

Integrating Education for Sustainable Development into Elementary Mathematics: An Action Research on Curriculum Mapping, Teacher Experiences, and Instructional Guide Validation

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ABSTRACT:

Background: Integrating Education for Sustainable Development (ESD) into mathematics equips learners with problem-solving and critical thinking skills to address sustainability challenges. While global research highlights curricular opportunities, few studies have systematically mapped Sustainable Development Goals (SDGs) within Philippine mathematics instruction. This study addresses that gap by embedding sustainability into Grades 4–6 mathematics and developing a validated instructional guide.

Methods: A descriptive-qualitative action research design guided by the ADDIE framework was used. Content analysis mapped curriculum competencies to SDGs, while semi-structured interviews captured teachers' strategies and challenges. Thematic analysis identified patterns in teacher experiences, and expert validators assessed the guide's clarity, organization, and appropriateness.

Results: The findings revealed that ESD themes can be integrated across the economic, environmental, and social pillars without compromising mathematical rigor. Examples included operations through budgeting (SDG 8), geometry with marine resource maps (SDG 14), and decimals contextualized in financial literacy (SDG 10). Teachers reported stronger engagement and interdisciplinary connections, though barriers included time constraints and limited curriculum standards. Validation confirmed the guide's clarity, relevance, and classroom usability.

Conclusion: This study demonstrates the feasibility of integrating ESD into mathematics through a validated, context-sensitive guide that aligns competencies with SDGs while maintaining rigor. It further highlights the need for institutional support, curriculum adaptation, and teacher training to ensure sustainability themes are embedded as integral outcomes, advancing both national and global educational agendas.

KEYWORDS: Education for Sustainable Development (ESD), Mathematics Education, Curriculum Integration, Sustainable Development Goals (SDG), Action Research, Instructional Design, Philippines Education, Expert Assessment, Teacher's experiences

INTRODUCTION

Integrating Education for Sustainable Development (ESD) into elementary mathematics education is increasingly recognized as vital in preparing students to become responsible and environmentally conscious citizens. Mathematics, as a discipline, provides not only foundational numeracy but also a powerful tool for problem-solving and decision-making in addressing sustainability challenges. Linking mathematical competencies with real-world issues fosters critical thinking, contextualized learning, and interdisciplinary connections. At the elementary level, such integration enables learners to appreciate mathematics beyond abstract symbols, as it becomes a means to understand social, economic, and environmental concerns. This study, therefore, focuses on embedding sustainability principles within the mathematics curriculum for upper primary levels, emphasizing both curriculum alignment and teacher practice in the Philippine context.

Research evidence underscores the growing recognition of embedding sustainability into mathematics curricula. Analyses of elementary textbooks across Japan, Korea, and Singapore reveal that sustainability-related activities are already introduced in Grades 3–4 and can be used to introduce and apply mathematical concepts, indicating clear curricular entry points for ESD (Kim & Pang, 2022). National curriculum work likewise reveals that—even when “sustainability” is not explicitly named—core elements such as modeling, problem-solving, and reasoning create authentic opportunities to thread ESD through mathematics without sacrificing rigor (Tefamicael & Enge, 2024). Conceptual scholarship further argues that mathematics education needs to be re-envisioned so ESD is integrated as a twentyfirst-century priority, detailing what sustainable mathematics education could look like

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in practice (Li & Tsai, 2021). At the same time, primary curriculum audits reveal that sustainability competencies are often underdeveloped in mathematics compared to other subjects, highlighting ongoing gaps in explicit guidance for teachers and the need for more substantial alignment (López-Serentill et al., 2024).

