
Development of a Conceptual Model for Eco-Literacy Integration in Pre-Service Science Teacher Education

Jean Camile C. Ermino¹, Danilo G. Soriano, Jr.² Cynthia P. Lopez³

<https://orcid.org/0009-0009-9157-0837>¹, <https://orcid.org/0000-0003-2529-7536>²,

<https://orcid.org/0002-0002-0448-8059>³

Lyceum Northwestern University^{1,3} Department of Education²,

jcermino.binmaley@psu.edu.ph¹, danilo.soriano@deped.gov.ph², cplopez@lyceum.edu.ph³

ABSTRACT

Eco-literacy has become an essential component of education for sustainable development, requiring teacher education institutions to prepare future science educators who are capable of promoting environmental responsibility through meaningful teaching practices. This study explored the current integration of eco-literacy in Basic Education Institutions as the basis for developing a conceptual model for eco-literacy integration in pre-service science teacher education. Using a qualitative phenomenological research design, data were gathered from science teacher educators through semi-structured interviews and open-ended survey responses. The collected data were analyzed using Braun and Clarke's thematic analysis framework. The findings revealed six interrelated themes: (1) integration through content and competencies, (2) experiential and practical eco-literacy, (3) awareness, responsibility, and sustainable habits, (4) uneven yet improving preparedness of pre-service teachers, (5) required competencies and ecological mindsets, and (6) the need for teacher education program improvements. These themes collectively demonstrate that while eco-literacy is already embedded across the curriculum, its implementation remains inconsistent due to variations in instructional practices, teacher preparation, and institutional support. Drawing from these findings, the study proposes a conceptual model that positions curriculum integration, teacher capacity, and institutional enablement as interconnected dimensions that collectively foster the development of eco-literate pre-service science teachers. The model offers a research-informed guide for curriculum developers, teacher educators, higher education institutions, and policymakers seeking to strengthen sustainability education through coherent and systematic eco-literacy integration in pre-service science teacher education.

Keywords: - Eco-literacy, pre-service science teacher education, sustainability education, curriculum integration, teacher capacity, conceptual model, environmental education.

INTRODUCTION

Environmental sustainability has become a global priority as societies face increasingly complex ecological challenges such as climate change, biodiversity loss, pollution, and

resource depletion. These issues have underscored the vital role of education in cultivating environmentally responsible citizens capable of making informed and sustainable decisions. In response, Education for Sustainable Development (ESD) has emphasized integrating sustainability concepts across educational systems, recognizing teachers as key agents in fostering ecological awareness and responsible environmental behavior among learners (Parry Thompson, 2023). Within this context, eco-literacy has emerged as a fundamental educational outcome that extends beyond ecological knowledge to include environmental values, critical thinking, responsible decision-making, and sustainable action.

Science education provides one of the most appropriate contexts for developing eco-literacy because it enables learners to understand ecological systems while applying scientific concepts to real-world environmental issues. Consequently, teacher education institutions play a critical role in preparing future science teachers who possess not only scientific competence but also the pedagogical capacity to integrate sustainability into classroom instruction. Previous studies have demonstrated that inquiry-based learning, experiential activities, and place-responsive pedagogies significantly enhance eco-literacy among pre-service teachers by connecting scientific knowledge with authentic environmental experiences (Kelly & Pelech, 2020; Ma & Green, 2021). Likewise, curriculum innovations and eco-literacy modules have been shown to strengthen environmental understanding and promote sustainability-oriented teaching practices among future educators (Arga & Rahayu, 2019; Gustian et al., 2022).

Despite these advances, the integration of eco-literacy within teacher education remains inconsistent across educational contexts. Existing literature suggests that environmental concepts are frequently embedded across different subject areas rather than being articulated as explicit competencies supported by coherent pedagogical and assessment structures (Nurwidodo et al., 2020; Skamp & Green, 2022). Such approaches often result in fragmented implementation, where the extent and quality of eco-literacy integration depend largely on individual teachers' practices and institutional priorities rather than on systematic curricular design. Consequently, pre-service teachers experience varying levels of preparation in developing the ecological competencies necessary for effective sustainability education (Bilianska & Yaroshenko, 2020; Kyi et al., 2023).

Although previous studies have examined eco-literacy, sustainability education, and environmental pedagogies, most have focused on evaluating instructional interventions, measuring environmental literacy levels, or assessing the effectiveness of specific teaching strategies (Arga & Rahayu, 2019; Gustian et al., 2022; Wulandari et al., 2024). Comparatively fewer studies have explored how science teacher educators themselves perceive the current integration of eco-literacy within teacher education programs and how these lived experiences can inform the development of a comprehensive conceptual model for pre-service science teacher education. Existing models generally emphasize instructional approaches or curriculum innovations but provide limited explanation of how curriculum integration, teacher capacity, and institutional support interact to foster eco-literacy as a coherent educational practice. This

conceptual gap limits the ability of higher education institutions to establish systematic and sustainable approaches to eco-literacy integration.

