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Culturally Responsive Sustainability Education in Early Childhood: A Mixed-Methods Evaluation of a Net-Zero Green Living Curriculum in an Indigenous Preschool in Taiwan

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Abstract

This study developed and evaluated a culturally responsive net-zero green living curriculum for Indigenous preschoolers in the Rinari community of Pingtung County, Taiwan. In response to Taiwan's 2050 net-zero policy, the curriculum integrated local cultural knowledge into three instructional strands: green diet, resource circulation, and energy conservation and carbon reduction. A mixed-methods single-group pretest-posttest design was implemented in a mixed-age preschool classroom. Eighteen children with matched pretest and posttest data were included in the quantitative analysis, while classroom observations, teacher notes, children's work, and post-activity discussions were used to document qualitative changes in learning and behavior. The intervention consisted of nine core activities delivered over three instructional weeks within a five-week project cycle, with additional support from learning-center exploration. Children's environmental behavior was assessed using a self-developed pictorial Preschool Environmental Behavior Scale adapted from the *Children's Attitudes Toward the Environment Scale–Preschool Version*. Results showed a significant increase in total environmental behavior scores from pretest (M = 16.6, SD = 4.13) to posttest (M = 19.6, SD = 3.87), W = 22.5, p = .011. Among the seven individual items on the Preschool Environmental Behavior Scale, the greatest improvement was found in children's preference for obtaining food from nearby farms rather than supermarkets (p = .019). Qualitative findings further indicated that children used concrete and culturally meaningful language to discuss carbon emissions, local ingredients, biodegradable materials, and leftover food reuse, and that some of these practices extended to home settings. These findings suggest that culturally grounded, hands-on environmental education can enhance preschoolers' environmental understanding and practices while offering early childhood teachers a practical framework for embedding local knowledge and everyday sustainability routines into Indigenous community-based curricula.

Keywords: Sustainability Education; Early Childhood Intervention; Tribal Curriculum; Circular Use; Low-Carbon Habits;

Introduction

Environmental sustainability education is increasingly recognized as a legitimate and developmentally appropriate domain of learning in early childhood. A growing body of research indicates that well-designed pedagogical interventions can deepen young children's environmental understanding, strengthen pro-environmental dispositions, and, under some conditions, foster observable pro-environmental behaviors [1]. This emerging evidence is important because early childhood is a formative period during which everyday habits, value orientations, and socially mediated patterns of action begin to take shape. Sustainability learning in the early years therefore involves more than knowledge acquisition; it also concerns the formation of dispositions, routines, and relational ways of engaging with the more-than-human world.

Despite this growing recognition, important conceptual and methodological limitations remain. First, although scholarship on early childhood education for sustainability has expanded, relatively few studies have examined how sustainability learning can be meaningfully embedded in culturally responsive or Indigenous community contexts, where environmental practices are closely tied to local knowledge, place-based identity, and intergenerational ways of living. Second, recent evidence syntheses suggest that intervention-based research with young children remains limited, and behavior-focused evaluations are still less common than studies emphasizing attitudes, awareness, or representational understandings [2]. These limitations matter because claims about sustainability learning in early childhood remain incomplete unless they are supported by evidence of how children's everyday practices change and under what cultural and pedagogical conditions such change becomes possible.

To address these limitations, the present study examined a five-week net-zero green living curriculum implemented in an Indigenous preschool in Taiwan. The study is significant in both empirical and contextual terms. Empirically, it responds to the need for intervention-based and behaviorally oriented research in early childhood sustainability education. Contextually, it situates sustainability learning within an Indigenous community in which local lifeways, ecological knowledge, and culturally grounded practices are central to children's everyday experience. By integrating culturally grounded pedagogies with a mixed-methods pretest-posttest design, the study aims to contribute not only to the literature on early childhood sustainability education but also to broader discussions of how community-based, behaviorally meaningful, and culturally situated forms of environmental learning can be designed and evaluated in the early years.

Conceptual and Empirical Foundations for Early Childhood Net-Zero Sustainability Education

The literature relevant to the present study can be organized around three intersecting strands: (a) early childhood education for sustainability and early childhood environmental education (ECEfS/ECEE), (b) Indigenous and culturally responsive approaches to environmental education in early childhood, and (c) interventions intended to promote young children's pro-environmental behaviors (PEBs). Taken together, these strands provide the conceptual and empirical basis for examining how a culturally grounded net-zero green living curriculum may be developed and evaluated in an Indigenous preschool context.

