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Small practices, big impacts: solid waste management, selective collection, and environmental education in early childhood education — a case study

Pequenas práticas, grandes impactos: gestão de resíduos sólidos, coleta seletiva e educação ambiental na educação infantil — um estudo de caso

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Maria Emília Moraes
https://orcid.org/0009-0004-1894-5114
Natássia Jersak Cosmann
https://orcid.org/0000-0002-6927-390X
Dartel Ferrari Lima
https://orcid.org/0000-0002-3633-9458

ABSTRACT

Solid waste management in educational institutions represents a key challenge for environmental sustainability and science education. This qualitative case study with a participatory intervention examined waste generation, handling, and disposal at the Infância Feliz Municipal Early Childhood Education Center (CMEI) in Cascavel, Paraná, Brazil. Data were collected through systematic observation, photographic records, and document analysis, combined with environmental education activities integrated into the Science curriculum. Findings showed the predominance of organic and recyclable waste and indicated that selective collection and composting reduced the volume of waste sent to landfills. Evidence from observational records and institutional practices demonstrated increased engagement of teachers, staff, and students in waste management routines. Alignment with local public policies supported implementation and continuity. The study proposes a replicable pedagogical-environmental framework integrating waste management and science teaching, contributing to sustainability practices and the development of environmentally responsible attitudes in early childhood education.

Keywords: solid waste management; environmental education; selective collection; composting; early childhood education; science teaching

RESUMO

A gestão de resíduos sólidos em instituições educacionais representa um desafio central para a sustentabilidade ambiental e para o ensino de Ciências. Este estudo de caso qualitativo, com intervenção participativa, analisou a geração, o manejo e a destinação de resíduos no Centro Municipal de Educação Infantil Infância Feliz (CMEI), em Cascavel, Paraná, Brasil. Os dados foram coletados por meio de observação sistemática, registros fotográficos e análise documental, associados a atividades de educação ambiental integradas ao currículo de Ciências. Os resultados evidenciaram a predominância de resíduos orgânicos e recicláveis e indicaram que a coleta seletiva e a compostagem reduziram o volume de resíduos destinados a aterros. Evidências provenientes dos registros observacionais e das práticas institucionais demonstraram aumento do engajamento de professores, funcionários e estudantes nas rotinas de gestão de resíduos. O alinhamento com políticas públicas locais favoreceu a implementação e a continuidade das ações. O estudo propõe um referencial pedagógico-ambiental replicável, integrando gestão de resíduos e ensino de Ciências, contribuindo para práticas sustentáveis e para a formação de atitudes ambientalmente responsáveis na Educação Infantil.

Palavras-chave: gestão de resíduos sólidos; educação ambiental; coleta seletiva; compostagem; educação infantil; ensino de Ciências.

1 **Introduction**

The construction of a sustainable society begins with small everyday actions, and Early childhood education emerges as a decisive context for cultivating environmentally conscious practices. Contemporary society faces complex challenges related to sustainability, particularly regarding the generation and management of solid waste. Educational institutions, as both formative and social spaces, play a central role in shaping conscious habits and responsible environmental practices, serving as strategic arenas for the implementation of critical educational interventions (Lima & Lima, 2017; Gomes & Chagas, 2024). In this context, Early childhood education (ECE) is understood as a strategic stage for the development of socio-environmental values, as early experiences can influence behaviors that extend to family life and the wider community (UNESCO, 2023; OECD, 2022; Bilibio & Lima, 2025).

Despite growing interest in Environmental Education in schools, studies indicate that the practical application of solid waste management policies remains limited and fragmented. International evidence shows that recycling programs and sustainability projects in schools enhance children's ecological awareness and promote active community participation (Lima; Malacarne & Strieder, 2012). In Brazil, pilot experiences in Curitiba (2020) and São Paulo (2014) demonstrate that the National Solid Waste Policy – PGRS (Brazil, 2010), when combined with interdisciplinary pedagogical practices, can be effective. However, these initiatives also reveal significant gaps in the systematization and monitoring of such actions (Bandeira et al., 2025; Ferreira et al., 2023). This scenario highlights the need for structured and context-sensitive approaches that articulate policy guidelines with pedagogical practice.