Addressing this gap requires a deeper understanding of how eco-literacy is currently embedded within educational practice before meaningful institutional improvements can be proposed. Exploring the experiences of science teacher educators offers valuable insights into existing curricular practices, experiential learning opportunities, teacher preparedness, competency development, and institutional conditions that collectively influence the integration of eco-literacy. These insights provide an empirical basis for identifying the essential dimensions that characterize effective eco-literacy implementation in pre-service science teacher education.

Guided by these considerations, this study explored the current integration of eco-literacy in Basic Education Institutions through the perspectives of science teacher educators. Specifically, it sought to identify the prevailing approaches and practices that characterize eco-literacy integration and to synthesize these findings into a conceptual model for eco-literacy integration in pre-service science teacher education. The proposed conceptual model contributes to the growing body of sustainability education literature by providing a research-informed representation of the interconnected roles of curriculum integration, teacher capacity, and institutional enablement in preparing future science teachers to promote environmental sustainability through meaningful science instruction.

Statement of the Problem

This study investigated the current integration of eco-literacy in Basic Education Institutions and developed a conceptual model for eco-literacy integration in pre-service science teacher education.

Specifically, it sought to answer the following questions:

1. What is the current integration of eco-literacy in Basic Education Institutions?
2. Based on the findings, what conceptual model can be developed to strengthen eco-literacy integration in pre-service science teacher education?

Scope and Delimitations

This study examined the current integration of eco-literacy in Basic Education Institutions to inform the development of a conceptual model for eco-literacy integration in pre-service science teacher education. Specifically, it explored how eco-literacy is currently embedded in the curriculum, instructional practices, learning experiences, teacher preparation, and institutional initiatives that support environmental education. The study identified the prevailing approaches, practices, and conditions that influence eco-literacy integration and synthesized these findings into a conceptual model intended to guide curriculum enhancement and teacher preparation in higher education institutions.

The study was limited to the perspectives of selected science teacher educators and faculty members involved in teacher education and science instruction. Data were gathered using

qualitative methods and analyzed through thematic analysis to identify the major themes related to eco-literacy integration. The investigation focused solely on the current state of eco-literacy integration in Basic Education Institutions and did not evaluate the effectiveness of specific eco-literacy programs, measure students' environmental literacy levels, or assess the implementation of the proposed conceptual model. Furthermore, the conceptual model developed in this study is intended as a research-informed framework based on participants' experiences and existing practices, and it was not subjected to implementation or validation within educational institutions.

Review of Related Literature

Eco-Literacy in Contemporary Education

Eco-literacy has become an essential component of twenty-first-century education as schools increasingly recognize their responsibility in preparing environmentally responsible citizens capable of addressing complex ecological challenges. More than developing environmental awareness, eco-literacy equips learners with the knowledge, values, skills, and behaviors necessary to understand the interconnectedness of natural and human systems and to make informed decisions that promote sustainability. As environmental concerns such as climate change, biodiversity loss, and resource depletion intensify, educational institutions are expected to integrate sustainability principles into curricula and instructional practices rather than treating environmental education as an isolated topic.

Several scholars have emphasized that eco-literacy extends beyond the acquisition of environmental knowledge toward the development of ecological values and responsible action. Arga and Rahayu (2019) argued that environment-based learning materials significantly improve eco-literacy by connecting scientific concepts with authentic environmental experiences. Likewise, Gustian et al. (2022) demonstrated that eco-literacy modules enhance students' ecological understanding and encourage responsible environmental behavior through contextualized learning experiences. These findings suggest that meaningful eco-literacy develops when learners actively engage with environmental issues rather than merely acquiring theoretical knowledge.

The importance of eco-literacy has likewise been recognized internationally through curriculum reforms that emphasize sustainability education. Nadiroh et al. (2021) asserted that twenty-first-century teacher education programs should integrate eco-literacy into curriculum transformation to prepare future educators capable of promoting sustainable development. Similarly, Parry Thompson (2023) emphasized that higher education institutions play a critical role in embedding sustainability into teacher preparation by aligning curriculum, pedagogy, and institutional policies with environmental education goals. These studies collectively reinforce the growing expectation that eco-literacy should be an integral component of teacher education rather than an optional addition to instruction.

Eco-Literacy Integration in the Curriculum

Current educational practice generally adopts an integrated approach to eco-literacy,

embedding environmental concepts across multiple subject areas instead of establishing eco-literacy as a separate discipline. This interdisciplinary approach allows learners to encounter sustainability concepts through science, social studies, language, and values education, thereby promoting a holistic understanding of environmental issues.