Recent evidence syntheses suggest that scholarship on ECEE and ECEfS has expanded substantially, yet important limitations remain. In particular, the field continues to exhibit uneven methodological rigor and an imbalanced treatment of sustainability's environmental, social, and economic dimensions [1]. This suggests the need for research that conceptualizes sustainability more holistically and examines how such learning can be rendered developmentally meaningful for young children in specific sociocultural settings. In other words, the challenge is not only to introduce sustainability as a topic of learning, but also to determine how it can be pedagogically translated into forms of practice and understanding that are appropriate to early childhood.

Within this broader context, the concept of net zero provides a policy-relevant and educationally meaningful organizing framework for curriculum design. Authoritative climate and policy documents generally define net zero as a condition in which anthropogenic greenhouse gas emissions are balanced by removals, while also emphasizing that mitigation pathways depend on sustained emission reductions on the way toward net zero [3]. Importantly, Taiwan's publicly articulated net-zero transition strategy explicitly identifies lifestyle transition as a key dimension of social change [4]. This policy framing is especially relevant to early childhood education because it positions "green living" not merely as an abstract global concern, but as a locally relevant educational priority linked to everyday practice, community responsibility, and long-term societal transformation.

Taken together, these considerations support the importance of examining net-zero green living as an early childhood curricular focus. They also point to the need to explore how sustainability learning can be connected to children's daily routines, culturally grounded knowledge, and developmentally appropriate pedagogies within Indigenous preschool settings.

Synthesis of recent empirical evidence

Two evidence syntheses are particularly important for framing the present study. First, Ardoin and Bowers [1], in a systematic review of 66 studies on early childhood environmental education, concluded that early environmental education can support young children's affective and cognitive development and that nature-rich settings and experiences occupy a prominent place in the empirical literature. Second, Güler Yıldız et al. [5], in a systematic review of ECEfS studies published between 2008 and 2020, found that the field has been dominated by qualitative methods and environmentally oriented content, while intervention-based studies remain comparatively limited. They further called for research that addresses sustainability more holistically across its multiple pillars and that makes greater use of experimental and action-oriented designs.

Intervention effectiveness has likewise become an increasingly important concern. Wojciech et al. [2], in a meta-analysis of 65 studies and 76 effect sizes, reported that interventions generally improve children's pro-environmental behaviors, with an average effect size of approximately Hedges' $g = 0.53$. Their analysis further indicated that larger effects tend to be observed when actual behavior rather than self-reported behavior is measured, even though studies assessing actual behavior remain comparatively rare. They also found that intervention effects tend to decrease as children grow older, thereby reinforcing the argument that environmental learning and socialization should begin early. This body of evidence is highly relevant to preschool curriculum design because it underscores the value of implementing and evaluating sustainability interventions during the early years rather than postponing them until later schooling.

Recent empirical studies have also begun to clarify the mechanisms through which sustainability learning may be translated into pro-environmental orientations in young children. Li et al. [6], in a two-study investigation conducted in China, found that empathy with nature predicted preschoolers' pro-environmental attitudes above and beyond empathy with humans, and that a brief empathy-with-nature induction increased such attitudes relative to an active control condition. These findings suggest that affective-relational mechanisms are not only measurable in early childhood, but can also be intentionally shaped through pedagogical intervention. More broadly, they support the argument that sustainability education in the early years should move beyond factual transmission and instead cultivate relational care, empathy, and perspective-taking.

Evidence is especially compelling when early childhood designs combine concrete opportunities for practice, environmental prompts, and sustained adult-child interaction. For example, Iwasaki [7], in a study of an Eco Experience Education Program for Early Childhood in Japan, documented increases in children's water-saving behaviors at school following the intervention. The study further suggested that pro-environmental communication between teachers and children, together with visual prompts placed near faucets, contributed to the stabilization of these practices in the school setting, whereas home-based behaviors were less sustained in the absence of comparable prompts. This pattern is directly relevant to curriculum-based green living interventions because it highlights the importance of embedding sustainability goals into routines, environments, and communicative practices rather than treating them as isolated lesson content.