A substantial knowledge gap persists regarding the implementation of the PGRS in Municipal Early childhood education Centers (CMEI), particularly in mid-sized cities. Most research has focused on primary and secondary schools, overlooking early childhood, a critical stage when socio-environmental habits and perceptions begin to consolidate (Beckert & Lima, 2024). The absence of clear models and applicable frameworks hampers the integration of waste management, Environmental Education, and Science teaching in the curriculum, limiting the development of consistent and replicable educational practices (Beckert et al., 2025; Almeida, 2018).

This study is relevant because it integrates Science teaching with Environmental Education in a practical, critical, and interdisciplinary manner, addressing gaps identified in public policies and school curricula. The main contribution of this study is pedagogical, supported by managerial elements, as it proposes an integrated approach that connects waste management practices with science teaching in early childhood education. By developing an PGRS framework tailored to CMEI, this research contributes to the implementation of national policies and provides concrete pedagogical tools for teachers, administrators, and

children, promoting behavioral and social changes beyond the school environment (Brazil, 1999, 2010; Dal Bosco & Prates, 2017; Monteiro, 2016).

The central research question guiding this study is: How can the design and implementation of a Solid Waste Management Plan (PGRS) in Municipal Early Childhood Education Centers (CMEI) support interdisciplinary science teaching while fostering sustainable practices among children and the school community? To address this question, the study is guided by the following sub-questions: (i) What are the patterns of waste generation and management in the school context? (ii) How can waste management be integrated into pedagogical practices in early childhood education? (iii) To what extent can such practices inform replicable educational and management approaches? This formulation provides a clearer analytical focus and aligns the empirical investigation with the proposed objectives.

The objective of this research is to develop a methodological framework for designing and implementing PGRS in CMEI, linking Environmental Education and Science teaching in an interdisciplinary way. The study aims to understand waste generation and management in schools, propose contextualized educational activities for preschoolers, and provide replicable methodological references for other educational institutions (Muniz et al., 2025; Cascavel, 2020). In this sense, the term “framework” is understood as a context-based and analytically informed proposal, rather than a fully validated model.

The research focuses on CMEI in the municipality of Cascavel, Paraná, during the 2021 academic year, involving preschool students, teachers, staff, and administrators. The study relies on direct observation, photographic records, waste generation diagnosis, and the collaborative construction of an PGRS framework, prioritizing both implementation feasibility and curricular integration with Science and Environmental Education (Bilibio et al., 2025; Rissato, Santos & Nazzari, 2024).

This methodological approach integrates concepts from science, pedagogy, and environmental management, emphasizing educational practices that are simultaneously scientific, social, and

environmentally responsible. To improve conceptual clarity, the study articulates three analytical dimensions: (i) pedagogical (Science teaching and Environmental Education), (ii) managerial (waste management practices), and (iii) policy-oriented (alignment with public policies). By examining the interactions among school, child, and society, the study reinforces the view of ECE as a space for shaping attitudes, values, and habits that directly impact the community and foster critical socio-environmental awareness (Ruscheinsky, 2012; Almeida, 2023).

Ultimately, this research advances knowledge on waste management and Environmental Education, offering a replicable, coherent model aligned with Brazilian public policies. Rather than proposing a universal model, the study presents a context-sensitive framework that may inform similar initiatives in comparable educational settings. By connecting Science, pedagogy, and social engagement, it highlights the role of schools as spaces for critical, civic, and sustainable formation, providing theoretical and practical contributions to inform and inspire future policies and educational projects both nationally and internationally (UNESCO, 2023; OECD, 2022; Bandeira et al., 2025).

2 **Materials and Methods**

This study adopts a qualitative case study design with the incorporation of mixed operational indicators, considered the most appropriate to investigate complex and situated phenomena such as the articulation between solid waste management practices and Science teaching in a Municipal Early childhood education Center. While the study is primarily interpretive, quantitative indicators related to waste generation and management were used as complementary analytical elements, allowing for a more comprehensive understanding of the phenomenon. This methodological choice enabled an in-depth analysis of a specific context, capturing not only institutional and pedagogical dynamics but also the meanings attributed by the participants and the impacts of educational interventions aimed at sustainability.

