Maker Culture and Sustainability in Basic Education

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Abstract

This paper examines the integration of the Maker Culture into the pedagogical practices of teachers working in the early years of primary education as a strategy for developing socio-environmental competencies aligned with the Brazilian National Common Core Curriculum (BNCC) and the Sustainable Development Goals (SDGs). Adopting a qualitative approach, the study is designed as a case study with action research characteristics and was conducted in a philanthropic school located in the municipality of Tremembé, São Paulo, Brazil, involving five teachers and 94 students. The theoretical framework is grounded in Critical Environmental Education, active learning methodologies, the Maker Culture, and the Educational Psychogenetics proposed by Fr. Joaquim Ferreira Xavier Jr, sjr. The investigation combined a literature review, questionnaires and interviews, teacher training workshops, pedagogical monitoring, and the implementation of sustainable maker practices. The findings indicate that, although teachers recognised the importance of sustainability, their initial practices were isolated and insufficiently integrated into the curriculum. Following the training process, greater interdisciplinarity, increased student agency, and significant changes in socio-environmental attitudes were observed. The study concludes that the Maker Culture, when integrated with Environmental Education and Educational Psychogenetics, represents a promising pathway for pedagogical innovation and the development of critical citizenship in Basic Education.

Keywords: Maker Culture, sustainability, environmental education, teacher education, educational psychogenetics

Introduction

The contemporary environmental crisis poses complex challenges to school education, requiring pedagogical approaches capable of integrating scientific knowledge, ethical development, and social responsibility. In Brazil, the National Environmental Education Policy (Law No. 9,795/1999) establishes Environmental Education as a continuous, integrated, and cross-curricular practice across all levels of education (Brasil, 1999). In this context, the Brazilian National Common Core Curriculum (BNCC) reaffirms the role of schools in fostering critical, responsible, and sustainability-oriented citizens (Brasil, 2018).

Maker Culture has emerged as a pedagogical approach capable of addressing these challenges by emphasising learning through making, authentic problem-solving, collaboration, and creativity (Bacich & Moran, 2017; Valente, 2018). By bridging theory and practice, Maker Education promotes meaningful learning experiences, particularly in the early years of primary education, a critical stage for the development of values, attitudes, and lifelong habits.

This study is also grounded in the Educational Psychogenetics developed by Fr. Joaquim Ferreira Xavier JR, whose work highlights the role of proprioceptive experiences, concrete action, and subject–object interaction in the construction of knowledge (Xavier Jr., 2006). According to the author, cognitive and ethical development emerges through lived experience, experimentation, and the learner's active engagement with the surrounding world—principles that closely align with the Maker approach.

The aim of this paper is to analyse how the integration of Maker Culture into teachers' pedagogical practices contributes to the development of socio-environmental competencies and to the consolidation of sustainable practices in Basic Education.

Theoretical Framework

Maker Culture originated in the *Do It Yourself* (DIY) movement, which gained momentum through the widespread availability of accessible technologies, the growth of the sharing culture, and the appreciation of collaborative creation (Anderson, 2012; Zylbersztajn, 2015). Historically, DIY extends beyond a technical practice and represents a cultural attitude centred on authorship: repairing, adapting, building, and recreating become actions that shift individuals from the role of passive consumers to active producers of meaning and solutions. As access to digital resources and open-source culture expanded, this logic of authorship intensified and became institutionalised within networks, communities, and collaborative environments such as makerspaces and hackerspaces, where knowledge is generated through experimentation, trial and error, the sharing of prototypes, and collective refinement (Zylbersztajn, 2015). Anderson (2012) interprets this movement as part of a broader transformation in contemporary production, whereby tools once restricted to industrial settings have become locally accessible, fostering distributed innovation and solutions driven by real-world needs.

