

BETWEEN PROTOTYPES PROJECTS AND CREATIVE PROCESSES - EDUCATIONAL ROBOTICS TAKES SHAPE THROUGH THE MAKER CHALLENGE

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Abstract

The integration of Maker Culture and Educational Robotics emerges as a promising pedagogical approach for reshaping teaching practices, shifting the student from a passive consumer to an author and protagonist of their own learning process. The activities developed are primarily aimed at Basic Education teachers and university interns who act as supporters and multipliers of the project, playing a strategic role in technological mediation, peer training, and the sustainability of maker practices in schools. The project starts with the analysis of real problems in the school community and its surroundings, giving social meaning and relevance to the technological solutions developed by the students. The methodology adopted follows the Problem-Based Learning (PBL) model, articulated with Project-Based Learning, so that each maker challenge originates from a concrete problem situation, investigated and transformed into an opportunity for creative intervention through prototyping and automation. The analyzes are predominantly based on Seymour Papert's (1980) constructionism, for whom meaningful learning stems from the construction of shareable artifacts, and on Mitchel Resnick's (2017) perspective on creative learning, structured around projects, peers, and playfulness. Contemporary authors, such as Paulo Blikstein (2013, 2020) and Leo Burd (2016), expand this framework by associating Maker Culture with technological democratization, educational equity, and the development of computational thinking. The methodological structure is organized as a Maker Challenge, comprising: awareness-raising and participatory diagnosis, collaborative ideation, solution planning, prototyping with recyclable materials and open platforms such as Arduino, programming, iterative testing, and socialization of results. The activities are distributed into categories—automata, creative circuits, motorization, programming with Scratch, and automation with sensors—always guided by the appreciation of the investigative and construction process. The assessment, of a formative and continuous nature, prioritizes reflective records, peer collaboration, creativity, and the ability to iterate solutions. It is concluded that the articulation in the project between maker activities and educational robotics constitutes a fertile ecosystem for pedagogical innovation, fostering critical thinking and strengthening links between technology, sustainability, and social participation, especially when mediated by educators committed to authorship and equity.

Keywords: *Maker culture, educational robotics, creative learning, problem-based learning, constructionism.*

1. Introduction

The growing presence of digital technologies in contemporary society imposes on schools the challenge of redefining their pedagogical practices, overcoming transmission models and incorporating approaches centered on authorship and experimentation. This imperative intensifies in institutions that serve working-class populations, contexts in which access to technologies is not distributed equitably among students. In this scenario, the articulation between maker activities and educational robotics emerges as a powerful formative strategy, promoting technological creation experiences guided by the resolution of real problems. Far from technocratic or merely instrumental perspectives, this integration constitutes a space for investigation, imagination, and materialization of ideas, in which error is an inherent component of the process, collaborative work is systematically encouraged, and learning develops in a situated and meaningful way.

It is hoped that this will contribute to the debate about pedagogical strategies capable of bringing the school closer to the languages and logics that structure the contemporary technological world, without losing sight of the principles of equity, collaboration, and critical thinking that should guide all transformative educational practices.

In parallel, the research seeks to encourage scientific initiation and the implementation of structured technological activities, enabling students to act as active subjects in the construction of their own knowledge. In this context, the practice of robotics aims to provide opportunities for the development of fundamental cognitive and socio-emotional skills, with an emphasis on logical reasoning, creativity, autonomy, and student leadership. Ultimately, by enabling such experiences, the project intends to consolidate an environment of multiple learning experiences, in which practical and technical work serves as support for the exercise of critical, reflective, and transformative thinking in the face of contemporary technological reality.

2. Literature review and theoretical framework

Maker culture, consolidated as a socio-technical movement founded on the principles of *Do It Yourself* (DIY) and *Do It With. According to Dougherty* (2012), the democratization of the means of technological production represents a shift from exclusively occupying the role of consumers to becoming active producers of technology. In this perspective, Blikstein (2013, 2020) advocates for *makerspaces* as laboratories of educational innovation—environments where students learn science and engineering through invention—while Burd (2016) emphasizes the inclusive potential of this culture, especially in contexts of social vulnerability, by enabling critical and creative access to technologies. Learning based on hands-on experimentation is, therefore, a structuring element of this movement, fostering cognitive engagement, creativity, and autonomy in formative processes.