Despite these contributions, gaps remain in contextualizing ESD integration within the Philippine elementary mathematics curriculum. Most studies are international in scope, with limited research focused on systematically mapping SDG-related themes onto the mathematics curriculum in basic education. Local evidence indicates that the integration of SDGs in the Philippines is uneven across subjects, with mathematics in particular exhibiting significant gaps in incorporating sustainability concepts at the basic education level (Padilla, 2025). While some initiatives have produced validated, contextualized materials in mathematics, such as a Bikol Central instructional resource, these remain isolated efforts that highlight the broader need for a systematic and SDG-mapped guide responsive to classroom realities (Aguelo, 2024). These gaps underscore the need for a study that bridges global perspectives with localized curricular practices.

This study aims to address these gaps by identifying challenges and opportunities in aligning the mathematics curriculum with ESD, assessing the outcomes of integrating SDGs into upper primary-level mathematics instruction, and exploring teachers' lived experiences in embedding sustainability themes. It also seeks to design and validate a contextualized ESD instructional resource guide for elementary mathematics. By offering a practical and evidence-based instructional plan, this research contributes to the body of knowledge by equipping educators with strategies to foster mathematical competence while developing sustainability literacy. In doing so, it advances both the national educational agenda and the global call for quality education that supports sustainable development.

METHODS

Study Design, Population, and Setting

This study employed a descriptive-qualitative action research design guided by the ADDIE framework, specifically focusing on the Analysis, Design, and Development phases. The purpose was to evaluate the degree to which the Grades 4–6 mathematics curriculum aligns with Education for Sustainable Development (ESD) learning objectives and to design a contextualized instructional resource guide.

The study was conducted at one of the private institutions offering quality, community-oriented education in Cebu City, Philippines. The respondents consisted of all mathematics teachers in Grades 4–6, selected through purposive sampling. Twelve participants were actively involved in teaching mathematics and in preparing the mathematics syllabus and teaching lesson plans that incorporated sustainability themes, ensuring their firsthand experience and relevance to the study's objectives.

Action Plan

The action research followed systematic phases to integrate sustainability concepts into the mathematics curriculum. First, content analysis was conducted by mapping the Sustainable Development Goals (SDGs) onto the Math YIDP using UNESCO's ESD learning objectives. Next, research instruments, including semi-structured interview guides, were developed and validated by experts to capture teachers' perspectives on embedding ESD themes. Data were then collected through document analysis and teacher interviews, focusing on instructional practices, challenges, and strategies employed by teachers. Findings from these phases informed the design of a contextualized ESD reference guide, which was subsequently subjected to content and face validation by expert reviewers. This process ensured that the developed guide was aligned with sustainability principles, locally contextualized, and practically useful for classroom instruction.

Data Analysis

Two qualitative approaches were employed: content analysis and thematic analysis. In the content analysis phase, curriculum documents, instructional plans, and related materials were systematically coded according to sustainability themes, SDG objectives, and instructional strategies. This enabled the identification of the extent of ESD integration within the mathematics curriculum and highlighted existing gaps in the integration. Thematic analysis was applied to transcribed teacher interviews to uncover recurring themes and patterns in their experiences with ESD integration. Codes were clustered into themes that reflected teachers' strategies, challenges, and professional practices. The integration of findings from both analyses provided a comprehensive understanding of curriculum content and teacher experiences, which informed the creation of the enhanced instructional resource guide.

Ethical Considerations

Ethical standards were strictly observed throughout the research process. Approval was secured from the Recoletos Ethics Review Office (RERO) and the Data Privacy Officer (DPO) of the university, ensuring compliance with institutional guidelines for research involving human participants. Informed consent was obtained from all teacher participants, who were informed of the study's objectives, procedures, potential risks, and benefits. Participation was voluntary, and participants were assured of their right to withdraw at any time without consequence. Confidentiality and privacy were maintained through anonymization of responses and

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secure storage of data in password-protected files. Minor tokens of appreciation were provided to participants without coercion. Community considerations were also respected by aligning the study with institutional priorities and cultural contexts. Safeguards were established to protect the rights and welfare of participants, and debriefing was conducted to provide transparency and closure.