Several recent studies further emphasize the role of learning environments and children's participation in shaping sustainability learning. Nordén and Avery [8], for instance, reported a participatory action research project in an urban multi-ethnic preschool in Sweden, showing how the collaborative redesign of outdoor space supported sustainability learning opportunities, cooperation, participation, and leadership. At the same time, their study identified persistent constraints, including the need for deeper staff awareness, shared pedagogical frameworks, and stronger policy-level investment in professional learning. Complementing this, Biber et al. [9] found that 5- to 6-year-old children attending nature-centered kindergartens in Turkey demonstrated stronger environmental awareness and attitudes than peers in public kindergartens, suggesting that structured and

repeated contact with natural environments can meaningfully shape children's environmental orientations. Collectively, these studies indicate that sustainability learning in early childhood depends not only on curricular content, but also on place, routine, participation, and children's agency.

Another strand of research highlights young children's conceptual capacity for sustainability while underscoring the unevenness of what they understand in the absence of intentional instruction. Bahtić and Višnjić Jevtić [10], working with 43 children aged 3 to 7 in Croatia, found that older children were familiar with a wider range of sustainability-related ideas, including money use, recycling, and diversity, whereas younger children demonstrated fewer such concepts overall. Their findings support the view that early childhood programs can provide foundational understandings of sustainability and that teacher-designed activities can meaningfully expand children's conceptual repertoires. This point is especially important for the present study because net-zero green living requires the integration of multiple domains, such as energy use, waste reduction, and consumption practices, into a developmentally appropriate sequence of concepts and activities.

Empirical work also suggests that relatively sophisticated sustainability competencies can be intentionally fostered in preschool settings. In Turkey, Feriver and Göktepe [11] described a four-week project-based framework on "water" that integrated systems thinking and sustainability with children aged 5 to 6. Reported outcomes included significant improvements in children's ability to identify system elements, including less visible ones, and to articulate more complex causal relations among them. This is highly relevant for net-zero education because carbon-aware green living inherently involves causal reasoning, such as connecting everyday energy use to emissions and broader climate-related consequences. Accordingly, pedagogies that help young children relate daily practices to larger ecological systems may be especially valuable.

Finally, culturally responsive and Indigenous approaches remain central to the advancement of early childhood sustainability education, yet they continue to be underrepresented empirically. Acharibasam and McVittie [12], for example, drew on Kasena ontology and epistemology in northern Ghana and adopted a "two-eyed seeing" approach that brought Western and Indigenous ways of knowing into dialogue within early childhood environmental education. Through land-based learning led by Indigenous Elders, their study emphasized respect, reciprocity, and responsibility toward nature, and argued that Indigenous ecological knowledge can strengthen children's relational understanding of human-nature interdependence. This line of work is especially relevant to the Rinari context, where environmental knowledge is deeply connected to land, culture, and community life, and where Indigenous communities also face heightened vulnerability to climate-related hazards and relocation pressures.

Research Gaps and the Rationale for the Present Study

Despite the growth of scholarship reviewed above, several important gaps remain, and it is the convergence of these gaps that justifies the present study. First, intervention-oriented research in early childhood sustainability education remains limited relative to the larger body of descriptive and qualitative work, while the literature continues to privilege the environmental pillar more strongly than the social and economic dimensions of sustainability [5]. This imbalance is consequential because it narrows how sustainability is introduced to young children, often reducing it to isolated topics about nature rather than presenting it as a multidimensional way of living that involves resource use, responsibility, fairness, and community well-being. A net-zero green living curriculum is especially promising in this regard because it provides a framework through which these dimensions can be connected to children's everyday practices.

Second, the intervention literature increasingly calls for stronger behavioral outcome measures and for programs that begin earlier in childhood [2]. Yet many studies in early childhood still rely primarily on attitudes, drawings, interviews, or other representational accounts, whereas fewer examine observable behaviors or the extent to which such behaviors may be sustained and transferred across contexts, such as from school to home. This limitation matters because sustainability education in early childhood ultimately aims not only to influence what children say or know, but also to shape what they do in everyday life. The present study addresses this gap by adopting a mixed-methods single-group pretest-posttest design to examine whether a five-week curriculum intervention can support measurable changes in preschool children's environmental behavior.

