Ano VII, v.1 2026 | submissão: 24/10/2026 | aceito: 31/10/2026 | publicação: 05/11/2026

Educational meliponaries and critical socio-environmental education: pedagogical potential, student participation, and sustainability conditions
Meliponários educativos e formação socioambiental crítica: potencialidades pedagógicas, participação estudantil e condições de sustentabilidade
Meliponarios educativos y formación socioambiental crítica: potencialidades pedagógicas, participación estudiantil y condiciones de sostenibilidad

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Abstract: This theoretical-critical essay examines the potential and limitations of educational stingless-bee meliponaries for Critical Environmental Education and Education for Sustainable Development in basic education. It brings together publications on stingless bees in educational settings and conceptual perspectives on student participation, human agency, social-ecological systems and territorial contextualization. The discussion distinguishes educational experiences, didactic proposals and conceptual formulations, without drawing on primary data. As a contribution, it proposes five analytical dimensions: educational intentionality, curricular integration, student participation, socio-environmental and territorial contextualization, and institutional continuity with ecological responsibility. It argues that the educational potential of a meliponary depends on pedagogical mediation and opportunities for participation, rather than solely on the presence of colonies. The proposed dimensions are theoretical and have not been empirically validated.
Keywords: Educational meliponary; Critical Environmental Education; Student participation; Interdisciplinarity.

Resumo: Este ensaio teórico-crítico analisa potencialidades e limites dos meliponários educativos para a Educação Ambiental Crítica e a Educação para o Desenvolvimento Sustentável na educação básica. Articula publicações sobre abelhas sem ferrão em contextos educativos a referenciais sobre participação estudantil, agência humana, sistemas socioecológicos e contextualização territorial. A análise distingue experiências pedagógicas, propostas didáticas e formulações conceituais, sem utilizar dados primários. Como contribuição, propõe cinco dimensões de análise: intencionalidade formativa, integração curricular, participação estudantil, contextualização socioambiental e territorial e continuidade institucional com responsabilidade ecológica. Argumenta-se que o potencial educativo do meliponário depende da mediação pedagógica e das condições de participação, não apenas da presença das colônias. As dimensões apresentadas constituem proposição teórica, ainda não validada empiricamente.
Palavras-chave: Meliponário educativo; Educação Ambiental Crítica; Participação estudantil; Interdisciplinaridade.

Resumen: Este ensayo teórico-crítico analiza las potencialidades y los límites de los meliponarios educativos para la Educación Ambiental Crítica y la Educación para el Desarrollo

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Sostenible en la educación básica. Articula publicaciones sobre abejas sin aguijón en contextos educativos con referentes sobre participación estudiantil, agencia humana, sistemas socioecológicos y contextualización territorial. El análisis distingue experiencias pedagógicas, propuestas didácticas y formulaciones conceptuales, sin utilizar datos primarios. Como contribución, propone cinco dimensiones de análisis: intencionalidad formativa, integración curricular, participación estudiantil, contextualización socioambiental y territorial y continuidad institucional con responsabilidad ecológica. Se argumenta que el potencial educativo del meliponario depende de la mediación pedagógica y las condiciones de participación, no solo de la presencia de colonias. Las dimensiones presentadas constituyen una proposición teórica aún no validada empíricamente.
Palabras clave: Meliponario educativo; Educación Ambiental Crítica; Participación estudiantil; Interdisciplinariedad.

1. Introduction

The intensification of contemporary socio-environmental problems highlights the need for educational practices that move beyond conveying information about nature and promote a critical understanding of relationships among society, environment, and development. In this context, schools can help educate individuals capable of recognizing the complexity of environmental challenges and participating in the construction of socially just and ecologically sustainable alternatives.

Critical Environmental Education holds that environmental issues cannot be analyzed in isolation from historical, economic, political, and cultural relations. Environmental education, from this perspective, should encourage reflection, dialogue, and participation, overcoming approaches restricted to individual behavioral change (Loureiro, 2016).

Education for Sustainable Development, in turn, proposes integrating knowledge, values, and competencies related to sustainability. Target 4.7 of Sustainable Development Goal 4 highlights education for sustainable development, human rights, and appreciation of cultural diversity (ONU, 2015). Bringing these agendas together requires critical reflection on their assumptions and pedagogical implications (Barbieri; Silva, 2011; Shiroma; Zanardini, 2020).