Research indicates that integration across subjects provides opportunities for contextual learning while simultaneously presenting challenges in maintaining consistency and depth. Nurwidodo et al. (2020) observed that environmental literacy programs are frequently incorporated into broader school initiatives; however, implementation often varies depending on institutional commitment and teacher practices. Likewise, Skamp and Green (2022) argued that although sustainability concepts appear throughout school curricula, the absence of explicit pedagogical guidance frequently results in inconsistent classroom implementation. These findings suggest that curriculum integration alone is insufficient unless supported by coherent instructional strategies and clearly articulated learning outcomes.

Within teacher education, Ma and Green (2021a) further emphasized that place-responsive science teaching enables future educators to connect scientific knowledge with authentic environmental contexts. Their findings demonstrated that integrating environmental concepts into science instruction fosters deeper ecological understanding and strengthens instructional relevance. Similarly, Ma and Green (2021b) found that place-based pedagogies significantly transformed pre-service teachers' perspectives on science teaching by enabling them to appreciate environmental issues within local community contexts. Together, these studies highlight the value of integrating eco-literacy across curricula while emphasizing the need for intentional instructional design.

Experiential Learning as a Foundation for Eco-Literacy

Experiential learning has consistently emerged as one of the most effective approaches for developing eco-literacy. Rather than relying solely on classroom instruction, experiential learning allows students to participate directly in environmental activities that strengthen ecological understanding, critical thinking, and responsible action.

Kelly and Pelech (2020) demonstrated that place-conscious pedagogy significantly enhances science education by allowing learners to engage directly with environmental phenomena within their communities. Their findings revealed that authentic environmental experiences encourage students to connect scientific concepts with real-world ecological issues, thereby strengthening environmental responsibility. Likewise, Rosidah et al. (2022) found that thematic learning materials successfully cultivate eco-literacy among young learners by presenting environmental concepts through engaging and contextualized instructional resources.

Similarly, Sumarmi et al. (2021) reported that digital eco-learning significantly improves environmental project literacy and enhances pedagogical competence among future educators. Their findings indicate that technology-enhanced experiential learning can complement traditional environmental activities by expanding learners' opportunities for environmental inquiry and collaboration. Collectively, these studies demonstrate that meaningful eco-literacy develops through active participation, reflection, and authentic

environmental engagement.

Eco-Literacy and Teacher Preparation

Teachers remain central to the successful implementation of eco-literacy because they determine how sustainability concepts are interpreted, contextualized, and translated into classroom practice. Consequently, teacher education institutions play a critical role in preparing future educators with the competencies necessary to integrate environmental education effectively.

Bilianska and Yaroshenko (2020) found that prospective biology teachers' ability to foster ecological literacy depends largely on the quality of their professional preparation. Their study emphasized that teacher education should develop not only environmental knowledge but also instructional competence and ecological values that enable teachers to model environmentally responsible behavior. Likewise, Haggag (2023) demonstrated that green pedagogy significantly enhanced pre-service science teachers' eco-literacy while also improving inferential thinking and the formation of environmental values. These findings indicate that effective teacher preparation should integrate ecological knowledge, pedagogical competence, and ethical responsibility.

Cross-national research likewise highlights the importance of systematic teacher preparation. Kyi et al. (2023) compared pre-service science teacher education across Myanmar, the Philippines, and Japan and found considerable variation in the extent to which sustainability and environmental education are embedded within teacher preparation programs. The authors argued that stronger curricular alignment and institutional commitment are necessary to ensure consistent preparation of future science teachers. These findings reinforce the need for structured eco-literacy integration within teacher education programs.

Values Formation and Sustainable Environmental Behavior

Beyond cognitive understanding, eco-literacy seeks to cultivate attitudes, values, and behaviors that promote long-term environmental stewardship. Sustainable behavior develops when learners internalize ecological values and translate them into responsible everyday practices.

Latifah et al. (2022) emphasized that environmental character formation is fundamental to eco-literacy, as responsible environmental behavior results from the continuous internalization of values rather than from isolated instructional activities. Similarly, Salimi et al. (2021) reported that students in nature-based schools demonstrated stronger eco-literacy because environmental values were consistently reinforced through school culture, instructional activities, and daily routines. Bernal and Apdohan (2023) likewise found that integrating environmental literacy with disaster risk reduction strengthens learners' awareness and preparedness for environmental challenges, illustrating that eco-literacy extends beyond conservation toward broader sustainability competencies.

Furthermore, Tiwari (2023) demonstrated that eco-literacy significantly influences individuals' environmental attitudes and sustainable decision-making. Although conducted in the context of consumer behavior, the findings suggest that ecological

knowledge shapes long-term behavioral choices, reinforcing the importance of integrating eco-literacy into educational systems to promote lifelong environmental responsibility.

Synthesis of the Literature

The reviewed literature consistently demonstrates that eco-literacy is a multidimensional construct encompassing environmental knowledge, ecological values, experiential learning, responsible behavior, and teacher competence. Previous studies have established the importance of integrating eco-literacy across curricula, utilizing authentic learning experiences, and strengthening teacher preparation to promote sustainability education. However, existing research has primarily examined these components in isolation, focusing on instructional approaches, environmental behaviors, curriculum integration, or teacher competencies. Comparatively little attention has been given to synthesizing these interconnected dimensions into a unified conceptual framework to guide eco-literacy integration in pre-service science teacher education.