Within education, this approach challenges the traditional transmission-based model by promoting practices centred on the learner, inquiry, and experimentation (Papert, 1994). Learning is understood less as the passive reception of information and more as an active process of creation: producing tangible artefacts, testing hypotheses, observing outcomes, and refining solutions transform the classroom into a space of investigation and authorship. From this perspective, Papert's constructionism argues that thinking develops most effectively when

learners create meaningful artefacts that externalise their reasoning processes, thereby fostering metacognition and conceptual refinement (Papert, 1994). From a curricular perspective, this implies reorganising educational objectives, learning time, and teaching methods so that "making" becomes the central organising principle of learning. Projects become the primary unit of educational experience, integrating knowledge, procedures, and values around authentic, context-based problems.

At this point, the contribution of Fr. Joaquim Ferreira Xavier Jr, sjr. provides an important conceptual foundation for interpreting Maker Culture in the early years of primary education. Through the development of Educational Psychogenetics, Xavier argues that children's cognitive activity is primarily logical-concrete, relying on manipulation, interaction with physical objects, and sensorimotor experiences for the consolidation of coherent cognitive structures (Xavier Jr., 2006). This perspective shifts learning from the abstract domain to that of guided experience, where learning consists of performing actions, recognising patterns, constructing relationships, and reorganising psychological structures through processes of reversal and reversibility—that is, operations progressively refined through practice, comparison, and reflection upon one's own actions (Xavier Jr., 2006). Consequently, Maker Culture does not merely "fit" childhood because it is engaging or enjoyable; rather, it responds to an epistemological requirement of child development. Children between six and ten years of age learn more effectively when they are able to experiment, manipulate materials, make mistakes, reconstruct ideas, and integrate their experiences into increasingly stable cognitive schemas (Xavier Jr., 2006). Within this framework, curiosity—commonly regarded as the driving force of Maker Education—can be understood as both an attentional and affective condition for learning: novelty evokes emotion, and emotion enhances attention, facilitating knowledge retention and cognitive reorganisation (Xavier Jr., 2006).

According to Bacich and Moran (2017), active learning methodologies promote greater engagement and meaningful learning by involving students in contextualised problem situations that require participation, collaboration, argumentation, and decision-making. Maker Culture operates through practical challenges and design-based problems that encourage learners to conceive, test, and validate solutions while integrating critical thinking and creativity. Valente (2018) further argues that these practices are aligned with the competencies required in the twenty-first century, as they simultaneously mobilise cognitive, intrapersonal, and interpersonal dimensions, fostering collaboration, problem-solving, and autonomy. From Xavier's perspective, however, autonomy should not be regarded merely as an abstract educational objective but rather as a progressive achievement grounded in experience. Through active engagement with the surrounding world and with material objects, learners expand their capacity for action, develop awareness of their own learning processes, and acquire the confidence necessary to undertake intellectual and practical challenges (Xavier Jr., 2006). Consequently, Maker Culture may be understood as a pedagogical environment that supports the maturation of psychological mobilisation and cognitive elaboration because it provides concrete situations of purposeful action guided by explicit goals and evaluative criteria (Xavier Jr., 2006).

When integrated with Environmental Education, Maker Culture enhances critical reflection on the use of natural resources, responsible consumption, and socio-environmental responsibility (Carvalho, 2012; Jacobi, 2003). This occurs because maker activities, through their emphasis on materials, waste, reuse, and prototyping, make visible aspects of consumption that often remain unnoticed, including resource origins, material life cycles, and environmental impacts. Environmental Education, conceived as a political and pedagogical process, seeks to develop

individuals capable of understanding the complexity of socio-environmental issues and participating collectively in the search for sustainable solutions (Jacobi, 2003). Maker experiences provide an appropriate context for integrating reflection and action, enabling students to experience practices such as reduction, reuse, and recycling within authentic school projects rather than treating these concepts merely as theoretical principles. Carvalho (2012) argues that schools can foster environmental ethics through dialogue among different forms of knowledge and collaborative action. By organising learning around teamwork and co-creation, Maker Culture strengthens this collaborative and community-oriented dimension.