RESULTS

This section presents the study's outcomes on integrating Education for Sustainable Development (ESD) into the Grades 4–6 mathematics curriculum. Findings are organized into three main areas: (a) validation of the contextualized ESD instructional reference guide, (b) extent and nature of ESD integration within the curriculum, and (c) teachers' experiences in embedding sustainability themes.

Expert Validation of the Instructional Guide

The developed ESD instructional reference guide underwent content and face validation by three experts in education and curriculum development. Table 1 shows that the guide achieved excellent ratings across all categories of content validation. The clarity of the statement in the guide, consistency and accuracy of interpretation, organization and presentation of content, and appropriateness of items for target users all received perfect scores ($M = 5.00$, $SD = 0.00$). Only the alignment with the intended purpose was rated slightly lower ($M = 4.67$, $SD = 0.58$), but still within the “very good” range. The overall weighted mean of 4.93 ($SD = 0.08$) indicated an “excellent” interpretation.

Table 1. Summary of Content Validation of the ESD Reference Guide

Components	Weighted Means	Standard Deviation	Verbal Interpretation
Clarity of Statement in the Guide	5.00	0.00	Excellent
Consistency and Accuracy of Interpretation	5.00	0.00	Excellent
Organization and Presentation of Content	5.00	0.00	Excellent
Appropriateness of Items for Target Users	5.00	0.00	Excellent
Alignment with Intended Purpose	4.67	0.58	Very Good
TOTAL	4.93	0.08	Excellent

Legend: 5.00- Excellent; 4.00 to 4.99- Very Good; 3.00 to 3.99- Good; 2.00 to 2.99- Fair; 1.00 to 1.99 - Poor

Similarly, Table 2 presents the results of the face validation. Experts unanimously rated the guide as excellent ($M = 5.00$, $SD = 0.00$) in terms of clarity and defensibility of content, relevance and appropriateness of items, and visual presentation and overall layout. These results confirm that the guide is clear, defensible, user-friendly, and suitable for classroom use.

Table 2. Summary of Face Validation of the ESD Reference Guide

Components	Weighted Means	Standard Deviation	Verbal Interpretation
Clarity and Defensibility of Content	5.00	0.00	Excellent
Relevance and Appropriateness of Items	5.00	0.00	Excellent
Visual Presentation and Overall Layout	5.00	0.00	Excellent
Average	5.00	0.00	Excellent

Legend: 5.00- Excellent; 4.00 to 4.99- Very Good; 3.00 to 3.99- Good; 2.00 to 2.99- Fair; 1.00 to 1.99 - Poor

Extent and Nature of ESD Integration in Mathematics Curriculum

Content analysis of the Mathematics Curriculum Plan revealed that sustainability concepts were systematically mapped across the three ESD pillars—economic, environmental, and social—at each grade level. In Grade 4, competencies in the four operations (MDAS) were applied to household budgeting and employment data, aligning with SDG 8 on Decent Work and Economic Growth. Fractions were contextualized through resource allocation scenarios, while probability lessons were linked to market research and decision-making processes.

Integration was also evident in the environmental pillar. For instance, lessons on improper fractions were taught using data on waste management (SDG 12), while geometry tasks involving lines and angles were grounded in marine resource maps (SDG 14). Likewise, angles were illustrated through examples from biodiversity conservation areas (SDG 15). These approaches allowed mathematics lessons to strengthen numeracy and build environmental literacy simultaneously.

Within the social pillar, competencies were linked to issues of poverty, health, and housing. MDAS lessons utilized poverty data (SDG 1), and factors and multiples were contextualized with health statistics. Decimals were introduced through financial literacy and budgeting tasks. Geometry topics such as perimeter and area were taught using sustainable housing projects, aligning with SDGs 10 and 11.

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Similar patterns were observed in Grades 5 and 6, where activities included analyzing agricultural production, visualizing crop yields, applying divisibility rules to urban planning data, and using environmental statistics for geometry and data analysis. These examples demonstrate that mathematical competencies can be meaningfully connected to sustainability themes, showing both feasibility and richness of ESD integration across grade levels.

