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Development of a Framework Embedding Waste Management in Science Instruction: A Case Study of Anda National High School

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Abstract
This study addresses the persistent challenge of solid waste management in the Philippines through the lens of science education. Republic Act 9003 and Republic Act 9512 emphasize ecological responsibility in schools, yet classroom integration often remains limited. Anda National High School in Pangasinan implements Project ECO-LOVE, which illustrates how local initiatives can support environmental literacy and community participation. The study aimed to develop and validate a contextualized framework that embeds waste management principles into science instruction. Qualitative methods were used, including interviews, focus group discussions, and document analysis. These methods captured the experiences of teachers, school leaders, and project implementers. The framework was anchored on national laws and DepEd policies and integrated the 5Rs and Ecological Solid Waste Management concepts into Chemistry, Biology, and Earth Science through constructivist and sociocultural approaches. Results show that project-based learning, curriculum mapping, and localized instructional materials improve lesson relevance, strengthen learner engagement, and encourage community involvement. Project ECO-LOVE demonstrated effective alignment of policy and classroom practice. The discussion highlights the importance of experiential learning strategies and partnerships with stakeholders in sustaining environmental initiatives. The validated framework offers a practical model for promoting environmental literacy and ecological stewardship within secondary science instruction.

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1. Introduction

Solid waste management is recognized globally as a pressing environmental challenge, driven by unsustainable resource consumption and improper disposal practices (Nguyen, 2023) [17]. The growing accumulation of solid waste poses serious threats to ecosystems, human health, and sustainable development. Globally, the world generates approximately 0.74 kilograms of solid waste per person daily, amounting to 2.01 billion tons per year. Projections indicate that by 2050, global waste generation will rise to 3.40 billion tons due to inadequate waste management in some regions (World Bank, 2023). The East Asia and Pacific region, including Thailand, leads in per capita waste generation, averaging 1.03 kilograms daily, exceeding the global average. Improper waste disposal through open burning, uncontrolled dumping, and untreated incineration contributes to air, water, soil, and marine pollution and increases public health risks, such as respiratory diseases and vector-borne illnesses (Swami, 2021) [23]. Education plays a pivotal role in addressing these challenges. Equipping younger generations with knowledge and skills in waste management is essential to foster pro-environmental behavior and sustainable practices (Navykarn, 2015) [16]. International efforts, such as the International Education Alliance for Education in Radioactive Waste Management, highlight the importance of information dissemination, awareness, and confidence-building in waste management solutions (Swami, 2021) [23].

Research indicates that environmental education enhances scientific literacy, environmental awareness, and community participation, ultimately transforming individuals and communities toward sustainable development.

In the Philippines, solid waste generation has steadily increased, with 35,580 tons collected daily in 2014 and 16.63 million metric tons generated in 2020, up from 9.07 million metric tons in 2000 (Bagundang *et al*., 2023) [3]. The country's waste composition is dominated by high organic and recyclable content. National legislation, including Republic Act 9003 (Ecological Solid Waste Management Act of 2000) and Republic Act 9512 (Environmental Awareness and Education Act of 2008), mandates systematic waste management and integration of environmental education into curricula. The Department of Education has further strengthened these initiatives through the K-12 program, embedding disaster risk reduction, climate change adaptation, and environmental stewardship into core subjects and co-curricular activities such as the Youth for Environment in Schools Organization (YES-O), Gulayan sa Paaralan, Solid Waste Management, and tree-planting programs (DepEd, 2019) [5]. Recent curricular reforms under the Revised K to 10 (MATATAG) curriculum, guided by DepEd Order No. 10 s.2024, aim to equip students with 21st-century skills through hands-on, problem-based, and experiential learning approaches (Diquito, 2024) [8]. Despite these advances, challenges remain in teacher preparedness, curriculum implementation, and sustained learner engagement.