The United Nations 2030 Agenda further reinforces the role of education as a fundamental pillar of sustainable development, particularly through Sustainable Development Goal 4 (Quality Education) (UN, 2015; UNESCO, 2017). UNESCO (2017) emphasises that education for the Sustainable Development Goals should foster competencies such as critical thinking, collaboration, empathy, and the capacity to address complex problems. Sustainable maker projects connect global challenges with local realities, promoting situated citizenship by enabling students to recognise that everyday decisions—such as water consumption, waste management, and material reuse—have tangible consequences and can be transformed through conscious and collective action. Furthermore, Maker Culture encourages interdisciplinarity by integrating science, mathematics, language, and the arts in the creation of objects, campaigns, prototypes, and narratives, thereby narrowing the gap between curriculum and everyday life.

Within this framework, Xavier's research broadens the educational scope of these practices by explaining why learning for sustainability must be experiential rather than merely informational. If, as proposed by Xavier, the human capacity for innovation is supported by the learner's plasticity and progressive reorganisation when confronted with authentic challenges, then education for sustainability becomes coherent when structured around experiences that engage the body, perception, action, and reflection (Xavier Jr., 2006). Sustainability thus becomes simultaneously content, method, and ethos: it is not simply a topic to be studied but a way of acting and making decisions, developed through practice, intentional pedagogical mediation, and continuous opportunities for revision and improvement. Consequently, the articulation between Maker Culture, Environmental Education, and the 2030 Agenda may be understood as a comprehensive pedagogical strategy for holistic education. By learning through making, students develop cognitive, social, and ethical competencies while internalising habits and values grounded in responsibility and care for the shared world (UN, 2015; UNESCO, 2017; Xavier Jr., 2006).

Methodology

This study adopts a qualitative applied research approach and is designed as a case study with characteristics of action research (Marconi & Lakatos, 2010; Thiollent, 2011). The research was conducted in a philanthropic school located in Tremembé, São Paulo, Brazil, serving students in the early years of primary education. The school is situated in a predominantly rural area characterised by social vulnerability. It was established through the *Breaking the Cycle of Poverty* project, conceived by Fr. Joaquim Ferreira Xavier Jr, sjr., whose educational philosophy emphasises holistic development and education as a means of social emancipation (Xavier Jr., 2006). This institutional context is considered not merely as the setting of the investigation but as an interpretative component of the study, since the school's culture, community values, and educational identity directly influence the adoption of sustainable practices and active learning methodologies, particularly Maker Culture.

The participants comprised five classroom teachers (one representing each grade from Year 1 to Year 5) and 94 enrolled students. However, only 62 students participated effectively in the empirical phase after formal parental consent had been obtained, a prerequisite for research involving minors. This difference between the total student population and the effective research sample is methodologically significant because it defines the ethical boundaries of the study and delimits the corpus of analysed data. Teacher participation was voluntary and formalised through informed consent forms, ensuring confidentiality, anonymisation of data, and the right to withdraw from the study at any stage, in accordance with established ethical principles for educational research.

The first stage consisted of presenting the project to the school leadership, pedagogical coordinators, and teachers during a collective pedagogical planning session. This introductory phase adopted a dialogical and participatory format and served both diagnostic and relational purposes. It sought to clarify the objectives, theoretical foundations, and implementation schedule while identifying participants' expectations, potential resistance, and practical conditions for implementation. Within the action research tradition, this stage is essential because it establishes a collaborative partnership and promotes shared responsibility between the researcher and participants (Thiollent, 2011).

Subsequently, a diagnostic assessment of teachers' conceptions regarding sustainability, Environmental Education, and Maker Culture was conducted through digital questionnaires containing both closed-ended and open-ended questions. The instrument was designed to assess participants' familiarity with the principles of the 3Rs (Reduce, Reuse, and Recycle) and to examine how sustainability was understood and integrated into classroom practice. The use of an online questionnaire provided flexibility, minimised disruption to school routines, and facilitated subsequent organisation and analysis of the collected data. Analytically, this diagnostic phase fulfilled two complementary functions: (a) generating evidence regarding teachers' prior beliefs, knowledge, and pedagogical practices; and (b) informing the design of the subsequent training programme by identifying observed gaps and emerging professional development needs.