Among the possibilities for contextualizing these principles, meliponiculture, the keeping and management of native stingless bees, stands out. Its use in schools can connect biodiversity, pollination, conservation, food production, and community knowledge. Research and educational proposals already discuss using these bees in school activities (Godoy; Paro, 2023; Yamaguchi; Yamaguchi; Rebelo, 2023; Felipe Neto; Lima Neto, 2022).

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However, the educational contributions of a meliponary do not automatically follow from the presence of colonies: they depend on pedagogical intentionality, teacher mediation, and opportunities for student participation. The question arises: under what pedagogical and institutional conditions can educational meliponaries contribute to Critical Environmental Education and Education for Sustainable Development practices, considering interdisciplinarity, student participation, and the socio-environmental particularities of school territories?

This article aims to analyze, in light of the scientific literature, the potential and limitations of educational meliponaries as a pedagogical strategy for Critical Environmental Education and Education for Sustainable Development in basic education, considering interdisciplinarity, student participation, territorial contextualization, and pedagogical continuity.

2. Methodological approach

This work is a theoretical-critical essay with a qualitative and bibliographical approach. It aims to construct an argumentative interpretation of the potential and limitations of educational meliponaries, without claiming to provide a systematic review, exhaustive survey, or evaluation of the effectiveness of school interventions.

The references were gathered and verified during preparation of a master's dissertation in education. For this essay, the bibliographical selection was intentional, guided by relevance to the research problem. Two sets of publications were drawn upon: (a) studies on native stingless bees in educational settings, distinguishing reviews, experience reports, and didactic proposals; and (b) conceptual frameworks on Critical Environmental Education, Education for Sustainable Development, interdisciplinarity, human agency, social-ecological systems, and collective participation. No claim is made that a new systematic database search was conducted.

The interpretative reading distinguished the nature of each publication's contributions and limits of inference, comparing reported or proposed pedagogical possibilities with the assumptions of the conceptual frameworks. Bringing these two sets together grounded the theoretical synthesis of five analytical dimensions: educational intentionality, curricular integration, student participation, socio-environmental and territorial contextualization, and institutional continuity with ecological responsibility. The comparative table clarifies the

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argumentative role of some of the works used, without serving as a formal evaluation of their methodological quality.

The analysis distinguishes empirical findings published by third parties, pedagogical proposals, and conceptual formulations. This essay did not use primary data, interviews, questionnaires, or field observations. The five dimensions constitute a theoretical-interpretative proposition that has not yet been empirically validated and does not allow causal inferences about educational outcomes.

3. Theoretical analysis and discussion

3.1 Educational meliponaries: from environmental awareness to contextualized learning

Using native stingless bees in pedagogical practices can bring together scientific knowledge, biodiversity conservation, and socio-environmental issues in everyday school life. However, the presence of these organisms in educational activities does not, by itself, ensure critical learning or interdisciplinarity.

Godoy and Paro (2023) conducted a state-of-the-art investigation of pedagogical practices involving stingless bees in formal education. Playful and expository activities predominated in the 36 works selected by the authors; meliponaries were identified as an underused school resource. These 36 works belong to the authors' survey and are not the corpus directly examined in this essay. The source supports identifying trends and gaps but does not, in itself, demonstrate learning gains resulting from installing meliponaries.

In Coari, Amazonas, Yamaguchi, Yamaguchi, and Rebelo (2023) conducted an Environmental Education activity with 38 sixth-grade students at a municipal public school. Although the publication's title mentions “early childhood education,” the participants actually described in the abstract and study were in the sixth grade of elementary education. The intervention comprised five stages: a theoretical presentation, an ecological trail walk, a visit to a teaching meliponary, a playful workshop, and evaluation. At the end, 35 participants (92%) expressed interest in further similar activities, while three did not answer the question. This finding indicates receptiveness to the experience but is not evidence of lasting learning or changes in socio-environmental behavior.

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Felipe Neto and Lima Neto (2022) present an interdisciplinary didactic intervention proposal structured around reflection, experimentation, and integration. Their contribution lies in planning the proposal; it should not be cited as a demonstration of implementation outcomes.

