Robotics, developing Computational Thinking (CT) skills. The main contribution of this paper is the application of the IBPL methodology, integrated with maker culture by interactions between teachers and students. This was done through training of teachers and students to develop and execute ER applications. The focus of this work is on the pedagogical method used in the training, which includes skills development from both teachers and students.

II. Theoretical Background

IPBL constitutes an aspect of Project-Based Learning (PBL) [3], a teaching method in which students learn by actively engaging in real-world and personally meaningful projects, over an extended period, from a week up to a semester, that engages them in solving a real-world problem or answering a complex question involving more than one area of knowledge In this context, IPBL has proven to be an enriching and significant methodology in professional courses, especially with regard to the teaching of basic and technical subjects at same time, as it is clear that the development of teamwork promotes collaboration, planning, research, decision-making processes, as well as interaction between participants in a lively atmosphere that allows conflicts to be managed, respects ideas, opinions and enables the search for a common result, as shown in ROBÔ-TI project, executed at IFAM-CMDI [4]. Likewise, ER have been gaining space as an important tool for promoting interdisciplinarity, standing out both for their playful nature and for allowing the construction of different automated environments for different contexts. Furthermore, when considering professional courses, the use of ER can provide STEAM (Science, Technology, Engineering, Arts and Mathematics) training and many benefits, given that they are used to build more specific knowledge, such as the basic concepts of Mechanics, Kinematics, Automation, Hydraulics, Informatics and Artificial Intelligence, involved in the operation of a robot. Therefore, providing learning environments based on robotic devices that allow the construction of integrated knowledge between the most different disciplines contributes to overcoming the fragmentation of knowledge and segmentation of the curricular organization, therefore achieving interdisciplinarity. In turn, maker culture (or movement), within the “do-it-yourself” or “hands-on education” process, consists of creating and modifying objects or projects, where its main pillar is the idea that anyone can make, build, repair and alter objects of the most varied types and functions with one’s own hands, with collaboration and transmission of information between groups and people using one or several resources [5]. Therefore, when working with maker culture to develop an interdisciplinary project, students were introduced to a context of scientific training that allowed them to develop and apply the concepts acquired in classes for technological production [6]. Also, it is expected that the stimulation of Computational Thinking (CT) will bring a change in academic stance in second semester of 2024, both in teaching and training of PTE students, as CT promotes the construction of skills, such as logical reasoning, critical thinking, decision making, ability to recognize patterns, systematize abstract and logical reasoning, work in groups with collaboration and negotiation of arguments, actively participate in the formulation of hypotheses, in addition to reflecting and evaluating the different stages and procedures of problem solving [7]. These skills, when acquired, will certainly be applied in their daily life and professional practice for everyone involved.

III. Applying the IPBL Methodology

This work is being applied in the two academic semesters of 2024, divided into two stages: teacher training (in active methodologies and ER for building interdisciplinary projects, only in the first semester) and student guidance (for implementing projects through ER and maker culture, in both first and second semesters). All stages will be explained below.

A. Stage 01 - Teacher Training: Educational Robotics and Maker Culture

The teacher training was carried out by 1 teacher of Portuguese Language, who was part of the 21st Century Educators Training Program of the ARANOUÁ Project in 2023. This program was financed by Samsung of Amazônia (SEDA) and was based on teacher training for skills and interdisciplinarity, in order to expand operations in the area of education. The learning was adapted for teachers from various areas of knowledge and aimed at the development of skills by combining theory and practice in teaching of their own area of specialization, in multifunctional spaces, with active and innovative educational methodologies and technologies.

The teacher training also included 1 Informatics teacher who already works in ER and maker culture and 1 student from the Higher Course of Technology in Industrial Mechatronics, experienced in these areas either. In teacher training, initially a presentation of the project was made, its objectives, dynamics, days and times of meetings. It had the following topics: Leveling teachers' knowledge about IPBL; maker culture; Computational Thinking; Introduction to Arduino; Introduction to LEGO® Robot Inventor/Spike; project planning and execution. This stage took 20 hours. In other meetings the objectives to be achieved, the expected results and the interactions between teachers and students were also aligned. The types of student evaluations were also defined, in addition to the parameters for global evaluation of the success and scope of the project.