Moreover, while numerous studies recommend strengthening sustainability education, few provide a research-informed conceptual model that explicitly connects curriculum integration, experiential learning, teacher preparedness, ecological competencies, and institutional support. This gap underscores the need for a comprehensive framework that translates empirical findings into a structured guide for teacher education institutions. Addressing this gap, the present study investigates the current integration of eco-literacy in Basic Education Institutions and develops a conceptual model that can serve as a foundation for strengthening eco-literacy integration in pre-service science teacher education.

Theoretical Framework

This study is anchored on Experiential Learning Theory, Constructivist Learning Theory, and the principles of Education for Sustainable Development (ESD). These complementary perspectives provide the theoretical foundation for understanding how eco-literacy is integrated within the curriculum and how such integration informs the development of a conceptual model for pre-service science teacher education.

The primary theoretical foundation of this study is Experiential Learning Theory proposed by Kolb (1984). The theory posits that meaningful learning occurs through a continuous cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation. Rather than relying solely on classroom instruction, learners develop a deeper understanding when they actively engage with authentic experiences and reflect on them to construct new knowledge. Within the context of eco-literacy, experiential learning supports educational practices such as field investigations, environmental projects, tree-planting activities, community immersion, waste management initiatives, and other place-based learning experiences that enable learners to appreciate environmental concepts through direct interaction with their surroundings. This theoretical perspective is reflected in the present study's findings, particularly in the emergence of experiential and practical eco-literacy as an essential component of effective environmental education. It also provides the basis for emphasizing authentic learning experiences within the proposed conceptual model.

The study is likewise grounded in Constructivist Learning Theory, as advanced by Piaget (1972) and further enriched through the social constructivist perspective of Vygotsky (1978). Constructivism holds that learners actively construct knowledge by connecting new experiences to their prior understanding as they interact with their physical and social environments. Learning therefore becomes an active process of meaning-making rather than passive acquisition of information. In eco-literacy education, this perspective suggests that learners develop ecological understanding through inquiry, collaboration, problem-solving, reflection, and contextualized learning activities that allow them to interpret environmental issues within their own communities. The theory supports integrating eco-literacy across subject areas, enabling learners to connect environmental concepts to science, social studies, and values education while developing ecological awareness and responsible decision-making. It likewise reinforces the importance of preparing future science teachers to facilitate learner-centered and inquiry-based environmental education.

The third theoretical foundation is the framework of Education for Sustainable Development (ESD) advocated by the United Nations Educational, Scientific and Cultural Organization (UNESCO). ESD promotes the integration of sustainability principles across educational systems to develop learners with the knowledge, competencies, values, and behaviors needed to contribute to sustainable development. Rather than treating sustainability as a separate discipline, ESD advocates embedding environmental, social, economic, and ethical dimensions across curriculum, pedagogy, institutional policies, and community engagement. Within teacher education, this framework emphasizes that future educators should not only understand sustainability concepts but also demonstrate the competencies required to integrate them into instructional practice. The findings of this study, particularly those related to curriculum integration, teacher preparedness, competencies, and institutional improvements, closely align with the principles of ESD and provide the theoretical justification for developing a structured conceptual model for eco-literacy integration.

Collectively, these theoretical perspectives explain how eco-literacy develops through authentic environmental experiences, active knowledge construction, and the systematic integration of sustainability across educational processes. Experiential Learning Theory explains how learners acquire ecological understanding through direct engagement with environmental activities; Constructivist Learning Theory explains how ecological knowledge and values are constructed through meaningful learning experiences; and Education for Sustainable Development provides the broader educational context that supports the institutional integration of sustainability within teacher education. Together, these theories underpin the investigation into the current integration of eco-literacy in Basic Education Institutions and serve as the theoretical basis for developing the proposed conceptual model for eco-literacy integration in pre-service science teacher education.