These works support discussion of meliponaries as potential spaces for inquiry-based and contextualized learning. This potential depends on teacher mediation, defined objectives, and critical examination of relationships among biodiversity, society, and territory.

Using stingless bees in school activities can take different pedagogical forms. A lecture on pollination, an exhibition of materials, a guided visit, and sustained observation of a meliponary are distinct experiences, both in their organization and in the learning opportunities they offer.

From an inquiry-based perspective, studying stingless bees can begin with questions about pollinator diversity, the environmental conditions needed for species conservation, and changes in local landscapes. These questions can be linked to different curricular components, allowing students to formulate hypotheses, consult scientific sources, organize information, and discuss interpretations.

However, pedagogical inquiry must be distinguished from the technical management of colonies. Students' participation in educational activities does not imply their direct involvement in procedures requiring specialized knowledge, nor does it waive compliance with safety conditions and applicable environmental regulations.

From the perspective of Critical Environmental Education, inquiry should go beyond describing ecological processes to consider their relationships with human activities, territorial conditions, and collective responsibilities. In this sense, interdisciplinarity consists not merely of bringing different content together around bees, but of constructing study problems requiring coordinated contributions from different bodies of knowledge.

3.2 Critical Environmental Education, student participation, and civic-environmental agency

Critical Environmental Education requires moving beyond approaches focused solely on transmitting ecological knowledge and adopting individual behaviors. Loureiro (2016) helps critically examine conceptions of sustainability that insufficiently consider the social and political relations associated with environmental issues.

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In school projects, carrying out tasks must be distinguished from effective participation in planning, decision-making, and evaluation. Demo and Silva's (2020) reflection on student leadership and authorship helps view students as active subjects in education rather than merely recipients of activities.

Discussion of participation can engage with Bandura's Social Cognitive Theory, especially regarding human agency and self-efficacy beliefs. In this article, civic-environmental agency is used as an analytical category connecting intentional action, participation in collective issues, and socio-environmental responsibility. This formulation is part of the author's trajectory of theoretical reflection and should neither be attributed literally to Bandura nor presented as a term coined exclusively in this article.

A meliponary can thus create opportunities for inquiry, negotiation, and shared responsibility, but the development of agency cannot be inferred solely from students' presence in activities. This hypothesis requires studies that actually examine decision-making processes and participation practices.

Connecting participation and learning requires conceptual caution. Participation can occur at different levels: attending activities, carrying out tasks, making suggestions, deliberating, and following up on decisions. For analyzing an educational meliponary, these forms are not equivalent. Assigning maintenance duties to students, for example, may foster familiarity with management but does not, by itself, demonstrate participation in the choices guiding the project.

Bandura (2001) distinguishes personal, proxy, and collective agency. Collective agency involves coordinated efforts to produce shared outcomes without reducing action to a sum of individual decisions. Carefully transposed to education, this distinction allows questions about who defines project priorities, how responsibilities are distributed, and what opportunities exist to critically evaluate joint decisions. Civic-environmental agency is used here as an interpretative construction of the essay, rather than a concept originally named by Bandura.

This perspective avoids two simplifications: treating every practical activity as student leadership and assuming that an individual willingness to protect nature replaces analysis of collective and institutional conditions. A critical approach can raise questions about access to resources, territorial use conflicts, pollinator protection, and the responsibilities of different social actors. These questions are not observed findings of this study; they are didactic possibilities to be examined in future research.

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3.3 Interdisciplinarity, Amazonian territory, and traditional knowledge

The complexity of socio-environmental issues favors interdisciplinary approaches. Castelo Branco, Linard, and Sousa (2011) discuss connections among Environmental Education, Education for Sustainable Development, and interdisciplinarity. Within a meliponary, science concepts can engage with geography, mathematics, history, and Portuguese language, provided that the connection addresses shared research problems.

In Amazonian territory, studying native stingless bees can encourage discussion of biodiversity, landscapes, agriculture, and relationships between communities and the environment. The experience presented by Yamaguchi, Yamaguchi, and Rebelo (2023) indicates the topic's regional relevance but does not authorize generalizations across the diversity of Amazonian schools. Silva and Silva (2023), in analyzing ethnosciences in Pará's Modular Teaching Organization System, provide an additional framework for discussing the recognition of local knowledge in the Amazonian curriculum.