The unit of analysis selected was the Infância Feliz CMEI, located in Cascavel, Paraná, a public institution that serves children in both part-time and full-time modalities. The selection was based on criteria of convenience and relevance, considering the representativeness of the school within the municipal network and the openness of its administration to engage in educational and research-oriented projects. The study involved teachers, support staff, custodians, management, and children, all understood as key actors in the implementation of the PGRS within the school environment.

Data collection was carried out in three complementary stages. First, an institutional diagnosis was conducted through direct observation of daily routines concerning the generation, separation, and disposal of waste. Second, semi-structured interviews were conducted with teachers, administrators, and support staff in order to understand their perceptions, difficulties, and potential for advancing sustainability-related educational processes. Finally, institutional documents, including pedagogical plans and activity records, were analyzed, ensuring triangulation of data sources and greater interpretive consistency. Additionally, operational indicators related to waste typology and volume were recorded, enabling a descriptive quantitative dimension that complements the qualitative analysis.

The investigation also encompassed the implementation of participatory pedagogical practices, designed collaboratively with the teaching staff. The actions included the training of teachers and custodial staff, the installation of labeled containers for selective collection, the incorporation of composting as a pedagogical resource in Science classes, and playful activities with children focusing on the 3R (reduce, reuse, and recycle). All stages were systematically documented in field diaries, ensuring detailed records of actions and their repercussions on the school's daily routines.

Data analysis followed an interpretive qualitative approach, supported by thematic analysis. Field notes, interview transcripts, and documentary data were subjected to a process of open coding, allowing the identification of recurrent themes related to waste management practices, pedagogical integration, and

stakeholder engagement. These categories were subsequently organized into analytical dimensions aligned with the study objectives. Quantitative operational indicators were analyzed descriptively, serving to corroborate and contextualize qualitative findings. Triangulation among data sources (observations, interviews, and documents) was used as a validation strategy, enhancing the credibility and consistency of the interpretations.

Regarding methodological rigor, particular attention was given to reflexivity and potential biases inherent to observational research. The involvement of the researcher in the implementation process may have influenced participants' behavior (observer effect), which was mitigated through prolonged engagement in the field and systematic recording of practices over time. Semi-structured interviews were treated as complementary sources of information, and their interpretive limits are acknowledged (Davis, 2015).

Regarding ethical considerations, this research is grounded in Resolution No. 510/2016 of the Brazilian National Health Council (CNS), which establishes standards for research in the Human and Social Sciences. Specifically, it falls under Article 1, sole paragraph, item VII, which exempts from review by the CEP/CONEP system research that seeks the theoretical deepening of situations that emerge spontaneously and contingently in professional practice, provided no identifiable personal data are involved (Lima & Lima, 2021).

Furthermore, due to its essentially educational and formative nature, this study is also aligned with item III of the same Resolution, which exempts activities conducted exclusively for educational or training purposes, as long as they do not pose risks beyond those of everyday life. No sensitive data were collected, and the confidentiality and anonymity of participants were fully preserved. Ethical principles such as respect for dignity, transparency of objectives, voluntary participation, and institutional consent were strictly observed, ensuring scientific integrity and compliance with Brazilian legislation. All participants were informed about the objectives of the study, and institutional authorization was formally obtained from the

school management. Participation was voluntary, and no individual identification was recorded, particularly regarding children, whose involvement occurred exclusively within pedagogical activities and without any form of individual data collection.

Finally, it is important to acknowledge that, as a single-case study, the findings are context-specific and not intended for statistical generalization. However, the analytical framework proposed aims to offer transferable insights that may inform similar educational settings, respecting contextual adaptations.

Flowchart of the implementation stages of the solid waste management plan at the "Infância Feliz" CMEI.