Locally, provincial schools, including those in Pangasinan, have initiated programs to promote ecological awareness. In Anda, the municipal government has enacted ordinances aligning with RA 9003, and Anda National High School has implemented Project ECO-LOVE (Enhancing Concern Over garbage – Leaving Our school Vibrant and Environment-friendly). This program earned the school recognition as the Eco-friendliest School of Anda in 2024 and 2025, reflecting its commitment to instilling environmental stewardship among learners through policy-driven initiatives.

Despite strong national policies, international frameworks, and local initiatives like Project ECO-LOVE, challenges persist in integrating waste management systematically into science instruction. Studies in various Philippine regions indicate that learners may have high awareness of solid waste management yet demonstrate inconsistent practices (Abdon & Farin, 2022) [1]; (Bagundang *et al*., 2024) [3]; (Prisco & Cubillas, 2022) [18]; (Saldana & Domanog, 2024) [21]. Existing programs are often dependent on external support, lack formalized instructional frameworks, or fail to connect classroom learning with community engagement. Furthermore, learners' understanding of legislation, policy, and systematic environmental practices remains limited. This gap between policy mandates and classroom practice raises critical questions about how science education can foster environmental literacy, scientific reasoning, and civic responsibility while ensuring sustainability and relevance. There is a clear need for a contextualized, policy-aligned framework that integrates waste management principles—such as the 5Rs and Ecological Solid Waste Management—into science-related subjects like Life Science, Earth Science, and Chemistry.

This study aims to develop and validate a framework that embeds waste management concepts into science instruction at Anda National High School. Grounded in constructivist and socio-cultural learning theories, the framework aligns with national policies, including RA 9003, RA 9512, and relevant DepEd directives. It incorporates the 5Rs and Ecological Solid Waste Management principles into Chemistry, Biology, and Earth Science through project-based and experiential learning approaches, with the goal of promoting learner engagement, environmental literacy, and community participation. Using qualitative methods such as interviews, focus group discussions, and document analysis, the study examines the lived experiences of educators and learners in implementing the framework.

The resulting model seeks to provide a scalable and replicable approach that bridges policy, local initiatives, and classroom practice. By embedding environmental stewardship into science instruction, the framework supports Sustainable Development Goals (SDGs) including SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals). Ultimately, this study contributes to transforming science education into an active vehicle for ecological literacy, pro-environmental behavior, and sustainable community development, addressing both local and global environmental challenges.

Methodology

This study employed a qualitative-descriptive research design, specifically grounded in case study methodology, to explore how waste management concepts are integrated into science instruction at Anda National High School (Anda NHS). The qualitative approach was particularly suitable for examining the lived experiences, perceptions, and practices of educators and stakeholders within the unique ecological and educational context of the school. The primary aim was to develop a locally grounded instructional framework that aligns with national policies, addresses contextual realities, and reflects pedagogical theories, while also investigating the implementation of Project ECO-LOVE (Enhancing Concern Over garbage – Leaving Our school Vibrant and Environment-friendly) as a model for ecological solid waste management (ESWM) in classroom settings.

The research was conducted at Anda NHS, a public secondary school in the Municipality of Anda, Pangasinan, serving learners from Grades 7 to 12. The school has demonstrated a strong commitment to ecological sustainability through Project ECO-LOVE, making it an ideal site for studying the integration of environmental concepts into science-related instruction. Its programs, supportive leadership, and established environmental culture provided a rich and dynamic setting for data collection and framework validation.

Participants were selected using purposive sampling to capture diverse perspectives from individuals directly involved in science instruction or school-based environmental initiatives. The sample included science teachers with at least one year of teaching experience, learners from Grades 7 to 12, school administrators and subject coordinators, non-science teachers involved in interdisciplinary projects, maintenance personnel with experience in school waste handling, and representatives from the Local Government Unit (LGU) engaged in sustainability initiatives. All participants provided informed consent, and parental consent was obtained for student participants.