Teachers' Experiences in Integrating ESD

Thematic analysis of teacher interviews revealed several recurring themes. Teachers in this study reported that integrating ESD themes into mathematics lessons enriched learning and made instruction more relevant to students' lives—paralleling findings by Vásquez et. al. (2023), who found that mathematics educators believe contextualized tasks rooted in real-world sustainability issues enhance engagement and promote deeper learning. They highlighted strategies such as contextualizing lessons with real-world data, using collaborative activities, and applying problem-solving in sustainability contexts. This finding is consistent with Bulut & Borromeo Ferri (2025), who examined a teacher training program combining mathematical modeling and education for sustainable development (ESD) and found that collaborative, modeling-oriented pedagogies improved teachers' ability to integrate sustainability concepts into mathematics instruction. However, challenges were also identified, including limited instructional time, a lack of explicit curriculum standards for ESD, and the difficulty of balancing mathematical competency with sustainability content. These obstacles reflect conclusions from Su, Lai, & Lee (2023), who, in their investigation, found that mathematics teachers often cited rigid curriculum structures, pressure to cover content, and insufficient training as barriers to effectively incorporating sustainability concerns into mathematics instruction.

Table 3. Teachers' Reported Challenges and Strategies in Integrating ESD

Sub-theme	Description	Example Quotes
Time Constraints	Significant barrier to efficiently incorporating ESD subjects into the curriculum.	"Including ESD ideas in my lesson plan leaves little time for the main skills in my Math class."
Curriculum Alignment	Difficulty in aligning ESD concepts with current curriculum standards and goals.	"It may be challenging to ensure that ESD themes align with current standards and goals."
Knowledge Gaps	Gaps in teachers' understanding of ESD goals affect their confidence in teaching.	"We have limited ideas and knowledge on how to integrate ESD themes effectively."
Interactive and Engaged Approaches	Use of visual analysis, problem-solving, debates on sustainability concerns, and Mathematical modeling.	"When I incorporate ESD themes in my lessons, the pupils love to share more and even go beyond."
Student-centered Activities	Use of games, student-centered activities, and a combination of deductive and traditional methods.	"These initiatives make classes more exciting and relevant, enhancing students' participation."
Advantages	Increased student engagement and understanding promote sustainability through multidisciplinary learning.	"ESD integration allows for interdisciplinary connections, fostering a holistic understanding of sustainability issues."
Disadvantages	Time constraints, economic constraints, and the risk of teacher burnout.	"It takes time for teachers and delays priority skills in Math."

Teachers also described the positive outcomes of ESD integration, including increased student engagement, a deeper understanding of mathematical concepts, and a greater awareness of social and environmental issues. Collaborative and project-based approaches, in particular, were found to be effective in fostering both academic and sustainability-related learning outcomes. For example, Rehman et al. (2023) found that math project-based learning significantly enhanced primary students' interest and achievement in mathematics, while also developing twenty-first-century skills such as collaboration, problem-solving, and critical thinking.

DISCUSSION

The validation results indicate that the contextualized ESD instructional reference guide achieved excellent quality in terms of clarity, organization, and appropriateness, with only a minor opportunity to strengthen its purpose attainment. High agreement among expert validators suggests that the guide is readable, defensible, and classroom-ready—key attributes associated with higher uptake and fidelity in instructional use (Dicdiquin, Mobo, & Cutillas, 2023; Vásquez et al., 2023). In the context of sustainability education, strong content and face validity are especially consequential because teachers often look for concrete, well-structured exemplars before adopting innovations that connect mathematics to environmental, social, and economic issues (Vásquez et al., 2023). The present findings therefore provide preliminary assurance that the developed resource can serve as a practical vehicle for translating ESD principles into day-to-day mathematics lessons in upper primary levels.