Conceptual Framework

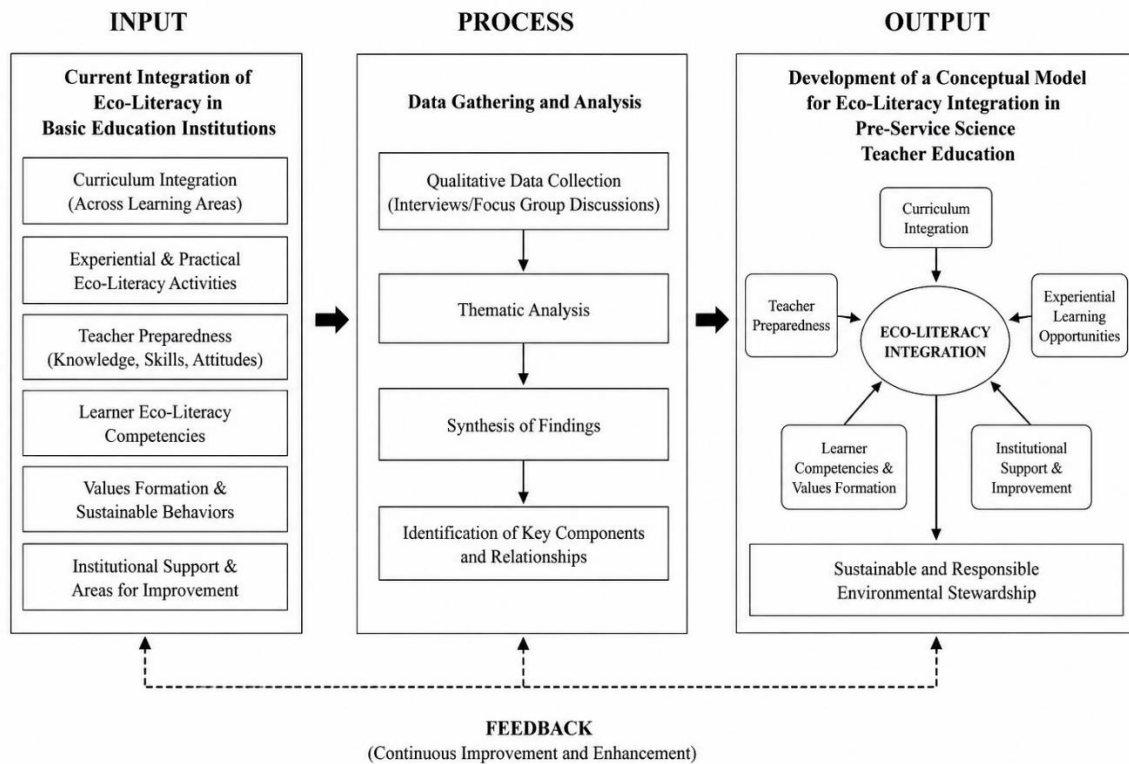


Figure 1 presents the conceptual framework of the study using the Input–Process–Output (IPO) Model, illustrating the logical flow of the investigation from the current integration of eco-literacy in Basic Education Institutions to the development of a conceptual model for eco-literacy integration in pre-service science teacher education.

The input component represents the primary focus of the investigation, which is the current integration of eco-literacy in Basic Education Institutions. This includes six essential dimensions identified in the literature and explored during data collection: curriculum integration across learning areas, experiential and practical eco-literacy activities, teacher preparedness, learner eco-literacy competencies, values formation and sustainable behaviors, and institutional support and areas for improvement. These dimensions collectively describe how eco-literacy is currently embedded within educational practice and provide the foundational information necessary for understanding existing strengths and opportunities for enhancement. Together, these elements serve as the basis for identifying the essential components of eco-literacy integration that can inform teacher education.

The process component illustrates the systematic procedures undertaken to generate the study's findings. Qualitative data were gathered from the participants through interviews and were analyzed using thematic analysis. The analysis involved organizing the participants' responses, identifying recurring patterns, synthesizing the emergent themes, and determining the relationships among these themes. Through this rigorous analytical

process, the study was able to capture the prevailing practices, experiences, and perspectives regarding eco-literacy integration in Basic Education Institutions. The synthesis of these findings enabled the researcher to identify the core elements necessary for constructing a comprehensive conceptual model.

The output component represents the principal contribution of the study, which is the Conceptual Model for Eco-Literacy Integration in Pre-Service Science Teacher Education. The model integrates the essential themes that emerged from the investigation, namely curriculum integration, teacher preparedness, experiential learning opportunities, learner competencies and values formation, and institutional support and improvement. These interconnected components collectively contribute to effective eco-literacy integration and ultimately promote sustainable and responsible environmental stewardship among future science teachers. The conceptual model serves as a guide for higher education institutions in strengthening curriculum design, instructional practices, faculty development, and institutional policies that support sustainability education.

The framework also incorporates a feedback mechanism, signifying that eco-literacy integration is a continuous and dynamic process rather than a one-time educational initiative. As educational contexts, environmental challenges, and sustainability priorities evolve, the conceptual model should likewise be periodically reviewed, evaluated, and refined using evidence generated from educational practice and research. This continuous improvement process enables teacher education institutions to maintain the relevance, responsiveness, and effectiveness of eco-literacy integration, ensuring that future science teachers remain equipped to foster environmental responsibility and sustainable development in diverse educational settings.

METHODOLOGY

This chapter presents the research methodology employed in the conduct of the study. It describes the research design, participants and sampling procedures, research instrument, data collection procedures, and data analysis techniques utilized to investigate the current integration of eco-literacy in Basic Education Institutions and to develop a conceptual model for eco-literacy integration in pre-service science teacher education.