To complement these data, individual semi-structured interviews were conducted with each participating teacher. These interviews sought to deepen the understanding of pedagogical practices, perceived barriers—including time constraints, limited resources, lesson planning demands, and curriculum alignment—and the opportunities for integrating Maker Culture with sustainability education.

Following the initial data collection, questionnaire responses and interview transcripts were organised and analysed through content analysis, following the procedures proposed by Bardin (2011), including pre-analysis, material exploration, and interpretation of findings. This analytical approach enabled the identification of recurring patterns within teachers' narratives and the construction of thematic categories that guided the intervention. The principal themes identified included limited conceptual understanding of Maker Education, a tendency to reduce sustainability to recycling practices, structural constraints affecting implementation, and the demand for continuing professional development.

The intervention phase consisted of teacher training workshops and pedagogical meetings designed to strengthen theoretical foundations and expand teachers' instructional repertoire. The training programme focused on integrating sustainability, the principles of the 3Rs, and interdisciplinary teaching with active learning methodologies and project-based learning.

Within applied research, professional development is not regarded as a peripheral activity but rather as the central mechanism for promoting pedagogical transformation, which is fully consistent with the action research paradigm, where investigation and intervention occur simultaneously (Thiollent, 2011).

Following the training programme, Maker-based activities were implemented in the participating classrooms under continuous pedagogical supervision. Classroom observations, implementation records, and reflective field notes documented the development of the activities throughout the intervention. Lesson planning adopted an interdisciplinary approach, integrating Science, Mathematics, Portuguese Language, and Arts around the themes of the 3Rs and the Sustainable Development Goals (SDGs). In practice, activities included measuring and recording water and electricity consumption (Mathematics); investigating decomposition processes, waste management, and material reuse (Science); producing argumentative texts and environmental awareness campaigns (Portuguese Language); and designing artistic and functional artefacts using recyclable materials (Arts). Within this framework, interdisciplinarity extended beyond the simple juxtaposition of curricular content, instead organising different disciplinary perspectives around a shared problem—sustainability—thereby fostering meaningful curricular integration.

Monitoring and evaluation were conducted systematically and collaboratively through regular meetings, feedback sessions, and progressive adjustments throughout the intervention. This iterative process is characteristic of action research, as it enables continuous feedback between planning, implementation, and reflection, allowing methodological refinements to be introduced throughout the study (Thiollent, 2011). The extensive use of recyclable and reusable materials—including cardboard, plastic bottles, and paper—combined with digital technologies such as online research tools, collaborative digital platforms, and audiovisual resources, reinforced the maker-oriented character of the intervention while expanding opportunities for documentation, communication, and dissemination of students' projects (Valente, 2018).

Table 1

Research Design and Stages of the Intervention

Stage	Purpose	Participants	Instruments and Procedures	Data/Outputs Generated	Expected Outcomes
1. Institutional awareness and alignment	To present the project, establish collaborative agreements, and assess implementation conditions	School leadership, pedagogical coordination, and five teachers	Dialogic presentation meeting; definition of the implementation schedule and operational agreements	Records of institutional alignment, participant commitment, and contextual conditions	Formal agreement for participation and a realistic implementation plan
2. Initial diagnosis of teachers' conceptions	To identify teachers' conceptions of sustainability, Environmental Education, and Maker Culture, as well as their previous pedagogical practices	Five teachers	Digital questionnaire comprising closed-ended and open-ended items	Baseline data on teachers' perceptions, knowledge, and existing practices	Identification of professional development needs and priority themes
3. Qualitative exploration	To understand pedagogical rationales, perceived barriers, and opportunities for curriculum integration	Five teachers	Individual semi-structured interviews; recorded responses	Interview transcripts and thematic meaning units	Expanded interpretation of the diagnostic findings and contextualisation of responses