Data were gathered through multiple qualitative methods to ensure triangulation and depth of understanding. Semi-structured interviews with teachers, administrators, and LGU representatives explored instructional practices, perceived challenges, and opportunities for integrating waste management into science teaching. Focus group discussions with learners examined their awareness, attitudes, and experiences related to waste management in the context of science education. Classroom observations documented real-time teaching strategies, student engagement, and the practical application of environmental concepts, while document analysis of policy documents, curriculum guides, lesson plans, and school reports provided evidence of alignment with national legislation and institutional sustainability efforts.

Data analysis followed a thematic approach, involving transcription, repeated readings, coding, and organization into patterns and overarching themes. Classroom observations and document analysis were integrated to triangulate findings and enhance interpretive credibility. Reflexivity and member checking were employed throughout the analysis to minimize researcher bias and validate interpretations. Trustworthiness was ensured through prolonged engagement with participants, detailed contextual descriptions, audit trails, peer debriefing, and transparent documentation of methodological decisions. Ethical standards were strictly observed, including voluntary participation, confidentiality, secure data storage, and cultural sensitivity during all research activities.

3. Results and Discussions

This section presents the findings and discussion of the study on integrating waste management into science instruction at Anda National High School (Anda NHS), organized according to the research sub-problems. Data from interviews, school documents, and LGU reports were analyzed thematically to develop a contextualized framework for embedding ecological solid waste management (ESWM) into science education.

3.1. Existing Policy Directives as Guiding Frameworks

Stakeholders identified a multi-level policy environment supporting the integration of waste management into science instruction. The policies can be summarized as follows:

Level	Policy / Framework	Purpose / Relevance to Science Instruction
International	United Nations SDGs	Promote environmental literacy and sustainable education globally; guide integration of waste management principles into education.
National	Republic Act 9003 (Ecological Solid Waste Management Act of 2000)	Mandates waste segregation, recycling, and ecological responsibility across institutions.
	Republic Act 9512 (Environmental Awareness and Education Act of 2008)	Requires environmental education at all levels; reinforces sustainability topics in science instruction.
	DepEd Orders & Modules	Provide curricular guidance embedding the 5Rs, climate change, and disaster risk reduction into science subjects.
Local / School	Municipal Ordinance No. 25-2023	Mandates school-level waste segregation, recycling, and environmental awareness; strengthens accountability.
	School Memoranda & LGU Collaboration	Contextualizes national and local directives; aligns Project ECO-LOVE and other initiatives with classroom practice.

Stakeholders confirmed that adherence to these policies shaped the school's environmental culture. An administrator noted, "We followed RA 9003 and RA 9512 closely, and our school memoranda reflected these laws in our daily routines and instructional content." LGU officials corroborated, emphasizing active monitoring through tools such as Daily Waste Diversion Sheets. The convergence of international goals, national laws, and local policies provided a coherent framework for embedding ESWM in science instruction.

3.2. Localized Implementation: Project ECO-LOVE

Project ECO-LOVE (Enhancing Concern Over garbage—Leaving Our school Vibrant and Environment-friendly) operationalized ESWM using the PDCA (Plan-Do-Check-Act) cycle (Figure 1).