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The curriculum mapping indicates that ESD themes can be meaningfully integrated across the three pillars—economic, environmental, and social—without compromising core mathematical competencies. Examples include using household budgeting and employment data for operations and fractions (SDG 8), waste-management and biodiversity contexts for fractions and geometry (SDGs 12, 14, 15), and financial literacy, health, and housing datasets for number sense, divisibility, perimeter, and area (SDGs 1, 2, 3, 10, 11). This integration aligns with recent findings that emphasize the importance of strengthening students' comprehension and problem-solving abilities to improve mathematics performance, skills that are also critical when embedding sustainability tasks into lessons (Ersando et al., 2025). Broader international evidence also supports the feasibility of linking mathematics with sustainability, with curriculum mapping in Qatar demonstrating clear entry points for SDG-related themes in mathematics (Said et al., 2024). In addition, conceptual work highlights that mathematics education must be re-envisioned through a strengths-based approach to sustainability, ensuring that numeracy and problem-solving remain rigorous while contributing to broader social and environmental goals (Makramalla, 2025). In short, the present mapping demonstrates feasibility: teachers can preserve mathematical rigor while situating competencies in authentic sustainability contexts.

Teachers' reports help explain why such integrations matter. Participants described increased student engagement, richer discourse, and clearer connections between mathematics and real-world concerns when lessons drew on sustainability data and scenarios. These experiences are supported by Boaler (2021), who found that mathematical mindset approaches—incorporating problem solving and inquiry—significantly improve participation and sense-making in mathematics classes. They also align with findings by Olawale et al. (2025), who identified similar constraints faced by teachers integrating ESD, including limited time, resource availability, and a lack of structured support. Together, these results suggest that while classroom-level innovation for ESD is promising and can enhance learning, systemic supports are necessary to sustain its effects in practice.

Interpreted through the study's theoretical lenses, the findings are coherent and actionable. The backward-design orientation that guided Analysis–Design–Development aligns with evidence that designing from desired outcomes improves instructional coherence and usability in education research and practice (Jensen & Kummer, 2017). Teachers' reflections on what worked and what did not mirror contemporary accounts of reflective practice situated within experiential learning cycles, where planning, acting, observing, and reflecting drive iterative improvement (Murphy, 2024). Moreover, the collaborative validation and sharing of strategies align with research on communities of practice and professional learning communities, which shows that joint problem-solving and knowledge exchange build professional capacity (Townley, 2020; Liu et al., 2024). Taken together, these frameworks help explain why the guide scored highly in terms of usability and why teachers reported both momentum and pain points.

The Philippine and school-specific context provides an important contribution to ESD research in mathematics. While much of the existing literature remains international or national in scope, few studies operationalize SDG linkages at the level of a Mathematics Instructional Plan for Grades 4–6. Gaanya et al. (2025) demonstrate how SDG-aligned opportunities in mathematics curricula are often unevenly embedded, underscoring the need for localized, competency-based mapping. Complementing this, Suaco (2024) documents SDG-related competencies in the Cordillera Administrative Region, highlighting gaps in benchmarks and teacher preparedness. In contrast, Lafuente-Lechuga et al. (2020) illustrate how mathematics can address sustainability issues without compromising academic rigor. By systematically mapping SDG opportunities onto existing competencies and producing a validated, context-sensitive guide, this study addresses a local implementation gap by translating UNESCO's ESD learning objectives into lesson-level decisions that help reconcile teachers' concerns with time and alignment.

The practical implications are therefore twofold. First, professional learning should focus on how to utilize real datasets and community issues to anchor required competencies—e.g., fraction operations with resource-allocation cases, or geometry with conservation mapping—so that teachers can plan efficiently under time constraints (Su, 2023; Bulut & Borromeo Ferri, 2025). In this regard, evidence from Philippine classrooms shows that data-driven approaches, such as the ARIMA-based forecasting of mathematics performance by Ersando and Ersando (2025), can strengthen teachers' capacity to align instructional pacing with learner needs, offering a model for how ESD-related data might also be integrated. Second, curricular tools (pacing guides, assessment blueprints) should explicitly signal ESD touchpoints adjacent to each competency to reduce search costs and increase fidelity (Wilson, 2025). Schools may also foster cross-subject projects—e.g., mathematics with science and social studies—so that sustainability themes are distributed rather than concentrated in one subject, a strategy linked to stronger outcomes and teacher buy-in (Bulut & Borromeo Ferri, 2025; Wilson, 2025).