3 **Results and Discussion**

3.1 Empirical characterization of the school context and waste generation

The CMEI has a built area of 244 m² and serves 75 children enrolled in morning, afternoon, and full-day shifts. The pedagogical and administrative staff comprises 17 professionals, including seven early childhood education teachers, two administrators, one pedagogical coordinator, two support staff members, one intern, and five custodians responsible for kitchen and facility maintenance. The infrastructure includes four classrooms, two adapted bathrooms, a reception hall, an administrative office, storeroom, laundry, cafeteria, library, kitchen with pantry, and an outdoor area of approximately 300 m², featuring a playground,

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playhouse, synthetic grass area, and solarium. This variety of spaces allowed for the identification of critical waste-generation points and the design of selective collection and composting strategies tailored to the institution's operational reality.

The initial characterization of waste at the "Infância Feliz" CMEI enabled an understanding of generation and disposal flows in each space. The systematization of this information, presented in Table 1, highlights the areas of highest waste production and the specific characteristics of each environment, facilitating a more targeted, efficient, and pedagogically informed approach to selective collection and composting.

Table 1. Typology and distribution of solid waste across different environments of the "Infância Feliz" CMEI, Cascavel, 2021.

Environment	**Type of waste**	**Destination**	**Notes**
Cafeteria	Organic, plastic	Compost / recyclable	Main waste: food scraps, snack packaging
Classrooms	Paper, plastic, metal	Recyclable / non-recyclable	Waste from educational activities and personal hygiene
Administrative Office	Paper, plastic	Recyclable	Low foot traffic; two small bins
Kitchen	Organic, plastic	Compost / recyclable	Custodians trained according to the Municipal Good Practices Manual
Outdoor Yard	Organic	Compost	Temporary external storage site during the pandemic

To support the evaluation of the efficiency of the PGRS, operational indicators were defined to measure the weekly average of collected waste, categorized by type. These indicators enable the monitoring of the progress of selective collection practices, the identification of bottlenecks in waste segregation, and provide insights for pedagogical and logistical adjustments at the targeted CMEI, thereby strengthening the integration of environmental management with the educational process (Table 2).

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Table 2. Performance indicators of selective collection at the "*Infância Feliz*" CMEI, showing weekly average of collected waste and distribution by material type, Cascavel, 2021.

Waste Type	**Average weekly collection (kg)**	**Destination**	**Notes**
Organic	15	Composting	Food scraps and fruit waste
Plastic	5	Recyclable	Packaging, disposable cups
Paper	3	Recyclable	Pedagogical activities, personal hygiene
Metals	0.8	Recyclable	Cans and small utensils
Non-recyclable	2	Municipal collection	Mixed materials not suitable for recycling

The implementation and monitoring schedule of the PGRS, summarized in Table 3, provided an integrated overview of the sequence of actions carried out at the "Infância Feliz" CMEI. This systematization of the stages emphasizes the relationship among strategic planning, staff training, and pedagogical execution, allowing for an understanding of how waste management practices were gradually, participatively, and sustainably incorporated into the daily school routine.

Table 3. Implementation and monitoring schedule of the solid waste management plan at the "*Infância Feliz*" CMEI, Cascavel, 2021.

Stage	**Action**	**Responsible**	**Frequency**
Planning	Waste mapping and distribution of containers	Internal Committee	Initial
Training	Training of cleaning staff and teachers	Internal Committee / SEMED*	Continuous
Pedagogical implementation	Activities with children (composting, container identification)	Teachers / Coordination	Weekly
Monitoring and evaluation	Observation, photographic recording, and feedback	Internal Committee	Continuous

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Stage	Action	Responsible	Frequency
Dissemination and engagement	Booklets, folders, and workshops with families	Teachers / Coordination	Monthly

3.2 Observed outcomes of the waste management plan

The analysis of the PGRS implemented at the "Infância Feliz" CMEI highlighted the predominance of organic waste, primarily food scraps, while recyclable and non-recyclable materials were mainly generated by pedagogical and administrative activities. This characterization enabled the identification of critical waste-generation areas and the targeting of selective collection and composting strategies, aligning operational efficiency with pedagogical potential (Ruscheinsky, 2012; Dal Bosco & Prates, 2017).