Fig. 1 presents one of the teacher training meetings in the first semester of 2024, with an explanation about maker culture. Teachers from different areas participated in this training: 3 from Portuguese Language, 1 from Physics, 1 from Chemistry, 1 from Mathematics, 1 from Control and Automation, and 1 from Informatics.

Fig. 1. Teacher training on maker culture.

B. Stage 2 – Presentation of the project and guidance of students by the teachers involved

After the teacher training stage, the teachers presented the IPBL and ER methodology to students, as well as analyzing whether the students had any interest in the proposed approach. Then, the interested students were divided into teams, observing interpersonal relationships, promoting integration, exchange of knowledge and expectations of the group's components. From then on, the conception of the interdisciplinary project began, with the definition of the project to be developed by each team, based on a guiding project being provided by each teacher. At this stage, teachers only act as advisors, leading students, organizing groups for integration, answering questions and giving suggestions, in addition to helping students with their planning and checking what materials will be needed to develop the project. Fig. 2 shows interactions between students, in an introduction workshop to Arduino and LEGO®, held in the first semester of 2024.

During the Stage 2, the teacher, being a mediator, interposes and selects external stimuli and acts as a learning facilitator. The problem to solve is responsible for stimulating curiosity, the sense of contribution, and analysis of scenarios to emerge in a solution, as well as the teamwork, as this deals with interpersonal relationships, conflict management and the dynamics of communication between students.

When carrying out the activities, students were trained, within IPBL, to use the following LEGO Education 4Cs [8] Processes:

I) Connect: establishes a connection between the student's previous knowledge and new knowledge. At this moment, the student comes into contact with the topic in which they will work in the next phase, and the teacher invites the student to participate in the practical activity, which will be carried out in this phase;

II) Construct: Active learning involves two types of construction: physical and mental. In other words, when students build artifacts in the "real" world, they simultaneously build knowledge in the mind. The process of physically constructing models provides a fertile learning environment for the mediation process to be carried out by the teacher, who will negotiate conflicts, listen to different ideas and opinions regarding the same proposed problems and provide guidance on the rational and effective use of technology and the acquisition of new knowledge;

Fig. 2. Interactions between students in an Introduction to Arduino and LEGO® workshop.

III) Contemplate: students are led to think about how their constructions work, experimenting, observing, analyzing, correcting possible errors, and thus validating the project. By analyzing what has been done, they have the opportunity to deepen their knowledge. As a result, they develop connections between previous knowledge and new experiences;

IV) Continue: students are invited to solve a problem situation. Thus, the student remains in a state of intrinsic motivation, making the teaching-learning process cyclical and continuous.

So, students continued implementing the projects, putting them into practice, that is, developing the projects according to planning. This is the time when students most developed their autonomy, responsibility with deadlines, and collaborative work; teachers remained mentors.

Some interdisciplinary projects applications emerged from student teams guided by professors in the first semester of 2024, which are ongoing and will finish at the end of second semester, including:

- A programmed tabletop robot that has the ability to teach a programmed class, to achieve greater student interest, in addition to making the class more interactive and fun, uniting the Portuguese Language with Robotics with a question-and-answer game, for example. For a correct answer, the green LED lights up; for a wrong answer, the red LED lights up.
- Use of Arduino and Scratch for Animatronic Robots.
- Educational Robot for Clarifying Disciplinary Questions, to solve questions related to the grammatical content of the Portuguese language.
- A color selector robotic arm, with the aim of teaching basic programming notions of the Information Technology area. This arm was built with 3D printing, servomotors and Arduino, which controls it. Fig. 3 shows the constructed robotic arm.

- An experiment with Arduino and Light-Dependent Resistors (LDR) to teach the propagation of electromagnetic waves, involving Physics.

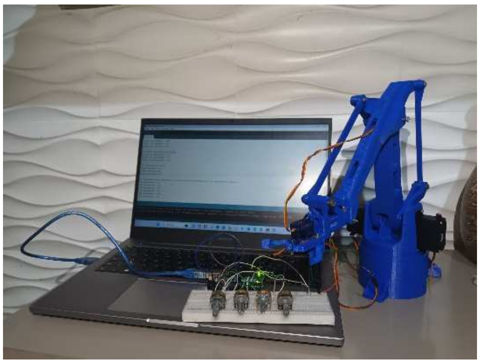

Fig. 3. Robotic arm built in one of the projects.