Dialogue with community knowledge should recognize its contexts of production and avoid treating it as mere illustrations of scientific knowledge. The literature used in this essay points to the importance of this dialogue but does not provide sufficient grounds for characterizing the diversity of traditional knowledge involved in Amazonian meliponiculture. This delimitation constitutes a theoretical gap in the selected bibliography.

Territorial contextualization is therefore a pedagogical possibility rather than a characteristic guaranteed by any school meliponiculture project.

In the Amazonian context, territorial contextualization must recognize the plurality of experiences composing the region. There is no single repertoire of knowledge or uniform relationship between communities and native bees. The pedagogical proposal should therefore begin by recognizing the practices, questions, and knowledge actually present in the school community, without presuming all students' prior familiarity with meliponiculture.

Bastos et al. (2016) offer a relevant connection by examining relationships between ethnozoology and environmental education in Amazonian schools. Their subject is not the effectiveness of school meliponaries; their contribution to this essay lies in attending to students' perceptions and connections with fauna. Cardoso (2016), in another Amazonian context, discusses learning processes involving traditional knowledge and practices. These studies are

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used through theoretical approximation and should not be presented as direct evidence of outcomes from stingless-bee projects.

Dialogue between bodies of knowledge requires more than inviting community members to confirm school content. It can involve jointly formulating questions about species, flowering seasons, landscape changes, land uses, and ways of caring for the environment. However, each community's right to decide what to share and how its knowledge will be acknowledged must be respected, avoiding inappropriate exposure of culturally sensitive practices or information.

Interdisciplinarity also requires effective integration rather than simply juxtaposing tasks by subject. A common research question, for example which landscape changes affect local pollinators, can guide contributions from science, geography, mathematics, history, and languages. This proposal must be adapted to each school's conditions and is not a procedure empirically tested in this essay.

Within Critical Environmental Education, territory cannot appear solely as a natural setting. Relationships among conservation, work, agriculture, infrastructure, ways of life, and public policies help explain that environmental problems have ecological and social dimensions. Teacher mediation is necessary to avoid both idealizing traditional knowledge and automatically subordinating it to decontextualized school explanations.

3.4 Institutional conditions and ecological responsibility

Implementing educational meliponaries involves curricular planning, monitoring activities, and defining responsibilities. Continuity can expand opportunities to observe ecological processes and reflect on socio-environmental problems, but its effectiveness must be examined through specific studies.

Participatory management is relevant to the continuity of socio-environmental educational projects because it involves collective planning, monitoring, and evaluation. Brito, Siveres, and Cunha (2019) discuss qualitative indicators and participatory management in building sustainable schools, highlighting belonging, coordination of efforts, partnerships, decentralized management, and joint learning. In this essay, this contribution supports an interpretative connection with educational meliponaries: the authors' indicators do not amount to validation of the five analytical dimensions proposed here.

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Implementation also requires technical guidance on suitable species, management, environmental conditions, colony health, safety, and compliance with applicable regulations. These conditions vary according to territory and institutional resources; presenting a single model for all schools is inappropriate.

An often-neglected issue in planning living pedagogical resources is the difference between inauguration and continuity. Operating a meliponary involves monitoring throughout the school calendar, including holidays and staff changes. Maintenance responsibility should therefore not depend exclusively on one teacher or a temporary group of students. Institutional planning must provide for duties, resources, and criteria for reassessing project feasibility.

Management decisions require technical guidance and attention to relevant environmental legislation. It cannot be assumed that any stingless-bee species can be installed anywhere or that every school has the necessary safety and conservation conditions. Before implementation, institutions should consult qualified professionals and applicable territorial regulations, avoiding the transformation of general pedagogical recommendations into technical management instructions.

For analytical purposes, implementation conditions should be separated from educational outcomes. Curricular planning, participation, and monitoring may make a proposal more coherent but do not prove that students have developed knowledge, attitudes, or agency. Evaluating these possible effects would require a specific empirical design, appropriate indicators, and corresponding ethical procedures.