In the field of educational robotics, the theoretical foundations are rooted in Seymour Papert's (1980) constructionism, which posits that learning occurs more meaningfully when the subject constructs shareable artifacts—programming, assembling, and testing prototypes thus becomes a way of thinking about their own knowledge. Resnick (2017) expands on this view by proposing creative learning structured around the four Ps: *Projects*, *Passion*, *Peers*, and *Play*, reaffirming that robotics projects allow students to develop ideas with personal meaning, collaboratively and playfully. Open platforms in education, such as Arduino, reduce technical and economic barriers, favoring the understanding of real-world projects.

Computational thinking, defined by Wing (2006) as a set of skills involving problem decomposition, pattern recognition, abstraction, and algorithm creation, is articulated within this set of perspectives. In maker robotics, such skills emerge from concrete and contextualized situations—activating a motor, automating lighting systems, or developing environmental sensors—demonstrating that technological learning does not depend exclusively on sophisticated equipment, but, above all, on pedagogical intentionality and a clearly delineated formative project.

Given this theoretical landscape and the contemporary demands for more active and meaningful educational practices, this article aims to analyze the theoretical and methodological foundations of the integration between maker culture and educational robotics, as well as to propose a practical activity structured in the form of a maker challenge, with an emphasis on prototyping processes with accessible materials and open platforms, transforming traditional classrooms into technological creation spaces ("*makerspaces*").

3. Objective

The Maker Challenge is an offshoot of the Educational Robotics Project, developed since 2015 in the Niterói Municipal Education Network. It is an essentially interdisciplinary proposal whose general objective is to foster integration between the various areas of knowledge that make up the curriculum, providing students with a comprehensive experience in building prototypes and functional physical models. In developing this research, specific objectives are outlined that primarily aim to identify and map teachers with a scientific vocation, in order to establish a network of multipliers capable of disseminating the methodology in the school environment.

4. Projects and methods

The Interns Project provides the necessary support to school teachers in all work done with technology. The interns, future teachers in different areas of knowledge—such as Mathematics, Portuguese Language, among others—are trained by the pedagogical team of the Municipal Department of Education (SME), responsible for assisting in the use of technology in daily school life and for conducting training workshops. This training team is composed of specialists, masters, and doctors with experience in educational technology. The teachers participated in two workshops, on different days, with the SME team providing assistance in the schools when necessary, with the aim of supporting the activities developed in the schools.

Workshop Stages and Procedures:

- A. Awareness and Problem-Solving: Discussion about everyday school or community problems—such as energy waste, flooding, and accessibility—and their possible solutions. The group of teachers collectively selects a problem to be analyzed and discusses possible solutions. Starting with the second workshop, this phase also includes sharing the progress and difficulties observed in practice with the students.
- B. Workshop Ideation: The group is divided into five categories, with no restrictions on the number of participants. The SME team leads the workshop, and the groups define the technological solution—preferably automated—that represents the answer to the identified problem, according to the following categories:
 - Category 1 — Automata: Machines with mechanical movement, usually operated by a crank, that imitate the movement of living bodies.
 - Maker Experimentation with Simple Electrical Circuits: Assembling prototypes with low-cost materials, such as LEDs, aluminum foil, modeling clay, and reusable materials.
 - Category 3 — Motorization: Activities with simple circuits and motors, and prototypes built with reusable or low-cost materials.
 - Category 4 — Programming/Scratch: Programming activities and representation of solutions using the Scratch environment.
 - Category 5 — Automation: Prototyping with Arduino interface, an electronic prototyping platform that enables automated control of prototypes.