Third, culturally responsive and Indigenous approaches to early childhood environmental education remain theoretically important but empirically underdeveloped, particularly in East Asian Indigenous communities. Although prior scholarship has demonstrated the promise of integrating Indigenous ecological knowledge, relational ethics, and community values into sustainability learning, much of this work remains conceptual or descriptive rather than intervention-based and evaluative. This leaves an important gap in understanding how culturally grounded sustainability education actually operates in practice within Indigenous preschool settings. By focusing on the Rinari community, the present study extends this emerging field by providing empirical evidence from an Indigenous preschool in Taiwan and by aligning sustainability learning with local cultural knowledge, everyday practices, and community lifeways rather than importing a decontextualized and generic sustainability curriculum.

Fourth, although prior studies have identified several mechanisms that may support young children's pro-environmental learning, including empathy with nature, pro-environmental communication, visual prompts, and participatory routines, these mechanisms have rarely been brought together within short-cycle, community-based interventions that are at once culturally grounded and explicitly linked to net-zero lifestyle transition. This is a significant omission because real-world early childhood settings often require interventions that are both pedagogically meaningful and practically feasible. The present study responds to this need by designing and evaluating a five-week curriculum that occupies such an intervention window: long enough to support repeated routines, dialogue, and hands-on engagement, yet realistic for implementation in a small community-based preschool setting.

Taken together, these gaps point to the need for research that is simultaneously intervention-based, behaviorally oriented, culturally grounded, community-based, and policy-relevant. The present study is designed to address this need by examining whether a culturally responsive net-zero green living curriculum can support meaningful environmental learning and behavior among Indigenous preschool children in Taiwan. Importantly, these gaps also indicate that the study requires a theoretical framework capable of linking policy discourse, developmental learning processes, and culturally situated forms of environmental meaning-making. It is to this theoretical grounding that the discussion now turns.

Theoretical framing

To address the gaps identified above, the present study is situated within a coherent theoretical framework that brings together policy-curricular, developmental, and culturally relational perspectives. Rather than treating net-zero green living as a purely policy-driven topic or as a narrowly behavioral intervention, the present study conceptualizes it as an early childhood learning domain that is simultaneously curricular, developmental, relational, and culturally situated. Accordingly, the study draws on three complementary layers of theoretical framing: (a) Education for Sustainable Development (ESD) as a policy-curricular orientation, (b) developmental mechanisms of early pro-environmental learning, and (c) culturally

responsive and Indigenous relational perspectives on environmental education.

At the policy and curricular level, Education for Sustainable Development (ESD) and the Sustainable Development Goals (SDGs) have frequently served as organizing frameworks in early childhood sustainability research. These frameworks have been valuable in broadening the scope of early childhood education beyond narrow cognitive outcomes and in positioning sustainability as a multidimensional educational concern. However, empirical evidence suggests that such frameworks are insufficient when they remain at the level of vision statements or policy discourse without being translated into embodied daily practices. For example, in the Flemish action research project conducted in childcare settings for children under the age of three, the SDGs helped establish a shared language and introduced the complexity of sustainability, yet they did not in themselves transform everyday attitudes or pedagogical routines [13]. This suggests that sustainability frameworks must be pedagogically operationalized through practice-based curriculum design. In the present study, this insight provides a clear rationale for moving from abstract sustainability discourse toward concrete net-zero green living routines and activities that are developmentally accessible to preschool children.

At the level of developmental mechanisms, the present study is informed by several complementary perspectives emerging from recent empirical research. One is **systems thinking**, which has been shown to be developmentally supportable in preschool through project-based and scaffolded learning experiences that help children reason about causal relations among environmental phenomena. This perspective is particularly relevant to net-zero education because net-zero green living involves understanding the links among everyday practices, resource use, emissions, and environmental consequences. A second perspective is **socio-communicative learning**, according to which new practices become more stable when they are socially mediated through repeated dialogue, teacher guidance, peer interaction, and routine participation. Observational intervention studies suggest that pro-environmental communication, especially when reinforced by environmental cues or prompts, can help sustain young children's everyday environmental practices. A third perspective is **affective-relational learning**, supported by evidence that empathy with nature can be experimentally induced and can strengthen preschool children's pro-environmental attitudes. Considered together, these perspectives suggest that environmental learning in early childhood becomes behaviorally meaningful not through information transmission alone, but through the interplay of repeated practice, communicative mediation, and relational engagement.