4. Data analysis and categorisation	To organise and interpret the collected data in order to guide the intervention and subsequent monitoring	Researcher (with feedback provided to participants)	Content analysis following Bardin (2011): pre-analysis, coding, categorisation, and inference	Thematic categories (e.g., sustainability limited to recycling; time and infrastructure constraints; professional development needs)	Analytical foundation for designing the training programme and monitoring criteria
5. Professional development intervention	To broaden teachers' knowledge of Maker Culture, active learning methodologies, the 3Rs, and the SDGs, while supporting interdisciplinary planning	Five teachers	Teacher training workshops, guided study sessions, project-based planning, and formative feedback	Lesson plans and sustainable Maker project designs	Increased teachers' conceptual understanding and methodological confidence for implementation
6. Classroom implementation	To implement interdisciplinary Maker activities related to the 3Rs and the Sustainable Development Goals	Five teachers and 62 participating students (from a total enrolment of 94)	Maker projects, inquiry-based activities, artefact construction, and the use of recyclable and reusable materials	Artefacts and prototypes, implementation records, and evidence of student learning	Greater student agency, active learning, and effective interdisciplinary curriculum integration
7. Ongoing pedagogical monitoring	To monitor implementation, refine strategies, and consolidate sustainable educational practices	Teachers, students, and the pedagogical coordination team	Classroom observations, follow-up meetings, formative feedback, and iterative adjustments characteristic of action research	Monitoring records and documentation of implemented changes	Continuous improvement of pedagogical practices through reflective feedback cycles
8. Dissemination and project culmination	To validate and communicate project outcomes while strengthening a culture of sustainability within the school	School community	School exhibition or fair, student presentations, and display of projects and reflective activities	Public presentations and records of community participation	Consolidation of a sustainable Maker culture and dissemination of good practices within the institution
9. Educational product	To systematise guidelines and teaching materials to support replication and scalability	Teachers (primary audience) and the wider educational community	Development of an educational e-book containing teaching sequences, implementation guidelines, and project examples	Pedagogical e-book	Practical resource supporting the implementation of sustainable Maker methodologies in other educational contexts

Results and Discussion

The initial findings revealed that the participating teachers possessed only a partial understanding of sustainability, frequently associating it exclusively with recycling practices. This tendency reflects a limited and functional conception of sustainability, centred primarily on waste management and isolated environmental actions, without encompassing the broader ethical, social, economic, and political dimensions of sustainable development. Such findings are common in educational contexts where Environmental Education is treated as a cross-curricular theme but is insufficiently integrated into pedagogical planning, resulting in fragmented activities disconnected from a systemic understanding of sustainability.

By conceptualising sustainability as a multidimensional construct, Sachs (2008) argues that sustainable development requires the integration of environmental, social, economic, cultural, and political dimensions, thereby overcoming reductionist approaches that simplify its complexity into isolated practices. Similarly, Morin (2015) emphasises that contemporary problems cannot be adequately understood through disciplinary fragmentation but instead require complex thinking, capable of recognising relationships, interdependencies, and both short- and long-term consequences. The initial diagnosis, which demonstrated that sustainability was predominantly equated with recycling, therefore reveals both a conceptual gap and a pedagogical limitation. When teachers approach sustainability from such a restricted perspective, classroom activities tend to remain disconnected from both the curriculum and students' lived experiences, reducing their educational and transformative potential.

The professional development workshops contributed significantly to broadening teachers' understanding by incorporating the social, economic, and ethical dimensions of sustainability. However, this transformation should not be interpreted merely as the acquisition of additional theoretical knowledge. Rather, it represented a reconfiguration of teachers' pedagogical perspectives, enabling sustainability to be understood as an organising principle for curriculum planning rather than as an isolated supplementary topic. Following the training programme, teachers demonstrated a greater tendency to redesign their instructional planning with increased intentionality, selecting authentic problems, valuing the local context, and integrating competencies established by the Brazilian National Common Core Curriculum (BNCC), particularly those related to citizenship, values, and responsible action. The training programme also functioned as a legitimising mechanism by providing participants with a shared conceptual language, practical examples, and pedagogical models, thereby reducing uncertainty and increasing teachers' confidence in adopting active learning methodologies.

Maker-based activities—including the construction of reusable artefacts, environmental inquiry projects, and initiatives centred on the reuse of recyclable materials—generated high levels of student engagement, strengthened interdisciplinary learning, and promoted observable behavioural changes both within the school environment and in students' family contexts. These findings may be interpreted from three complementary perspectives.