Note: These categorizations allow teachers to develop projects suitable for different educational levels, with each group able to select one or more categories according to the level of their students.
- C. Prototype Design: Creating sketches, defining materials, and specifying how the device will function.
- D. Maker Construction, Circuit Assembly and Programming: Structural assembly with low-cost and recyclable materials; insertion of LEDs, motors and sensors; and coding in blocks or simplified language associated with Arduino, with a view to automating prototypes.
- E. Testing and Iterations: Construction of a model representing the solutions developed by the different groups.
- F. Socialization and Culmination: Teachers adapt the workshops to the reality of their classes and pedagogical projects for application in schools, preferably with the help of other teachers from the school. The culmination occurs with the presentation of the activities carried out by all participating school units.

5. Assessment

The evaluation of maker activities and educational robotics moves away from the traditional metric based on the "right or wrong" dichotomy to consolidate itself as a process-oriented and formative monitoring, in which learning is understood as a continuous flow, and not as a static result. In this paradigm, the centrality of the educational process relegates the final product to a secondary role, privileging the investigative path taken by the student.

The analysis begins with observing participation and collaboration, evaluating how the student interacts with the group, shares knowledge, and manages collective dynamics in problem-solving. Creativity in solutions is observed not only through aesthetic originality but also through the ability to apply limited resources innovatively to overcome technical challenges. Fundamentally, the capacity to test and iterate—the essence of engineering thinking and the maker approach—is valued, where error is not penalized but treated as valuable data for the continuous improvement of the prototype.

To document this evolution, procedural documentation becomes an indispensable tool, functioning as a portfolio of evidence that demonstrates the hypotheses raised and the paths discarded throughout the project. Finally, the evaluation culminates in the argumentation during the presentation of the models developed by all the schools. This is the moment when the student must be able to logically articulate their choices and defend the decisions made throughout the process. Therefore, the focus is on building critical thinking and student autonomy, ensuring that effective learning is anchored in lived experience, and not just in the final product created.

6. Discussion

Implementing maker -based projects in an educational environment demands a shift in perspective, where the pedagogical focus moves from the final product to the investigative journey and the development of the student's self-awareness. In this process, teacher mediation should foster moments of reflective pause, in which teachers and students are encouraged to analyze their own actions. This process begins with a critical analysis of the technical and conceptual obstacles encountered during prototyping, transforming error into an indispensable didactic variable for understanding the complexity of the object of study. By debating the strategies used to solve problems, the groups develop not only cognitive skills but also socio- emotional skills linked to resilience and horizontal collaboration.

Figure 1. The three images refer to the culmination event with all the schools participating in the Maker Challenge. In the first image on the left, a teacher makes adjustments to the program that automates the model; to the right of this image, two students explain a game they built; subsequently, one of the trainers displays the model produced by teachers during the workshops.



The practice of iteration—the act of testing, evaluating, and modifying—becomes the central axis of learning, leading teachers and students to design changes and refinements to the original prototype as an exercise in design thinking. Beyond technical mastery, the pedagogical journey seeks to contextualize knowledge, prompting students to perceive the socio- environmental impacts of their creations. Thus, by reflecting on the applicability of the solution in the community and the ethical commitment between technology and sustainability, learning transcends the instrumental dimension and reaches a critical-reflective sphere. The academic path of educational robotics is validated by the student's ability to document their progress, argue their choices, and recognize themselves as a subject capable of transforming reality through conscious innovation.

7. Conclusions

The integration of maker activities and educational robotics proves to be a powerful strategy for reshaping pedagogical practices, shifting the student from the position of technological consumer to that of solution creator. By emphasizing projects, prototyping, and experimentation—practices that promote meaningful, interdisciplinary, and socially contextualized learning—it is observed that the combined use of low-cost materials and open-source electronic prototyping platforms broadens access and strengthens educational equity. The exchange of experiences among teachers of different specialties and from different segments of Basic Education proves to be particularly enriching for the consolidation of a collaborative pedagogical culture.

It is concluded that maker projects in educational robotics constitute formative ecosystems capable of developing computational thinking, creativity, and student leadership, contributing to an education aligned with contemporary demands without abandoning its humanizing commitment.

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