For culturally responsive and Indigenous contexts, the present study is further informed by the "two-eyed seeing" approach and by Indigenous relational ethics centered on respect, reciprocity, and responsibility. These perspectives provide a coherent basis for integrating local ecological knowledge, place-based practices, and land-related meanings into early childhood sustainability education. More importantly, they reframe environmental learning from an individualistic model of behavior change toward a relational model of participation in community life. In the Rinari context, this means that a net-zero curriculum is not understood simply as a set of techniques for reducing waste or saving energy. Rather, it is conceptualized as a form of relational learning through which children develop culturally meaningful practices of care, resource responsibility, and community-connected environmental participation. Framed in this way, net-zero green living becomes not only a sustainability target, but also a pedagogical process grounded in place, culture, and everyday shared practice.

Taken together, these theoretical perspectives provide the conceptual basis for interpreting the present intervention as more than a short-term behavior program. Instead, they support understanding the curriculum as a culturally situated educational design that links policy relevance, developmental mechanisms, and Indigenous relational worldviews within an early childhood setting. On this basis, the study's research aims and analytic strategy are designed not only to assess whether change occurs, but also to illuminate how such change may be pedagogically and culturally mediated.

Research aims and hypotheses

Guided by the literature reviewed above and by the theoretical framing of the study, the present research was designed to examine whether a culturally responsive net-zero green living curriculum could support meaningful environmental learning among Indigenous preschool children in Taiwan. The aims were formulated to align directly with the study's mixed-methods single-group pretest-posttest design and with the major gaps identified in prior research, particularly the need for intervention-based, behaviorally oriented, and culturally grounded work in early childhood sustainability education.

Aim 1

To examine whether preschool children's overall net-zero green living behavior scores improved from pretest to posttest following the five-week curriculum intervention.

Hypothesis 1

Children's total posttest scores would be significantly higher than their pretest scores.

Aim 2

To investigate whether positive pretest-posttest changes could also be observed across curriculum-aligned domains of environmental behavior, including practices related to resource saving, waste reduction, and everyday green routines.

Hypothesis 2

Scores across most curriculum-aligned domains would show positive pretest-posttest change, indicating that the intervention's effects were not limited to a single aspect of green living behavior.

Aim 3

To explore how children and educators described, enacted, and socially reinforced green living practices during and after the intervention, including through classroom dialogue, peer reminders, routine participation, and references to everyday life.

Because this aim is exploratory and explanatory in nature, no formal hypothesis was specified. Instead, the qualitative component was intended to illuminate the processes through which curriculum experiences may have supported observable changes in practice.

Aim 4

To examine how culturally grounded and community-based elements of the curriculum, such as place-based practices, local knowledge, and culturally resonant stories and values, shaped children's engagement and the perceived relevance of green living learning within the Rinari preschool context.

This aim was likewise exploratory and was designed to assess whether the intervention functioned not merely as a generic environmental education program, but as a culturally meaningful form of sustainability learning situated within an Indigenous community.

Taken together, these aims reflect the study's dual emphasis on outcome and process. Quantitatively, the study evaluates whether measurable changes in children's environmental behavior occurred following the intervention. Qualitatively, it examines how such changes may have been mediated through communication, participation, routine, and culturally grounded meaning-making. In this way, the study responds directly to recent calls for early

childhood sustainability research that is not only intervention-based and behaviorally focused, but also culturally responsive and contextually interpretable.

Materials and Methods

Design

The study employed a mixed-methods, single-group pretest-posttest quasi-experimental design. Quantitative data were collected using a pictorial environmental behavior scale administered before and after the intervention. Qualitative data were collected concurrently through classroom observation records, children's verbal responses during learning-center guidance, photographs of activities, and children's work samples. The mixed-methods design was used to capture not only whether scores changed after instruction but also how children interpreted and enacted environmental ideas during classroom participation.

Setting and Participants

The study took place in the affiliated preschool of Changrong Lily Elementary School in the Rinari community, Majia Township, Pingtung County, Taiwan. The preschool operated as a mixed-age class. Twenty-four children were enrolled in the class across junior, middle, and senior kindergarten levels. For the quantitative analysis, one child with special educational needs who could not complete the questionnaire was excluded, one younger child who was unable to understand the instrument during the pretest was excluded, and four children who were absent during the pretest did not contribute paired data. The final matched quantitative sample therefore consisted of 18 preschoolers. Qualitative observations documented the implementation of the intervention in the natural classroom setting.

Intervention

The project extended over five weeks. The core instructional intervention was implemented across three thematic weeks, with three group sessions per week (nine core activities in total), while the full project cycle also included baseline assessment, post-intervention assessment, and a culminating exhibition. Learning centers linked to the themes remained available to support repeated exploration.