Several limitations temper the conclusions. As action research conducted in a single institutional context with a purposive teacher sample, transferability depends on local similarities in curriculum, pacing, and resources. Outcome evidence is primarily qualitative (expert validation; teacher perceptions) with limited quantitative triangulation at the learner-achievement level, a constraint common to earlystage integration studies (Po et al., 2025). Future work should (a) incorporate student-level performance and attitude measures tied to ESD-embedded tasks, (b) examine fidelity and dosage over time, and (c) compare alternative designs (e.g., project-based vs. problem-based sequences) to identify cost-effective models (Wilson, 2025).

Despite these limitations, the study advances a practical pathway for aligning mathematics instruction with sustainability goals in Grades 4–6. It provides a validated, teacher-usable guide; demonstrates curriculum-level feasibility across ESD pillars; and

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documents teacher strategies and constraints that mirror and extend the broader literature. Evidence from Philippine classrooms further reinforces this contribution, as Ersando and Ersando (2025) demonstrated how data-driven action research—through ARIMA-based forecasting of mathematics performance—can guide instructional pacing and planning. This approach parallels embedding sustainability markers in daily lessons. In line with reflective, iterative models of teacher learning such as experiential cycles (Murphy, 2024) and the global emphasis on curriculum transformation for sustainability (UNESCO, 2017), the following steps are clear: scale pilots; embed ESD markers into Mathematics instructional and assessment plans; and institutionalize professional collaboration so that sustainability becomes a routine context for mathematical thinking rather than an occasional add-on.

CONCLUSION

This study demonstrated that Education for Sustainable Development (ESD) can be effectively integrated into the upper primary levels in mathematics curriculum through a contextualized instructional reference guide validated by experts and informed by teachers' experiences. Findings confirmed that sustainability concepts across the economic, environmental, and social pillars can be mapped onto existing competencies, making mathematics instruction more relevant and engaging for learners. Teachers reported that ESD integration enriched student participation and critical thinking, though they also identified challenges such as time limitations and the need for curricular alignment and professional development.

The study contributes to practice by providing a validated and context-specific resource that equips educators with strategies for embedding ESD in mathematics teaching. It underscores the importance of institutional support, teacher training, and curriculum adaptation to ensure sustainability themes are not treated as add-ons but as integral to learning outcomes. In doing so, the research advances both national and global educational agendas by strengthening the role of mathematics in developing sustainability literacy among elementary learners.

Author Contributions

The authors: Conceptualization, Methodology, Data curation, Writing – original draft preparation, Investigation, Visualization, Supervision, Writing – review and editing. The authors take full responsibility for all aspects of the work.

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Ethical Approval

This study was reviewed and approved by the Recoletos Ethics Review Office (RERO) and the Data Privacy Officer (DPO) of the University of San Jose-Recoletos, Cebu City, Philippines. All participants were provided with detailed information about the study's objectives, procedures, potential risks, and benefits, and written informed consent was obtained prior to participation. Participation was voluntary, and confidentiality was assured through anonymization of data and secure storage of records.

Competing Interest

The author declares that they have no conflicts of interest.

Data Availability

The corresponding author will make the data available upon request.

Declaration of Artificial Intelligence Use

In this work, the author utilized an artificial intelligence (AI) tool, specifically OpenAI's ChatGPT, for language refinement, formatting, and editorial assistance only. After using this tool, the author evaluated and revised the content as necessary, taking full responsibility for the published content.

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