During the development of the projects, partial follow-up evaluations were carried out, so that the teachers involved could provide feedback to the students on the activities developed, in addition to encouraging them to continue, even in the face of possible difficulties. At the end of these projects, participating students will present their work, showing the problems established and the proposed solutions. Preferably, the presentation of these works will take place in the form of a maker faire in second semester of 2024. The teachers involved in the project will be part of the evaluation, as the presentations can also be evaluated by other teachers, students, and external audiences.

IV. Preliminary results

The success of this work and the use of its learning methodology should be measured based on the idea of a school that provides integral human education for its students. In order to obtain feedback from the 8 teachers that participated in the first semester of 2024, we created a questionnaire based on the Likert scale (1-Totally Disagree; 2-Partially Agree; 3-Neutral; 4-Partially Agree; 5-Totally Agree), about the training that took place, with the following questions:

- Q1: Was the execution of the training workshops for teachers and students at IFAM-CMDI, in Educational Robotics, through IPBL and maker culture, positive?
- Q2: Did the explanations about IPBL and Maker Culture meet your expectations?
- Q3: Do you agree that the workshops provided teachers and students with a practical vision of the possibilities of working on interdisciplinary content through robotic constructions and experiments?
- Q4: From your participation in the workshops, do you feel encouraged to use Computational Thinking to analyze and propose solutions to educational problems presented in your daily life in the classroom?
- Q5: Was the equipment (notebooks, LEGO® and Arduino kits) available in the workshops sufficient to provide learning?
- Q6: Did your participation in the robotics project workshops serve as a basis for you to choose to guide a student in a project?
- Q7: What can we do to improve training workshops in future projects?

Table I shows a summary of how many teachers chose each alternative for each question (in %). Q7 was a discursive question and will be discussed later.

TABLE I. Teachers' Answers (%).

Question	Teachers' answers (%)				
	1	*2*	*3*	*4*	*5*
Q1	0	0	12.5	12.5	75
Q2	0	0	12.5	12.5	75
Q3	0	0	0	0	100
Q4	0	0	12.5	25	62.5
Q5	0	0	37.5	0	62.5
Q6	25	0	0	0	75

We can see, based on the responses in Table I, that although the majority of teachers presented positive responses about their impressions of the training, there are still points to be improved. One of the items that drew a lot of attention was the fact that we did not have much equipment available for teachers and students, which influenced the neutral answers in Q5. Regarding Q7, most teachers mentioned that it would be better to have more space available and more materials, such as laptops. Furthermore, a suggestion from a teacher was to use the experience report from this first moment, so that teachers feel more confident in relation to the success of practicing the methodology used in addition to Computational Thinking.

In addition to the teachers, we also questioned the students to obtain their perceptions about this training. Of the 20 students participating in the workshops, 12 responded. Questions Q1 to Q5 were the same as those applied to teachers. Questions Q6 to Q9 were as follows:

- Q6: Did you feel confident in applying Maker Culture to solve everyday problems with the knowledge gained during the workshops?
- Q7: Regarding the Arduino and Lego Kit workshop, were the guidelines and knowledge passed on sufficient to apply to current or future projects?
- Q8: What was the biggest difficulty experienced during the practical Arduino and Lego Kit workshops?
- Q9: Tell us what we can improve for the development of workshops in future projects.

Table II shows a summary of how many students chose each alternative for each question (in %). Q8 and Q9 were discursive questions and will be discussed later.

Based on student responses summarized in Table II, student evaluations were partly neutral and partly positive. Although it is not a perfect result in relation to the approach taken, this motivates the training team to continue the IPBL process with students and teachers, but making adjustments and improvements in relation to the availability of equipment and materials in the classroom, besides the methodology applied, making learning more fun and students motivated.

TABLE II. STUDENTS' ANSWERS (%).

Question	Students' answers (%)				
	1	*2*	*3*	*4*	*5*
Q1	0	8.3	16.6	33.3	41.8
Q2	0	0	33.3	33.3	33.4
Q3	0	0	16.6	0	83.4
Q4	0	0	41.6	33.4	25
Q5	0	0	41.6	0	58.4
Q6	0	25	8.3	33.3	33.4
Q7	0	0	8.4	41.6	50

As for Q8, the students were divided into 3 groups: those who had no difficulties, those who had some difficulties with programming the robots, and those who had difficulties with assembling the LEGO® Robot. And regarding Q9, the students suggested that to improve the workshops, there should be more equipment, such as laptops and robotics kits, more meetings during the week between teachers and students to carry out the workshops. One student pointed out that there should be greater discussion between students and teachers and greater dissemination of the project at IFAM-CMDI.