The first thematic strand addressed energy conservation and carbon reduction. Activities included a teacher-developed drama in which carbon emissions were personified as a "Dirty Monster," a science experiment comparing carbon dioxide production in bottles representing low- and high-emission transport choices, and local plant cultivation intended to illustrate ecological care and carbon absorption. The second strand addressed resource circulation through recycling-sorting games, the transformation of outgrown clothing into reusable bags, and hands-on recycled-paper making. The third strand addressed green diet through shell ginger leaf weaving as an alternative to disposable containers, millet rice-ball making with reminders to take only what one could eat, and the reuse of leftover millet to prepare millet aiyu jelly. Across all strands, local indigenous materials and practices were used to situate environmental learning in children's home community.

Measures

Preschool Environmental Behavior Scale. The primary quantitative measure was a self-developed pictorial questionnaire adapted from the Children's Attitudes Toward the Environment Scale–Preschool Version. The instrument included seven paired-choice items, each accompanied by illustrations representing a more environmentally friendly and a less environmentally friendly behavior. After choosing the child figure that best matched their own typical behavior, participants indicated whether they were "very much" or "a little" like that child, yielding a 4-point score per item. Total scores ranged from 7 to 28, with higher scores indicating stronger environmental behavior. The seven items assessed: (1) preference for walking/bicycling rather than motorized transport, (2) waste sorting, (3) upcycling outgrown clothes, (4) reusing milk cartons, (5) refrigerating leftover food, (6) transforming leftovers into new food, and (7) obtaining food from nearby farms rather than supermarkets.

Qualitative records. Qualitative sources included teacher and researcher observation notes, learning-center dialogue, activity photographs, children's creations, and post-activity sharing. These records were used to identify recurring themes in children's understanding, participation, and transfer of learning.

Data Analysis

Descriptive statistics were calculated for pretest and posttest scores. Because of the small sample size and paired ordinal-format measurement, Wilcoxon signed-rank tests were used to evaluate pretest-posttest differences in total scores and individual items. Qualitative data were analyzed through thematic review of observation records and children's utterances, with attention to repeated patterns across the three curricular strands.

Ethical Considerations

The project followed classroom-based educational research ethics for studies involving young children. Written permission was obtained from the preschool and classroom teachers, and written informed consent was obtained from parents or legal guardians before data collection. Children's identities were anonymized in all records, participation was treated as voluntary, and children who showed discomfort or reluctance were allowed to withdraw from specific activities. All hands-on activities involving scissors, hot glue, cooking, or experiments were conducted with adult supervision and safety precautions.

Results

Quantitative Findings

Table 1 presents the pretest and posttest results. Overall environmental behavior scores increased significantly after the intervention. The mean total score rose from 16.6 (SD = 4.13) at pretest to 19.6 (SD = 3.87) at posttest (W = 22.5, p = .011), indicating a measurable improvement in the children's reported environmental behavior.

Measure	Pretest M (SD)	Posttest M (SD)	W	p
Overall environmental behavior	16.60 (4.13)	19.60 (3.87)	22.5	.011
Low-carbon transportation	1.50 (0.99)	2.00 (1.03)	13.5	.275
Waste sorting	2.94 (1.43)	3.39 (0.98)	15.0	.397
Upcycling outgrown clothing	2.72 (0.96)	2.78 (0.94)	16.0	.829
Reusing milk cartons	2.78 (1.06)	3.06 (0.87)	10.0	.279
Refrigerating leftovers	3.17 (1.20)	3.67 (0.77)	4.0	.105
Transforming leftovers into new food	2.11 (1.13)	2.67 (0.91)	22.0	.095
Choosing nearby farm food	1.33 (0.77)	3.33 (3.01)	0.0	.019

Table 1. Pretest and Posttest Results for Environmental Behavior Measures

Note. Higher scores indicate more environmentally friendly behavior.

At the item level, all seven indicators improved numerically from pretest to posttest. However, only one item reached statistical significance: children's preference for obtaining food from nearby farms rather than supermarkets increased from M = 1.33 (SD = 0.77) to M = 3.33 (SD = 3.01; W = 0.00, p = .019). This finding suggests that the green diet strand, especially its emphasis on local ingredients and community-based food sources, was particularly salient for the children.