Research Design

This study employed a qualitative phenomenological research design to explore the current integration of eco-literacy in Basic Education Institutions and to develop a conceptual model for eco-literacy integration in pre-service science teacher education. Phenomenology was appropriate because the study sought to understand the lived experiences, perceptions, and professional practices of science teacher educators regarding the integration of eco-literacy within teacher education programs. Rather than measuring predetermined variables, the study focused on capturing participants' perspectives to identify common patterns and meanings that characterize eco-literacy integration.

The qualitative approach enabled an in-depth examination of participants' experiences, providing rich descriptions of how eco-literacy is embedded in curriculum, instructional

practices, and teacher preparation. The findings served as the empirical foundation for developing a conceptual model that explains the essential dimensions of eco-literacy integration in pre-service science teacher education.

Research Steps

After obtaining the necessary institutional approvals and informed consent from participants, data collection was conducted through individual semi-structured interviews and open-ended online questionnaires. Face-to-face or virtual interviews were scheduled based on participants' availability and were audio-recorded with their permission. Participants who were unable to participate in interviews completed the Google Forms questionnaire containing the same set of open-ended questions.

Throughout the data collection process, the researcher maintained field notes to document contextual observations, emerging reflections, and non-verbal cues observed during interviews. These notes complemented the interview transcripts by providing additional contextual information that supported data interpretation.

All interview recordings were transcribed verbatim and reviewed alongside participants' online responses to ensure completeness and accuracy. Participant identities were protected through the use of pseudonyms and identification codes to maintain confidentiality throughout the study.

Data Collection and Sample Selection

The participants consisted of science teacher educators actively involved in preparing pre-service science teachers in selected Basic Education Institutions across different regions of the Philippines. Participants were purposively selected based on their ability to provide rich and relevant information regarding eco-literacy integration in science teacher education.

The inclusion criteria required participants to have at least three years of experience teaching science education, direct involvement in mentoring or supervising pre-service science teachers, and active participation in curriculum implementation or instructional planning. Preference was also given to educators affiliated with institutions implementing environmental education initiatives or sustainability-related programs.

Purposive sampling with maximum variation was employed to capture diverse institutional contexts and instructional experiences. Data collection continued until data saturation was achieved, resulting in twelve (12) participants. Saturation was considered reached when subsequent interviews and written responses no longer generated new codes, themes, or conceptual insights relevant to the phenomenon under investigation.

Data Analysis Methods

The qualitative data were analyzed using Braun and Clarke's (2006) thematic analysis framework. Initially, all interview transcripts, online responses, and field notes were read repeatedly to facilitate familiarization with the data. Significant statements relevant to eco-

literacy integration were then coded systematically, allowing similar concepts to be grouped into preliminary categories.

The initial codes were subsequently examined to identify recurring patterns and broader themes that represented participants' shared experiences. Themes were reviewed, refined, and clearly defined to ensure coherence and accurate representation of the data. Through this iterative analytical process, six major themes emerged: (1) integration through content and competencies, (2) experiential and practical eco-literacy, (3) awareness, responsibility, and sustainable habits, (4) preparedness of pre-service teachers, (5) required competencies and ecological mindsets, and (6) teacher education program improvements.

To enhance the trustworthiness of the findings, data triangulation was employed by comparing evidence obtained from interviews, online responses, and field notes. Peer debriefing was likewise conducted to validate the consistency of the coding process and thematic interpretation. Finally, the six emergent themes were synthesized into a conceptual model that illustrates the interrelationships among curriculum integration, teacher capacity, and institutional enablement in fostering eco-literacy within pre-service science teacher education.

Validation of the Research Instrument

Prior to data collection, the researcher-developed semi-structured interview guide underwent content validation to ensure its clarity, relevance, and alignment with the objectives of the study. The validation process was conducted by a panel of experts composed of specialists in science education, curriculum and instruction, environmental education, and educational research. The validators evaluated each interview question based on its relevance to the research problem, clarity of language, appropriateness of content, logical sequencing, and ability to elicit rich and meaningful responses related to eco-literacy integration in Basic Education Institutions.

The experts likewise examined whether the interview questions adequately captured the essential dimensions of eco-literacy integration, including curriculum implementation, instructional practices, experiential learning, teacher preparedness, learner competencies, values formation, and institutional support. Their recommendations focused on improving the wording of several questions to enhance clarity, minimize ambiguity, and encourage participants to provide comprehensive descriptions of their experiences and perspectives.

Based on the validators' comments and suggestions, necessary revisions were incorporated before the final administration of the interview guide. The refinement process involved simplifying technical terms, reorganizing the sequence of selected questions to improve the flow of the interview, and adding probing questions to obtain deeper insights into participants' responses. These revisions strengthened the instrument's content validity and ensured that it was capable of generating credible and information-rich qualitative data aligned with the study's objectives.