3.5 Proposing five analytical dimensions

The literature discussed allows recognition of the pedagogical potential of educational meliponaries but does not justify attributing automatic educational effects to them. Godoy and Paro (2023) analyze educational practices involving stingless bees; Felipe Neto and Lima Neto (2022) present a didactic proposal. These contributions differ in nature and must be interpreted according to their procedures and limitations.

In light of Critical Environmental Education, learning about biodiversity can be associated with critically examining social, economic, and territorial issues. Bandura's (2001) theory of human agency provides foundations for distinguishing task execution from

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participation in collective decisions; the notion of civic-environmental agency used here is an interpretative articulation of the essay rather than a category attributed literally to the author.

Ostrom's (2009) social-ecological systems approach helps understand relationships among resources, actors, and governance arrangements. Applying it to schools is a conceptual approximation proposed in this article, rather than an outcome of Ostrom's research on educational meliponaries.

The analytical proposition developed in this essay does not assume that interdisciplinarity, student participation, territorial contextualization, or participatory management are new categories in educational literature. Its specific contribution is organizing these elements into five interdependent dimensions for examining educational meliponaries, distinguishing institutional conditions, pedagogical processes, and possible educational outcomes. This theoretical-interpretative synthesis requires subsequent empirical examination.

From this articulation, five analytical dimensions are proposed: (1) educational intentionality, clarifying objectives and critical questions; (2) curricular integration, connecting components and practices; (3) student participation, including real decision-making opportunities; (4) socio-environmental and territorial contextualization, valuing local problems and knowledge; and (5) institutional continuity with ecological responsibility, encompassing monitoring, safety, and maintenance.

The dimensions represent a theoretical synthesis to guide analysis and future investigations. They are not empirically validated indicators and do not guarantee learning outcomes. Their usefulness lies in shifting the focus from the meliponary's physical existence to the quality of pedagogical relationships established around it.

The five dimensions are not intended to establish a mandatory sequence for implementing meliponaries but to offer a lens for examining pedagogical choices. Educational intentionality connects learning objectives to relevant socio-environmental problems: the question is not only what to teach about bees but which relationships among biodiversity, ways of life, territorial use, and collective responsibility should become objects of inquiry. An observation activity may be relevant to studying pollination but does not, by itself, constitute a critical approach to the social conditions affecting conservation.

Curricular integration should be analyzed through the quality of the connections built rather than the number of subjects mentioned in a plan. When science, geography, mathematics, and languages address the same problem, it matters whether their contributions complement

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each other and whether students can use them to interpret concrete situations. Interdisciplinarity therefore does not equal juxtaposing tasks: it requires coordinating questions, pedagogical time, concepts, and forms of monitoring.

Student participation can take different degrees. Students may observe, keep records, or communicate without participating in defining objectives and decisions. In another arrangement, they may help formulate research questions, discuss environmental care criteria, and collectively evaluate the process. This distinction does not discredit teacher-guided activities; it recognizes execution and deliberation as different educational experiences. The connection with Bandura (2001) supports reflection on agency but does not justify claiming that a meliponary alone develops civic-environmental agency.

Socio-environmental and territorial contextualization requires investigating communities' relationships with bees, plants, and surrounding environments without assuming a uniform Amazonian culture. Local knowledge can provide questions and dialogue, provided its holders are acknowledged and school treatment does not turn situated knowledge into decontextualized curiosities. This dimension includes reflecting on environmental pressures and material conditions affecting the territory without assigning communities sole responsibility for larger-scale problems.

Institutional continuity and ecological responsibility concern the conditions that make the proposal sustainable as a school practice. A project may have relevant objectives yet face maintenance difficulties, staff changes, absent curricular coordination, or insufficient technical monitoring. Analyzing this dimension requires considering appropriate species selection, management conditions, colony protection, and compliance with applicable regulations, whose verification depends on context and cannot be replaced by general pedagogical recommendations.

The dimensions may also come into tension. A proposal with broad student participation may require more time than the school calendar allows; fragmented schedules can hinder integration among subjects; valuing community knowledge requires attention to consent, attribution, and respect for those involved. Recognizing these tensions prevents turning the analytical proposal into an idealized checklist and reinforces the need for contextualized decisions.