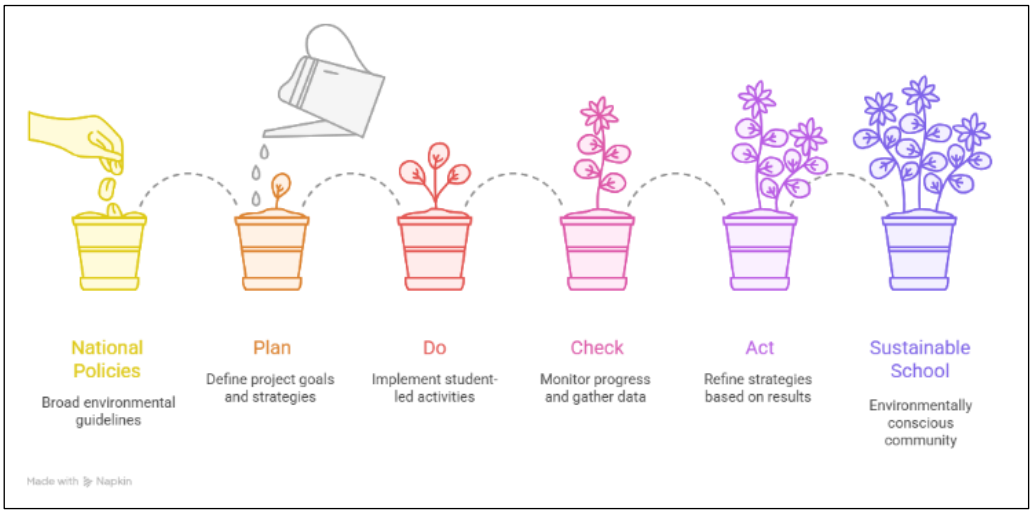

Fig 1: Project ECO-LOVE: PDCA Cycle

Plan: The initiative aimed to embed ESWM into school culture through student-led activities, community

engagement, recognition programs, and alignment with RA 9003, RA 9512, DepEd Orders, and Municipal Ordinance No. 25-2023. Key activities included *Plastic-Free Fridays, Gulayan sa Paaralan, EcoWarrior campaigns,* and *Clean As You Go (CLAYGO).*

Do: Implementation spanned eco clubs, YES-O, BKD, and SSLG, integrating waste management across science and non-science subjects. LGU-supported seminars, IEC materials, and infrastructure (MRFs, composting sites) facilitated experiential learning. Localized instructional tools such as recycled crafts and community data were used to contextualize lessons.

Check: Monitoring employed Daily Waste Diversion Sheets, feedback forms, contest metrics, and LAC sessions to evaluate student participation, comprehension of the 5Rs, and teacher integration.

Act: Sustainability strategies included refining initiatives based on stakeholder feedback, scaling practices to other schools and barangays, updating instructional materials to address emerging environmental challenges, and strengthening partnerships with LGUs, DENR, and NGOs.

Teachers and LGU officials noted the initiative's success. Students actively participated in clean-up drives and campaigns, demonstrating the translation of policy into practice. Project ECO-LOVE exemplified how national mandates could be localized into actionable and sustainable school programs.

3.3. Effective Teaching Strategies

Grade-Level Scaffolding:

Grade	Key Concepts	Sample Learning Competencies
3	Segregation, harmful material disposal	LC 6: Explain material changes affecting living/non-living things
4	Biodegradability, chemical properties	LC 3: Describe chemical properties of materials
5	Erosion, water cycle, weather disturbances	LC 5: Demonstrate erosion; LC 6: Explain water cycle
6	Ecosystems, biotic/abiotic factors	LC 7: Describe ecosystem components
9	Biodiversity, human impact	LC 10: Effects of human activities on ecosystems
10	Climate change, renewable energy	LC 8–12: Identify climate impacts and mitigation strategies

Inquiry-Based Tasks: Students conducted investigations on biodegradability, erosion, water pollution, biodiversity, and renewable energy.

Interdisciplinary Integration: Waste management themes were connected to Math (data analysis), English (advocacy writing), Araling Panlipunan (policy awareness), and Values Education (stewardship).

Teacher Collaboration and Competency Mapping: LAC sessions, HOTS tasks, and curriculum mapping ensured systematic embedding of the 5Rs and ESWM across grade levels and subjects.

3.5. Localized Instructional Materials

Effective instruction relied on materials contextualized to the community:

- **Community Data and Case Studies:** Students analyzed local waste statistics and school initiatives.