The first concerns student engagement. By organising learning around authentic challenges, Maker Culture shifts education from a model centred on knowledge reproduction towards one focused on knowledge production. This transition tends to enhance students' motivation, perseverance, and sense of purpose by positioning them as active participants in the learning process rather than passive recipients of information.

The second perspective relates to interdisciplinarity. Because Maker projects are structured around authentic problems, they naturally require the integration of multiple disciplinary perspectives. The development of a single artefact or the investigation of a real-world problem simultaneously involves mathematical reasoning, scientific inquiry, written communication, argumentation, artistic expression, and technological skills, thereby fostering meaningful curricular integration rather than the simple juxtaposition of subject content.

The third perspective concerns behavioural change. When sustainability is experienced through concrete practices—such as reducing waste, reusing materials, redesigning discarded objects, and critically reflecting on consumption—students are more likely to internalise sustainable habits through repeated meaningful experiences, emotional engagement, and social validation

within their peer groups. Consequently, these behaviours tend to extend beyond the school environment and become incorporated into everyday family practices.

These findings are consistent with previous research demonstrating the effectiveness of active learning methodologies in promoting meaningful learning and strengthening student agency (Moran, 2018; Vickery, 2016).

From the perspective of Educational Psychogenetics, these outcomes acquire additional explanatory significance. According to Xavier (2006), cognitive development is consolidated through concrete action, sensory experience, and reflective interaction with the environment. The Maker activities implemented in this study created conditions in which students were able to manipulate materials, formulate hypotheses, test solutions, evaluate outcomes, and reconstruct their ideas through iterative processes. Consequently, sustainability was not approached merely as conceptual knowledge but as lived experience, allowing environmental values to become progressively integrated into students' cognitive and behavioural structures. This interpretation suggests that the observed behavioural changes were not simply the result of increased environmental awareness but reflected deeper processes of cognitive and ethical development supported by meaningful action.

Taken together, the results indicate that integrating Maker Culture with Environmental Education and Educational Psychogenetics creates a pedagogical environment capable of promoting not only conceptual learning but also the development of socio-environmental competencies, interdisciplinary thinking, and responsible citizenship. In this context, sustainability emerges simultaneously as educational content, pedagogical methodology, and ethical orientation, reinforcing the potential of Maker Education to contribute to transformative educational practices in Basic Education.

Table 2

Comparison of Educational Practices Before and After the Intervention

Analysed Dimension	Before the Intervention	After the Intervention
Conception of Sustainability	Predominantly limited understanding, mainly associated with recycling and isolated environmental actions.	Broader understanding incorporating social, economic, and ethical dimensions; sustainability recognised as a curricular and educational organising principle.
Curriculum Integration	Sporadic and poorly systematised activities, with limited integration across curriculum subjects.	More intentional and interdisciplinary planning, integrating sustainability into Science, Mathematics, Portuguese Language, and Arts.
Pedagogical Planning	Emphasis on isolated activities focused on immediate products and rapid execution.	Emphasis on project-based learning, sequential processes, documentation, inquiry, reflection, and continuous assessment.
Teacher's Role	Predominantly transmissive and instructional, with limited opportunities for experimentation.	Facilitator and inquiry-oriented role, supporting decision-making, collaboration, and problem-solving throughout the projects.
Student Engagement	Variable engagement, often dependent on occasional “different” activities lacking continuity.	High and sustained engagement driven by authentic challenges, resulting in greater autonomy, participation, and sense of purpose.
Interdisciplinarity	Fragmented organisation by subject area, with limited connections among curricular contents.	Integration through problem- and project-based learning, mobilising multiple disciplines, languages, and procedures around sustainability challenges.