The validated interview guide subsequently served as the primary data collection instrument for the study and provided the empirical foundation for identifying the emergent themes and developing the proposed conceptual model for eco-literacy integration in pre-service science teacher education.

Study Limitations and Ethical Considerations

The researcher ensured that the study was conducted in accordance with established ethical principles governing educational research. Prior to data collection, permission to conduct the study was obtained from the appropriate institutional authorities. All participants were informed of the purpose of the study, the research procedures, the expected duration of their participation, and the intended use of the data. Their participation was entirely voluntary, and informed consent was secured before the interviews were conducted. Participants were likewise informed of their right to decline answering any question or to withdraw from the study at any point without penalty or adverse consequences.

The researcher maintained the confidentiality and anonymity of all participants throughout the research process. Personally identifiable information was excluded from the transcripts, analyses, and final report, with participants identified only through assigned codes (e.g., P1, P2, P3). All interview recordings, transcripts, and related research documents were securely stored and were accessible only to the researcher. To preserve the authenticity of the findings, participants' responses were presented accurately, with verbatim quotations included where appropriate while ensuring that no information could reveal their identities. Throughout the conduct of the study, the researcher adhered to the ethical principles of respect for persons, beneficence, justice, and research integrity.

Despite these ethical safeguards, certain limitations should be considered when interpreting the findings. This study focused on examining the current integration of eco-literacy in Basic Education Institutions through the perspectives of selected science teacher educators and faculty members. As a qualitative investigation, the findings reflect the participants' experiences and professional insights within their respective educational contexts and are therefore not intended to be statistically generalizable to all educational institutions or teacher education programs. The study also concentrated on describing current eco-literacy integration and did not evaluate the effectiveness of specific environmental education initiatives or measure learners' actual levels of eco-literacy.

Furthermore, the proposed conceptual model was developed from the emergent themes generated through thematic analysis of the participants' narratives. Although grounded in empirical evidence and supported by relevant literature, the model was not implemented or empirically validated within teacher education institutions. Consequently, its applicability across different educational settings remains subject to future implementation, validation, and refinement. Nevertheless, the study provides valuable insights into existing eco-literacy practices and offers a research-informed conceptual model that may serve as a useful guide for strengthening eco-literacy integration in pre-service science teacher education.

RESULTS AND DISCUSSION

SOP 1. What is the current integration of eco-literacy in Basic Education Institutions?

The integration of eco-literacy within the current DepEd curriculum plays a vital role in developing learners' environmental knowledge, values, and sustainable practices.

Understanding how eco-literacy is presently embedded in the curriculum provides important insights into the strengths and gaps of existing educational practices and serves as a basis for enhancing teacher preparation for sustainability education. Through the perspectives of science teacher educators, this study examined the current approaches to eco-literacy integration in Basic Education Institutions. The findings were organized into six emergent themes that describe the prevailing practices, competencies, and institutional conditions influencing eco-literacy integration. Table 1 presents the thematic insights generated from the participants' narratives.

Table 1: Eco-Literacy Integration in the Current DepEd Curriculum

Thematic Insight	Representative Participants	Brief Descriptor
Integration via content and competencies	P1, P3, P5–P12	Environmental ideas are embedded in standards and topics rather than framed as a stand-alone strand.
Experiential/practical eco-literacy	P2, P6, P7, P8, P11, P12	Hands-on activities strengthen understanding and relevance.
Awareness, responsibility, sustainable habits	P1–P4, P6–P12	Intended outcomes include pro-environmental attitudes and everyday practices.
Preparedness of pre-service teachers is uneven yet improving	P1–P3, P5–P9, P11, P12	Exposure varies by mentors, courses, and campus resources.
Required competencies and mindsets	P1–P12	Content knowledge must be coupled with modeling, values, and reflective practice.
Teacher education program improvements needed	P1–P12	Calls for tighter alignment of curriculum, pedagogy, and assessment.

Integration through Content and Competencies

Participants (P1, P3, P5–P12) consistently described eco-literacy as being integrated into the current DepEd curriculum through subject content and learning competencies rather than as a distinct curricular component. As Participant 7 explained, “Environmental issues are already discussed in Science and Araling Panlipunan, but they are spread across topics, not as a focused subject.” This finding indicates that while environmental concepts are embedded across various learning areas, their implementation remains largely implicit, resulting in variations in instructional depth and emphasis. Such integration promotes interdisciplinary learning by allowing sustainability concepts to be addressed within existing curricular standards; however, the absence of explicit eco-literacy competencies may lead to fragmented classroom implementation that depends on individual teachers' instructional practices. Similar observations were reported by Nurwidodo et al. (2020), who noted that environmental literacy is often infused across school programs rather than established as a distinct curriculum component, while Skamp and Green (2022) emphasized that sustainability education requires intentional pedagogical direction to achieve meaningful and consistent learning outcomes. Likewise, Nadiroh et al. (2021) argued that eco-literacy should be recognized as a core competency within teacher education to ensure systematic integration into curriculum,

instruction, and assessment. Collectively, these findings suggest that curriculum integration provides an important foundation for eco-literacy, although stronger curricular articulation is necessary to promote coherent and sustained environmental education across educational contexts.