Systematic monitoring of the program revealed positive impacts on the environmental behavior of the school community. Direct observations, photographic records, field notes, and staff feedback indicated improvements in waste segregation and children's engagement, suggesting a progressive incorporation of sustainable practices into daily routines rather than an immediate or homogeneous behavioral change (Ferreira, Oliveira & Marques, 2023; Bandeira et al., 2025).

Collaboration with the school community was associated with the consolidation of sustainable practices. Workshops, meetings, and joint activities with teachers and families contributed to a shared understanding of environmental impacts and to the gradual incorporation of waste management routines, although variations in participation levels were observed among families and staff, indicating that engagement was uneven and context-dependent (Almeida, 2023).

Despite the overall positive trends, some operational challenges were observed, particularly in maintaining consistent waste segregation practices across all environments and shifts. These inconsistencies

suggest that behavioral change is gradual and requires continuous reinforcement, monitoring, and pedagogical mediation.

3.3 Interpretation of pedagogical and environmental impacts

Integrating waste management practices into Science teaching promoted active learning, involving observation, classification, and disposal of waste, development of educational materials, and composting. Experiencing the principles of reduce, reuse, and recycle contributed to scientific literacy, environmental awareness, and the internalization of socio-environmental values, fostering attitudes of environmental responsibility from early childhood (Cascavel, 2020; Brazil, 2010; UNESCO, 2023).

From a theoretical perspective, these findings suggest that experiential and context-based learning environments can enhance the connection between scientific concepts and everyday practices, reinforcing the role of schools as spaces for socio-environmental formation. However, the extent to which these learning outcomes translate into long-term behavioral change beyond the school context remains uncertain and requires longitudinal investigation (Evans; Whitehouse & Hickey, 2012).

Pedagogical, community, and institutional integration emerged as a central vector for consolidating scientific and socio-environmental competencies. The combination of waste separation, composting, and production of educational materials provided experiential learning that transcends theoretical knowledge, fostering critical awareness, sustainable habits, and early environmental responsibility (Ferreira et al., 2020; Santos et al., 2020).

Nevertheless, the observed outcomes largely confirm expectations established in the literature, with limited evidence of disruptive or contradictory findings. This alignment may reflect both the effectiveness of the intervention and the influence of prior theoretical frameworks guiding the implementation, which can shape both practices and interpretations.

Transforming waste management into active learning proved feasible through curriculum integration with Science, addressing sustainability, conscious consumption, material cycles, and human–nature relationships. Experiencing the 3R principles, combined with educational material development and composting practices, enabled children to internalize ethical values and attitudes of environmental responsibility from the earliest years (Cascavel, 2020; Brazil, 2010; UNESCO, 2023).

3.4 Institutional dynamics and challenges

The effectiveness of these practices also depends on strategic institutional interactions. Collaboration with municipal agencies, such as the Municipal Department of Education and the Municipal Environmental Secretariat, provides technical support, normative guidance, and pedagogical resources, ensuring consistent operationalization of selective collection and composting programs (Brazil, 2010; Dal Bosco & Prates, 2017; Oliveira & Silva, 2019; Ferreira et al., 2020; Santos et al., 2020).

Implementing waste management practices faces intrinsic challenges of school dynamics, including space reorganization, continuous staff training, and adaptation of routines. Differences in perception among teachers, assistants, and families, as well as external limitations, highlight the need for ongoing awareness, consistent pedagogical articulation, and systematic monitoring (Barr; Gilg & Ford, 20025).

In addition, contextual constraints such as pandemic-related adaptations, temporary changes in space usage, and fluctuations in attendance may have influenced both waste generation patterns and engagement levels, introducing variability that should be considered when interpreting the results (US EPA, 2026).

Administrative barriers, municipal restrictions, and financial sustainability are critical factors that require strategic planning and coordination with institutional partners to ensure continuity and operational efficiency.

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Initial resistance to new practices was observed among some staff and routines, requiring continuous mediation and reinforcement strategies. This finding highlights that institutional change processes are gradual and may involve negotiation, adaptation, and partial adherence rather than immediate transformation.