Type of Learning	Predominantly reproductive learning and activities involving limited investigative complexity.	Active and meaningful learning characterised by experimentation, prototyping, inquiry, and argumentation.
Materials and Resources	Limited use of educational materials, with little emphasis on reuse or prototyping.	Extensive use of recyclable and reusable materials, with reuse practices functioning simultaneously as content and pedagogical methodology based on the **3Rs**.
Socio-environmental Values and Attitudes	Sustainability approached primarily at the discursive level, with limited evidence of behavioural change.	Internalisation of environmental values through lived experiences, reflected in observable behavioural changes at school and reported transfer of sustainable practices to students' homes.
School Culture	Sustainability treated as a peripheral cross-curricular theme with limited presence in everyday school life.	Sustainability incorporated into school projects and events, demonstrating potential for long-term cultural consolidation and replication.

At the same time, from the perspective of Educational Psychogenetics, the findings indicate that concrete action and experimentation facilitated the internalisation of socio-environmental values, reinforcing the central role of lived experience in the educational process (Xavier JR., 2006). Xavier's theoretical contribution helps explain why the intervention extended beyond simply increasing students' interest, promoting more profound cognitive and ethical transformations. If cognitive and moral development is grounded in experiential engagement and the progressive reorganisation of psychological structures through action in the world, then sustainable Maker activities constitute a particularly favourable educational environment. Students learn by manipulating materials, recognising relationships, testing hypotheses, and evaluating the consequences of their decisions.

Consequently, socio-environmental values are not acquired merely as abstract concepts but are internalised through lived experience. Caring for materials, recognising waste, negotiating solutions collaboratively, and understanding the impact of individual and collective choices become processes through which practical awareness is constructed, fostering an ethics embedded in everyday action. Learning, therefore, extends beyond the acquisition of knowledge to encompass the reorganisation of habits, perceptions, and attitudes towards the surrounding world.

The intervention also generated important effects on teachers' professional practice. Through planning, implementing, and monitoring Maker projects, teachers progressively adopted a more inquiry-oriented pedagogical role characterised by observation, documentation, questioning, reflective dialogue, support for student decision-making, and process-oriented assessment. This transformation is consistent with the pedagogical shift promoted by active learning methodologies, in which teachers move beyond the traditional role of knowledge transmitters to become facilitators of learning experiences and curators of students' learning pathways (Moran, 2018). In practice, this change contributed to the development of a learning culture in which mistakes were recognised as an essential part of the learning process, collaboration became a central pedagogical principle, and educational outcomes were evaluated not only through the final products but also through students' reasoning, documentation, reflective processes, and collaborative interactions.

Conclusions

The findings of this study demonstrate that the integration of Maker Culture, Environmental Education, and Educational Psychogenetics constitutes a coherent and promising approach to

pedagogical innovation in Basic Education. The articulation of these perspectives enabled the study to move beyond fragmented approaches to sustainability, traditionally limited to isolated environmental activities, by promoting pedagogical practices grounded in experience, inquiry, and student authorship. The results confirm that learning is strengthened when students are actively engaged in solving authentic problems, producing artefacts, and reflecting critically upon their own actions, in accordance with the principles established by the Brazilian National Common Core Curriculum (BNCC) and the United Nations 2030 Agenda for Sustainable Development.

The educational legacy of Fr. Joaquim Ferreira Xavier, sjr. proved particularly valuable in interpreting the outcomes of the intervention. Educational Psychogenetics provided a theoretical framework that emphasises the centrality of concrete experience, embodiment, and affective-cognitive mobilisation within the learning process. By demonstrating that socio-environmental values are constructed through lived experience rather than through the simple transmission of information, this research highlights both the contemporary relevance and the enduring significance of Xavier's work for addressing current educational challenges, particularly those related to ethical development and citizenship education during the early years of primary schooling.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that generative artificial intelligence (ChatGPT, developed by OpenAI) was used solely to assist in translating the original manuscript from Portuguese into English. The use of this technology was strictly limited to language translation and linguistic refinement to ensure clarity, fluency, and conformity with academic English. The authors confirm that all ideas, study design, methodology, data collection, analyses, interpretations, discussions, and conclusions are entirely their own and were developed through the original conduct of the research. The authors carefully reviewed and edited the translated manuscript and assume full responsibility for the accuracy, integrity, and final content of the submitted work.

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