The preliminary results obtained in this work served as a basis for improvements in the approach presented in this paper for future approaches.

V. FINAL CONSIDERATIONS AND EXPECTED RESULTS

Utilizing the IPBL methodology with ER and maker culture, extracting the best of both with interactions between teachers and students in a positive symbiosis will be the significant contribution of the continuation of this work. Additionally, it highlights the necessary redefinition of the teacher's role. In this new context, the teacher is no longer the possessor of knowledge and a verifier of learning but rather a coach who facilitates an environment where students are the main actors in their learning. More specifically, this work aims to achieve the following outcomes:

- Training of teachers in ER, maker culture and active methodologies, mainly IPBL, so that they acquire favorable subsidies for their development in new pedagogical practices, thus improving the quality of their classes;
- Motivation of teachers and students to develop Computational Thinking to analyze and make solutions to proposed problems;
- Medium and long-term increase in the number of students trained to enter the world of work, in sectors focused on the development and application of technological knowledge in a practical and proactive way;
- Allow the student to manage their feelings and expression, knowing how to communicate, verbalize their knowledge and experiences, developing the skill to argue and generate their critical sense.

Furthermore, this teacher and student training project seeks to promote quality education, in accordance with the United Nations 2030 Agenda, and its 17 Sustainable Development Goals (SDG), especially with Goal 4, which commands "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". With regard to Target 4.4, it commands "By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship" [9]. Therefore, this is another expected result to be achieved in the future.

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REFERENCES

[1] L. Bacich and J. Morán. Active methodologies for innovative education (Metodologias Ativas para uma educação inovadora), Porto Alegre/BR. Penso Editora, 2018.

[2] V. Bremgartner, P. Fernandes, J. Sousa and J. C. Souza, "Project-based learning applied to initial and continuing training courses in the Maker Culture", Rev. Ibe. Est. Ed., vol. 17, nº 3, p. 1943–1957, jul. 2022.

[3] M. A. Almulla, "The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning", SAGE Open, vol. 10. N. 3, July 2020. https://journals.sagepub.com/doi/abs/10.1177/2158244020938702.

[4] J. M. d. Santos, V. Bremgartner, J. P. Queiroz-Neto, H. Lima and M. Pereira, "ROBÔ-TI: Educational Robotics and Project-Based Learning Stimulating High School Students in the Information Technology Area," 2019 IEEE Frontiers in Education Conference (FIE), Covington, KY, USA, 2019, pp. 1-8, doi: 10.1109/FIE43999.2019.9028401.

[5] P. Blikstein, "Maker Movement in Education: History and Prospects," M.J. de Vries (ed.), Handbook of Technology Education, Springer International Handbooks of Education, DOI 10.1007/978-3-319-44687-5_33, 2018.

[6] L. Melo, V. Bremgartner and D. Fonseca. "Using Interdisciplinary Maker Culture with Arduino to Teach Thermodynamics and Computer Programming", ICERI2020 Proceedings, pp. 3042-3047, 2020.

[7] J. Wing. "Computational Thinking". Communications of the ACM, 3 ed.:33-35, 2006.

[8] LEGO Education Academy Planning Your Lesson, 2023, https://education.lego.com/en-us/academy-training/planning-your-lesson/

[9] United Nations. The 17 Sustainable Development Goals (SDGs) of United Nations (UN) 2024, https://sdgs.un.org/goals

[10] MEC. BRAZIL Ministry of Education of Brazil, (2017), Base Nacional Comum Curricular (BNCC), Brasília, BR, [Online]. Available: http://basenacionalcomum.mec.gov.br/images/BNCC_EI_EF_110518_versaofinal_site.pdf

[11] MEC. BRAZIL Ministry of Education of Brazil, (2020). Professional and Technological Education (PTE), Brasília, BR, [Online]. Available: https://www.gov.br/mec/pt-br/acesso-a-informacao/institucional/estrutura-organizacional/orgaos-especificos-singulares/secretaria-de-educacao-profissional/educacao-profissional-e-tecnologica-ept