3.5 Comparative analysis with national and international experiences

Comparisons with national and international experiences suggest convergence on fundamental principles. In Fernando de Noronha (Oliveira & Souza, 2022), Belo Jardim-PE (Almeida, 2018), Singapore, and Canada (UNESCO, 2023), structured selective collection and composting programs, combined with teacher training and community engagement, demonstrated lasting impacts on waste reduction and environmental education.

These convergences reinforce the relevance of community engagement, teacher training, and curriculum integration as key elements of effective environmental education. However, differences in infrastructure, governance models, and resource availability indicate that such practices cannot be directly transferred without contextual adaptation (Phan & Kato, 2016).

Despite contextual differences, community engagement, teacher training, and the integration of education and sustainability are essential for enduring changes, validating the relevance of the project at the "Infância Feliz" CMEI and reaffirming its potential contribution to a broader movement for environmental responsibility.

3.6 Comparative critique between local policies and national guidelines

The comparative analysis between local policies and national guidelines highlights divergences and convergences that directly affect the effectiveness of solid waste management programs in early childhood education institutions. While the PGRS establishes general principles of shared responsibility, environmental

education, and waste reduction, municipal regulations and guidelines may vary in terms of detail, available resources, and implementation strategies (Brazil, 2010; Cascavel, 2020).

At the local level, the Municipal Department of Education (SEMED) and the Municipal Environmental Secretariat (SEMA) defined routines, provided collection containers and educational materials, and offered staff training. These measures translated the principles of the PGRS into practical actions adapted to the CMEI context, such as the use of vermicomposting systems and the strategic placement of collection containers (Oliveira & Souza, 2022).

Despite convergence in objectives, some gaps were identified in policy articulation. The PGRS provides broad and conceptual recommendations without detailing specific methodologies for early childhood education institutions, whereas municipal guidelines require ongoing adaptations to fit the school's physical dimensions, number of children, and staff capacities (Dal Bosco & Prates, 2017; Cascavel, 2020).

This gap between normative guidance and operational implementation suggests that national policies, while essential as a legal framework, may lack sufficient specificity to support effective pedagogical integration in early childhood education contexts. As a result, local institutions often rely on interpretative and adaptive processes, which can generate variability in implementation quality and outcomes (Mohamad et al., 2024).

A particularly relevant aspect is the availability of financial and logistical resources. While the PGRS provides general incentive mechanisms, local realities do not always offer sufficient support, requiring institutional articulation and innovation (Monteiro, 2016; Oliveira & Silva, 2019; Ferreira et al., 2021).

These findings indicate that the effectiveness of public policies depends not only on their formal design but also on the existence of operational conditions, technical support, and continuous professional

development. Without these elements, policy implementation risks remaining predominantly normative rather than transformative.

3.7 Study limitations, strengths, and future research

3.7.1 Study limitations

Despite the progress achieved, the study presents limitations that should be considered when interpreting the results. First, the investigation focused on a single institution, the "Infância Feliz" CMEI, which limits the generalizability of the findings to other school contexts.

Another limitation concerns the temporality of data collection. Monitoring of waste management practices occurred over a relatively short period, which may not fully reflect the consolidation of long-term sustainable habits among children, teachers, and families.

Additionally, seasonal factors or specificities of the school calendar could influence waste generation and community engagement, which were not fully captured in the analysis.

From a methodological perspective, the use of observational records, photographic documentation, and field notes may also introduce observer-related influences, as the presence of researchers can affect participants' behavior and engagement levels.

Furthermore, contextual factors such as pandemic-related adjustments may have influenced both routines and participation, limiting the stability of the observed patterns.

3.7.2 Study strengths

Among the positive aspects, the integrated approach combining Environmental Education, Science teaching, and waste management stands out, enabling the articulation between pedagogical practice, environmental awareness, and experiential learning.

Another strength was the active participation of the school community and the coordination with municipal agencies, which ensured technical support, normative guidance, and continuity of actions.

The combination of operational monitoring and pedagogical integration represents a relevant contribution, as it connects environmental management practices with educational outcomes in a structured and context-sensitive manner.