Stakeholders identified several constructivist and socio-cultural strategies as particularly effective:

- **Project-Based Learning (PBL):** Engaged learners in authentic problem-solving activities such as waste audits, recycling challenges, and community clean-ups (Dewey, 1938; Blumenfeld *et al*., 1991).
- **Hands-On Activities:** Recycled crafts, poster-making, and experiments like composting enhanced retention and conceptual understanding (Kolb, 1984).
- **Multimedia and Visual Tools:** Infographics, videos, and digital campaigns made abstract concepts relatable, supporting Mayer's Cognitive Theory of Multimedia Learning (2001).
- **Community-Based Learning:** Field visits to LGU facilities and participation in barangay-led seminars connected classroom content to real-world practices (Vygotsky, 1978).
- **Collaborative and Reflective Practices:** Debates, journaling, and interdisciplinary projects promoted critical thinking and environmental responsibility (Brookfield, 1995; Mezirow, 1991).

Teachers reported that these strategies effectively fostered both scientific literacy and civic engagement, while students valued experiential and community-connected learning.

3.4. Systematic Mapping of Waste Management Concepts

Waste management content was progressively integrated into the K to 12 science curricula through grade-level scaffolding, inquiry-based tasks, interdisciplinary links, and teacher collaboration.

- **Visual Aids and IEC Materials:** Posters, decay timelines, and LGU-provided resources reinforced ESWM principles.
- **Recycled Art and Installations:** Student-created art fostered creativity and environmental awareness.
- **Digital Resources and Modules:** Interactive lessons aligned with DepEd and LGU standards supported in-school and home-based learning.
- **DENR and LGU Expertise:** Seminars and field visits provided authoritative insights into waste management practices.

These resources bridged policy, pedagogy, and practice, making environmental education tangible and locally relevant.

3.6. Contextualized Framework for Science Instruction

A holistic, multi-dimensional framework was developed to embed waste management into science instruction (Figure 2).

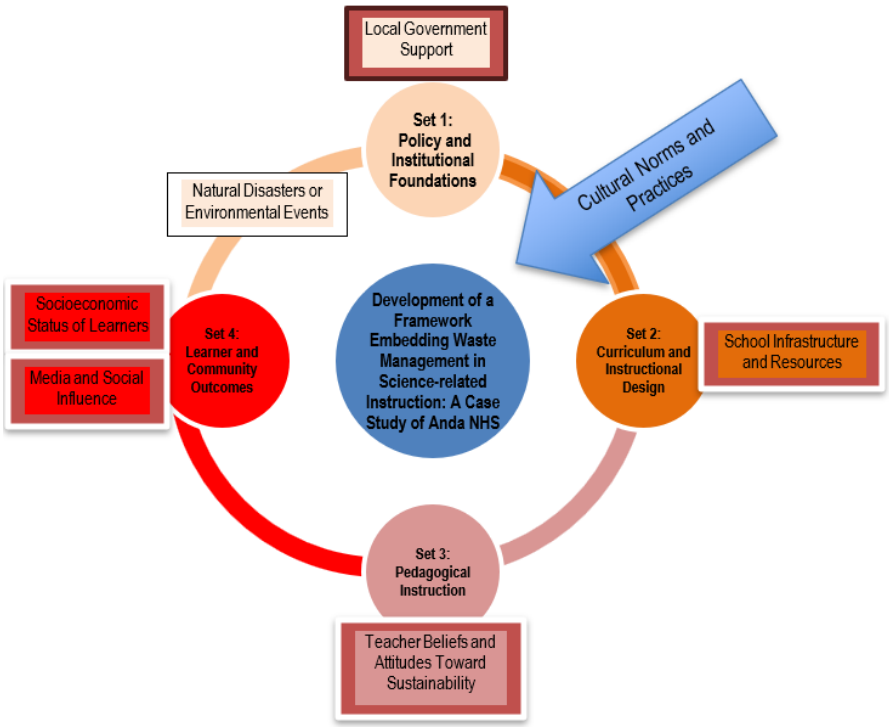

Fig 2: Waste Management Framework for Science Instruction

It comprises six interrelated components:

1. **Policy Alignment:** Anchored in RA 9003, RA 9512, DepEd Orders, and local ordinances.
2. **Curriculum Mapping:** Systematic integration across grades using competency-based tagging.
3. **Localized Implementation:** Project ECO-LOVE operationalized the framework through student-led and community-based initiatives.
4. **Pedagogical Strategies:** Constructivist and socio-cultural approaches fostered experiential, collaborative, and reflective learning.
5. **Instructional Materials:** Community data, visual aids, digital modules, and recycled art ensured contextual relevance.
6. **Monitoring and Evaluation:** Tools such as Daily Waste Diversion Sheets and LAC feedback guided continuous improvement.

The framework positioned Anda NHS as a model for sustainable science instruction, transforming policy mandates into practical, actionable, and replicable educational practices. Extraneous variables—socioeconomic status, teacher beliefs, infrastructure, LGU support, cultural norms, environmental events, and media influence—were recognized as moderators affecting implementation and outcomes.

4. Conclusions and Recommendations

Conclusions

The study concludes that the integration of waste management concepts into science instruction at Anda National High School is most effective when anchored in both national mandates and localized practices. The alignment with Republic Act 9003, Republic Act 9512, and Municipal Ordinance No. 25-2023 provides a legally supported and coherent foundation for instructional practices, ensuring that environmental education is not merely an add-on but an integral component of the curriculum. Project ECO-LOVE serves as a concrete example of how schools can operationalize these policies, transforming legal directives into meaningful, community-responsive programs that actively engage students and reinforce ecological values.

Constructivist and socio-cultural teaching strategies emerged as essential for fostering deep learning and ecological responsibility. Experiential approaches, such as project-based learning, hands-on recycling activities, debates, and multimedia campaigns, enabled students to connect scientific concepts with real-world environmental challenges. Furthermore, systematic curriculum mapping ensured that waste management concepts were scaffolded across grade levels and subjects, promoting continuity, thematic depth, and coherence in science instruction.

The use of localized instructional materials, including community waste data, IEC materials, recycled art, and visual media, significantly enhanced lesson relevance and student engagement. When learners saw their own community reflected in instructional content, their understanding, retention, and application of environmental concepts were strengthened. Finally, monitoring and evaluation mechanisms, such as Daily Waste Diversion Sheets, feedback forms, and contest metrics, proved critical for sustaining, refining, and validating the framework. Overall, the study concludes that embedding waste management into science instruction through a multi-dimensional, policy-aligned, and context-responsive framework can cultivate environmental stewardship, critical thinking, and active community engagement among students.

Recommendations

In light of the study's conclusions, it is recommended that school administrators institutionalize the multi-dimensional framework for waste management integration through school-wide memoranda and its incorporation into School Improvement Plans and Annual Implementation Plans. Strengthening partnerships with the Local Government Unit and the Department of Environment and Natural Resources

is also essential to ensure consistent resource provision, policy support, and program sustainability.

Science teachers are encouraged to continue employing constructivist and socio-cultural strategies while expanding interdisciplinary collaborations to deepen the integration of waste management concepts. Developing, documenting, and sharing localized instructional materials during Learning Action Cell sessions and professional development workshops will further support pedagogical innovation and knowledge transfer. Non-science teachers can complement these efforts by embedding ecological solid waste management principles into relevant topics and subjects, thereby promoting cross-curricular sustainability education.

Local government units and community stakeholders should sustain support for Project ECO-LOVE and expand its reach through complementary initiatives, such as wildlife conservation and coastal management programs. Providing regular training, updated IEC materials, and infrastructure support is crucial to facilitate the continued implementation and scaling of school-based environmental programs. For future researchers, replicating this study in other schools or regions is recommended to validate and refine the framework, as well as to examine the long-term effects of waste management integration on student behavior, academic performance, and community engagement.

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