As a direction for future research, the five dimensions can guide research questions without yet functioning as a validated assessment scale. Researchers could examine, for

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example, how curricular objectives are negotiated, which decisions are entrusted to students, how local knowledge is incorporated, and which institutional arrangements sustain activities over time. The proposition's usefulness depends on critical discussion and possible subsequent empirical examination conducted with appropriate methodological and ethical care.

The five dimensions are interdependent but not equivalent. The following table organizes their definitions, analytical questions, and theoretical foundations; future use requires contextualization and specific empirical investigation.

Table 1 – Analytical dimensions proposed for examining educational meliponaries

Dimension	Theoretical definition	Guiding question	Supporting references
Educational intentionality	Connection between educational objectives and critical examination of socio-environmental relations.	Do the objectives enable critical examination of biodiversity, society, and sustainability?	Loureiro (2016); ONU (2015)
Curricular integration	Planned connection among fields of knowledge around common problems.	Do curricular components jointly investigate socio-environmental problems?	Castelo Branco, Linard, and Sousa (2011); Felipe Neto and Lima Neto (2022)
Student participation	Opportunities to propose questions, deliberate, implement, and evaluate collective decisions.	At which stages do students effectively participate in decisions?	Bandura (2001); Demo and Silva (2020)
Socio-environmental and territorial contextualization	Critical dialogue among local problems, community knowledge, and school knowledge.	How do environmental issues and community knowledge enter planning?	Bastos et al. (2016); Cardoso (2016); Silva and Silva (2023)
Institutional continuity and ecological responsibility	Connection among curricular continuity, shared institutional responsibility, and technical-ecological care.	What conditions sustain the project and responsible care for colonies?	Ostrom (2009); Brito, Siveres, and Cunha (2019)

Criteria for composing the comparative table:

The nine publications were intentionally selected from references gathered and verified during preparation of the dissertation, considering their role in this essay's argument: three works directly related to native bees and educational practices, three conceptual frameworks for critical education, agency, and social-ecological systems, and three studies supporting territorial dialogue, participation, and evaluation of socio-environmental projects. The selection does not result from a systematic search and is not an exhaustive sample of research on the

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topic. The table compares contributions and limits of inference without assigning methodological equivalence to studies of different natures. Including conceptual frameworks in this matrix does not turn them into empirical meliponary studies: their contributions are theoretical, and transferability to schools remains an interpretative hypothesis.

Table 2 – Contributions and limitations of the publications used in the essay

Reference	Nature / focus	Contribution to the essay	Limit of inference
Godoy and Paro (2023)	Review of works on native bees in education	Mapping pedagogical practices and gaps	The review's 36 works are not equivalent to studies directly analyzed in this essay.
Yamaguchi, Yamaguchi, and Rebelo (2023)	Report of an activity with 38 sixth-grade students in Coari (AM); the published title mentions “early childhood education.”	Situated example of an approach involving students	Interest in repeating activities (35 of 38) does not measure lasting learning or behavioral change.
Felipe Neto and Lima Neto (2022)	Interdisciplinary didactic intervention proposal	Curricular planning possibilities	A proposal does not equal empirically demonstrated effectiveness.
Loureiro (2016)	Critical discourse analysis of education for sustainable development	Questioning instrumental approaches to sustainability	Does not directly investigate school meliponaries.
Bandura (2001)	Conceptual foundations of human agency	Distinguishing individual and collective action	Neither formulates the expression civic-environmental agency nor validates this essay's model.
Ostrom (2009)	Framework for social-ecological systems	Analyzing organization and shared responsibility	Application to schools is an interpretative approximation.
Bastos et al. (2016)	Ethnozoology and environmental education in Amazonian schools	Valuing students' perceptions and relationships with fauna	Does not demonstrate effects of educational meliponaries.
Cardoso (2016)	Traditional knowledge and practices and community learning	Grounding dialogue between schools and territorial knowledge	The researched context cannot be generalized to all of Amazonia.
Brito, Siveres, and Cunha (2019)	Qualitative indicators and participatory management of socio-environmental projects	Discussing monitoring and collective participation	The study's indicators do not automatically validate the five dimensions proposed here.

Source: author's elaboration based on the cited publications.

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Table 2 summarizes the argumentative role of publications used in the essay. It is a preliminary interpretative matrix rather than an exhaustive review or evaluation of the studies' methodological quality.