3.7.3 Future research and implications

This study highlights the need for future research that expands the analysis of solid waste management practices across multiple early childhood education institutions, including diverse socioeconomic contexts and geographic regions.

Comparative investigations could identify contextual factors influencing school community engagement, the effectiveness of pedagogical strategies, and the sustainability of actions.

Future interventions could also explore the incorporation of educational and digital technologies to enhance environmental learning. Tools such as waste monitoring applications, educational games, and interactive resources can support scientific literacy, promote continuous engagement, and broaden family and community participation (UNESCO, 2023; OECD, 2022).

Longitudinal studies are particularly recommended to assess the durability of behavioral changes and the long-term impact of environmental education practices, allowing for a more robust evaluation of their effectiveness and scalability.

5 **Final considerations**

The experience at the “Infância Feliz” CMEI demonstrated that developing a methodological framework for implementing a PGRS constitutes a viable strategy to integrate Environmental Education and Science teaching in an interdisciplinary manner. Structured practices, such as selective waste collection,

composting, production of educational materials, and hands-on pedagogical activities, contributed to reducing the institution's environmental impact while fostering engagement, critical reflection, and socio-environmental responsibility among children, teachers, and families.

Rather than merely confirming previously discussed results, these findings indicate that the integration of environmental management and pedagogical practice can function as a strategic axis for early childhood education, linking scientific literacy, social responsibility, and everyday practices in a coherent and context-sensitive manner.

The challenges encountered, including adaptation to new routines, continuous staff training, and infrastructure limitations, highlight pedagogical, structural, and cultural dimensions that require systematic attention. Innovative strategies, such as workshops, vermicomposting, playful activities, and continuous monitoring, proved essential for overcoming obstacles, emphasizing the importance of strategic planning, ongoing teacher development, and the collective engagement of the school community. The integration of practical activities, awareness-raising, and curricular alignment enhanced both scientific and socio-environmental learning, consolidating conscious habits of consumption and waste management from early childhood and demonstrating that the developed model is replicable and adaptable to other institutions with similar characteristics.

From a public policy perspective, the results suggest that national guidelines, such as the PGRS, require greater operational detailing and articulation with local educational systems to ensure effective implementation in early childhood education contexts. Strengthening institutional support, technical guidance, and funding mechanisms is essential to move from normative frameworks to concrete and sustainable practices (Florida Dep, 2024).

The promotion of institutional partnerships and the adoption of educational technologies emerged as key factors for the effectiveness and sustainability of the interventions. Collaborations with municipal

agencies provided technical support, educational materials, and regulatory guidance, ensuring consistent operationalization of practices and alignment with the PGRS. Meanwhile, digital tools improved the precision of monitoring, facilitated the recording of results, and engaged children in meaningful ways, fostering scientific literacy and the development of critical, responsible citizens.

Implications for teacher education are also evident. The findings highlight the need for initial and continuing teacher training programs that incorporate environmental education, interdisciplinary methodologies, and active learning strategies. Teachers play a central role in mediating the relationship between policy and practice, and their preparation is crucial for the effective integration of sustainability into daily school routines.

In terms of curriculum design, the study reinforces the importance of embedding environmental education as a transversal and structuring component, rather than as an isolated theme. The articulation between science teaching, environmental management, and experiential learning offers a pathway for developing competencies related to critical thinking, responsible consumption, and socio-environmental awareness from early childhood (Sustainable Jersey For Schools, 2018).

Overall, the implementation of a PGRS in early childhood education transcends environmental preservation, positioning the school as a central agent in the holistic development of conscious, critical, and engaged children. The experience offers a practical and replicable reference for integrating operational efficiency, meaningful learning, and the promotion of socio-environmental values, highlighting the potential of educational institutions to contribute effectively to sustainable development and civic formation from the earliest stages of education.

Finally, future advances in this field depend on the consolidation of long-term monitoring strategies, the expansion of studies across diverse educational contexts, and the strengthening of collaboration between schools, public authorities, and communities. Such efforts are essential to ensure that environmental

education initiatives evolve from localized experiences to structurally embedded educational practices with lasting social impact.

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