The remaining items showed positive but nonsignificant changes. Low-carbon transportation preference increased from M = 1.50 to M = 2.00 (p = .275). Waste sorting increased from M = 2.94 to M = 3.39 (p = .397). Upcycling outgrown clothing increased slightly from M = 2.72 to M = 2.78 (p = .829), and reusing milk cartons increased from M = 2.78 to M = 3.06 (p = .279). Food preservation by refrigerating leftovers rose from M = 3.17 to M = 3.67 (p = .105), and turning leftovers into new food rose from M = 2.11 to M = 2.67 (p = .095). Taken together, the pattern suggests broad positive movement across domains despite the short intervention period and limited statistical power.

Qualitative Findings

Three qualitative themes help explain the observed score changes and clarify how children made sense of the intervention.

Theme 1: Abstract environmental concepts became concrete through narrative and experiment

The energy conservation/carbon reduction strand translated an abstract idea carbon emissions into concrete and memorable classroom experiences. In the drama activity, carbon emissions were personified as a "Dirty Monster," which gave children a shared metaphor for discussing invisible pollution. In the related carbon dioxide experiment, children compared two bottles with balloons: one bottle symbolizing a higher-emission transport option produced an expanding balloon, whereas the comparison bottle did not. During guided discussion, one child exclaimed that "the big balloon is the Dirty Monster," and another child suggested that "for nearby places we can walk, and for far places we can drive," followed by the classroom slogan, "*Walk more, drive less; then the Earth smiles*." These responses suggest that the intervention helped children associate vehicle use with air pollution and articulate basic low-carbon alternatives.

Theme 2: Resource circulation was learned through visible material transformation

The resource circulation strand was effective when children could see, touch, sort, and remake objects. In a comparison activity, children observed that shell ginger leaves softened, faded, and appeared to break down in water, whereas a plastic bowl "*stayed the same" and "did not change.*" When asked which material would gradually disappear in water, children pointed to the leaf rather than the plastic. In another activity, children identified reusable alternatives to disposable containers, including ordinary lunch bowls and plant leaves. Recycling-sorting games, upcycled clothing bags, and handmade recycled paper further reinforced the idea that used materials can be classified and transformed rather than simply discarded. These observations suggest that material comparison and hands-on making supported the children's emerging understanding of circular use.

Theme 3: Local food connected environmental action, cultural identity, and anti-waste behavior

The strongest quantitative improvement was in the item about obtaining food from nearby farms, and qualitative evidence suggests that this effect was tied to both cultural familiarity and sensory engagement. The green diet strand introduced local ingredients such as millet and shell ginger leaves and framed them as foods and materials "*from our tribe*." Children were frequently observed commenting that local foods belonged to their community and could be used in many ways. In the food-preservation activity, children compared millet stored at room temperature with millet kept in the refrigerator. They described the room-temperature sample as watery, smelly, and no longer edible, while describing the refrigerated sample as still suitable for eating or for turning into rice balls. In the subsequent millet-aiyu activity, leftover millet from the previous day was reused to prepare a new food, making the principle of leftover transformation visible and edible. These episodes suggest that children learned not only to value local ingredients but also to connect food care, preservation, and reuse with environmental responsibility.

Cross-Cutting Observation: The curriculum appeared to stimulate environmental talk

Although communication was not formally measured, the qualitative records indicate that the intervention supported descriptive language, comparison, explanation, and slogan use. Children appropriated metaphors introduced in drama, used sensory language to describe food spoilage and biodegradability, and linked classroom experiences to home routines. This communicative dimension may have helped sustain learning across repeated activities.

Discussion

The present study examined whether a culturally grounded, hands-on, net-zero green living curriculum could improve environmental behavior in a mixed-age Indigenous preschool classroom. The significant increase in total environmental behavior scores suggests that even a brief intervention can influence young children's environmental practices when learning is embedded in everyday routines and culturally familiar materials. Qualitative findings further indicate that the children did not simply memorize isolated messages. Instead, they began to discuss, compare, and enact environmental ideas in ways that were concrete, socially shared, and locally meaningful.

One of the clearest findings concerns the strength of the green diet strand. The only statistically significant item-level change was observed in children's preference for obtaining food from nearby farms rather than supermarkets. This result is notable because local food was not taught merely as an abstract "buy local" principle. Rather, it was embedded in sensory exploration, cooking, food preservation, and culturally valued ingredients such as millet and shell ginger leaves. This pattern is consistent with research showing that children's food-related learning and food acceptance are shaped by tactile and sensory experience. In the present study, children did not only hear that local food was environmentally preferable; they touched it, cooked it, ate it, stored it, compared it, and reused it. The local food strand also appeared to strengthen identity and ownership, as reflected in the children's repeated comments linking ingredients to their tribe and community.