Bringing together studies of different natures does not presuppose methodological equivalence among them. In particular, Bastos et al. (2016) investigate relationships among students, fauna, and environment in Belém schools without evaluating meliponaries; Silva and Silva (2023) discuss ethnosciences and curricular contextualization in Pará's Modular Teaching Organization System; and Shiroma and Zanardini (2020) critically analyze education for sustainable development policies linked to the 2030 Agenda. These contributions are used, respectively, to consider territorial contextualization and the tension between institutional agendas and critical perspectives, rather than as evidence of meliponiculture's pedagogical effects.

3.6 Evidence gaps and research perspectives

Comparative reading of the works used in this essay reveals an initial convergence: stingless bees offer a topic with potential to connect biodiversity and school practices. However, the works neither begin from the same question nor present the same type of evidence. Godoy and Paro (2023) synthesize publications on educational practices; Yamaguchi, Yamaguchi, and Rebelo (2023) report a situated experience; Felipe Neto and Lima Neto (2022) formulate a didactic proposal. Differences among reviews, experience reports, and curricular propositions prevent treating them as equivalent demonstrations of pedagogical effectiveness.

A first tension concerns the distance between awareness and critical education. Activities sparking curiosity about pollination or conservation can be relevant entry points but are insufficient to demonstrate reflection on inequalities, territorial use conflicts, or participation in collective decisions. The critical perspective discussed by Loureiro (2016) functions here as a criterion for questioning educational purposes rather than evidence that meliponiculture experiences have already achieved them.

Another analytical gap concerns continuity. Interest observed during educational activities does not equal lasting learning or enduring changes in practices. Biological maintenance of colonies must also be distinguished from the project's curricular continuity: a school may maintain bee boxes without integrating the meliponary into teaching, just as it may

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develop teaching sequences about pollinators without installing colonies. This distinction helps prevent infrastructure from being treated as a sufficient indicator of pedagogical quality.

Finally, Ostrom's (2009) social-ecological systems approach provides a framework for considering interactions among actors, resources, and organizational rules but should not be presented as a model originally developed for schools or educational meliponiculture. Its use here is heuristic: it guides questions about responsibilities, decisions, sustainability, and monitoring without replacing field evidence or species-specific technical management protocols.

The essay's contribution follows from these convergences and tensions: the five dimensions proposed in the preceding section should serve as analytical questions rather than a performance scale or certification of good practices. Future research could examine how each dimension appears in different schools, its relationships with student experiences, and institutional obstacles arising over time. Until then, the proposal's strength remains conceptual and argumentative, and its limitations must accompany its presentation.

4. Final considerations

This essay analyzed the potential and limitations of educational meliponaries as a pedagogical strategy for Critical Environmental Education and Education for Sustainable Development. Connecting the frameworks indicates that their educational contribution does not follow automatically from stingless-bee colonies at school but from the educational experiences constructed around them.

The analysis enabled five dimensions to be proposed to guide reflection on these initiatives: educational intentionality, curricular integration, student participation, socio-environmental and territorial contextualization, and institutional continuity accompanied by ecological responsibility. These dimensions constitute a theoretical synthesis rather than an empirically validated evaluation instrument.

In the Amazonian context, connecting scientific knowledge, community experiences, and concrete socio-environmental issues is especially important. This connection requires recognizing territorial diversity and avoiding the use of local knowledge merely as illustrative elements in school activities.

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The study also highlights the need to distinguish environmental awareness, conceptual learning, and effective student participation. Although related, these experiences do not represent equivalent outcomes and must be investigated using appropriate procedures.

Because of its theoretical-critical nature, the essay cannot establish causal relationships between implementing meliponaries and changes in learning or civic-environmental agency. Future research, subject to appropriate ethical procedures, should examine the proposed dimensions in different school contexts, with longitudinal monitoring and compliance with relevant methodological and ethical requirements. The intentional bibliographical selection also limits the scope of the conclusions, which should be understood as interpretative propositions rather than generalizations about all school experiences.

Educational meliponaries can thus constitute spaces for interdisciplinary inquiry and critical socio-environmental education when integrated into intentional, participatory, and territorially contextualized pedagogical practices. Their relevance should be examined through the quality of these practices and the conditions enabling their continuity rather than solely through the existence of physical infrastructure.

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