The results for resource circulation and energy conservation and carbon reduction were also encouraging, although none of the individual items in these domains reached statistical significance. The qualitative data suggest that children's conceptual understanding may have changed more readily than some of their routine behaviors. For example, they could explain why shell ginger leaves were more environmentally friendly than plastic, identify correct sorting categories, and name reusable alternatives to disposable containers. They could also explain the classroom metaphor of the "Dirty Monster" and connect it to vehicle emissions. However, some everyday behaviors, especially transportation choices, remain strongly shaped by adult decision-making. Young children do not independently decide how they travel to school, and some household practices related to recycling or leftover management are also largely controlled by adults. The absence of statistical significance for several items may therefore reflect contextual constraints rather than an absence of learning.

Another important contribution of the study lies in its demonstration that cultural context can function as a pedagogical resource rather than merely a background variable. In many settings, environmental education is imported as a standardized program. In the present study, by contrast, local cultural materials did not simply decorate the curriculum; they structured it. Shell ginger leaves supported learning about biodegradability, alternatives to disposable containers, and weaving practices. Millet anchored discussions of local agriculture, respectful consumption, and leftover reuse. Planting activities connected ecological care to Indigenous relationships with land. The children's comments suggest that this culturally situated design strengthened motivation because environmental action felt connected to "our place" and "our food," rather than to decontextualized rules.

The study also suggests that environmental learning in preschool is partly communicative. The intervention repeatedly invited children to describe what they observed, compare alternatives, explain causes, and participate in memorable slogans. Although the study was not designed to assess speech or language outcomes, the qualitative records indicate that concrete metaphors and repeated classroom discourse gave children usable vocabulary for talking about less visible or more system-level issues, such as carbon emissions and decomposition. This point is educationally important because action is often reinforced by language: children are more likely to remember and repeat practices when they can name, discuss, and explain them.

Several limitations should be acknowledged. First, the study involved a small sample from a single preschool, which limits generalizability. Second, the design did not include a comparison group, so the observed improvements cannot be attributed exclusively to the intervention with the same degree of confidence as in a randomized design. Third, the primary scale was adapted and self-developed from an existing preschool environmental measure, but no reliability or validity coefficients were reported for the adapted version in this dataset. Fourth, the intervention period was short, and some behaviors may require a longer duration or stronger home-school collaboration before measurable change becomes stable. Fifth, several enrolled children were excluded from the matched quantitative sample because of age, special learning needs, or missing pretest data. Finally, the study did not include a delayed follow-up, parent report, or direct observation checklist outside the classroom.

Despite these limitations, the findings have clear practical implications. For preschool teachers, the study supports the use of integrated environmental themes linked to food, materials, and everyday energy use, rather than isolated awareness lessons. For schools serving Indigenous or culturally distinct communities, the findings suggest that place-based and culturally responsive environmental education can increase relevance, participation, and continuity between school and community life. For researchers, the study highlights the need for longer interventions, larger multisite samples, stronger psychometric validation of preschool instruments, and more explicit measures of home-school transfer. Future research could also examine whether culturally grounded environmental programs influence other developmental domains, including narrative ability, explanatory language, and family conversations about sustainability.

In conclusion, a culturally responsive net-zero green living curriculum can support meaningful environmental learning in early childhood. In this mixed-age Indigenous preschool, children showed an overall improvement in environmental behavior and developed richer ways of talking about carbon emissions, food care, material reuse, and local ecological responsibility. The strongest gains appeared where environmental action, sensory experience, and cultural identity were closely aligned. Together, these findings support locally grounded, hands-on environmental education as a promising direction for early childhood practice.

Competing Interests: The authors declare that they have no competing interests.

Data Availability Statement

Because the dataset involves minors in a single classroom and consent was obtained for research purposes only, the underlying data are not publicly available. De-identified materials may be made available from the corresponding author on reasonable request and subject to ethics and school permission.

List of Abbreviations

CATES-PV: Children's Attitudes Toward the Environment Scale–Preschool Version.

CO2: Carbon dioxide.

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