Experiential/Practical Eco-Literacy

Participants (P2, P6, P7, P8, P11, and P12) emphasized that eco-literacy becomes more meaningful when learners actively engage in experiential and community-based activities. As Participant 6 shared, “It was during tree planting and clean-up drives that students really learned how to care for the environment,” while Participant 11 added, “The most effective lessons are those that allow learners to touch the soil, plant trees, or join fieldwork.” These responses demonstrate that authentic environmental experiences promote deeper ecological understanding by allowing learners to apply scientific knowledge to real-life situations. Experiential learning not only enhances cognitive understanding but also cultivates environmental stewardship, responsibility, and long-term behavioral change. This finding supports Kelly and Pelech (2020), who argued that place-conscious pedagogy strengthens learners’ environmental responsibility through authentic experiences, and Ma and Green (2021), who found that place-responsive teaching transformed pre-service teachers’ perceptions of science education by connecting classroom instruction with local ecological contexts. Similarly, Arga and Rahayu (2019) reported that environment-based learning significantly improved eco-literacy by situating learning within meaningful environmental experiences, highlighting experiential learning as a critical component of effective eco-literacy integration.

Awareness, Responsibility, and Sustainable Habits

Almost all participants (P1–P4, P6–P12) identified awareness, environmental responsibility, and sustainable habits as the primary outcomes of eco-literacy integration. Participant 2 explained, “The goal is not only to give knowledge, but to change behaviors—students should learn to recycle, conserve energy, and care for their surroundings,” while Participant 9 remarked that “Awareness is important, but the challenge is whether students continue practicing it after leaving school.” These findings suggest that eco-literacy extends beyond the acquisition of environmental knowledge and seeks to develop enduring values and behaviors that influence everyday decision-making. Participants recognized that meaningful sustainability education should encourage learners to internalize ecological responsibility and translate environmental awareness into consistent action. This observation is consistent with the findings of Haggag (2023), who demonstrated that green pedagogy enhances both eco-literacy and environmental values among pre-service teachers, while Arga and Rahayu (2019) similarly reported that eco-literacy initiatives contribute to the development of environmentally responsible attitudes. Furthermore, Yuniawan et al. (2022) emphasized that institutions with strong conservation-oriented cultures are more successful in cultivating sustainable habits among learners, reinforcing the importance of embedding ecological values throughout educational experiences.

Preparedness of Pre-Service Teachers is Uneven yet Improving

Most participants (P1–P3, P5–P9, P11, and P12) acknowledged that the preparedness of pre-service science teachers to integrate eco-literacy remains inconsistent across teacher education institutions. Participant 3 noted, “Some of us were exposed to eco-literacy activities, but not everyone had the same training,” while Participant 8 observed that “Preparedness depends on who your professors are—some integrate eco-literacy, some do not.” These responses indicate that opportunities to develop eco-literacy competencies are largely influenced by faculty expertise, institutional priorities, and curriculum implementation, resulting in varying levels of readiness among future science teachers. Although participants recognized growing awareness of sustainability education, they also emphasized the need for more systematic teacher preparation. This finding aligns with Bilianska and Yaroshenko (2020), who concluded that prospective teachers’ capacity to foster ecological literacy is largely determined by the quality of their professional preparation. Likewise, Kyi et al. (2023) reported significant variations in pre-service science teacher education across different countries, emphasizing the need for more standardized approaches to integrating sustainability competencies within teacher education curricula.

Required Competencies and Mindsets

All participants (P1–P12) emphasized that effective eco-literacy requires science teachers to possess not only adequate environmental knowledge but also ecological values, reflective practice, and the ability to model sustainable behaviors. Participant 1 explained, “It is not enough that teachers know the concepts; they must model an ecological lifestyle to inspire students,” while Participant 10 stated, “Eco-literacy is both knowledge and attitude. Teachers should embody care for the environment if they expect students to follow.” These findings suggest that eco-literacy is a multidimensional competence that integrates cognitive, affective, and behavioral domains, requiring teachers to demonstrate sustainability principles through both instruction and personal practice. Beyond mastering scientific concepts, participants viewed teachers as role models capable of influencing learners’ environmental attitudes through authentic demonstration of ecological responsibility. These observations support Haggag (2023), who found that green pedagogy strengthens both environmental literacy and value formation among pre-service teachers. Similarly, Bilianska and Yaroshenko (2020) emphasized that teacher education should cultivate ecological competencies alongside professional dispositions, while Ma and Green (2021) argued that reflective, place-responsive pedagogies contribute significantly to developing environmentally conscious science educators.

Teacher Education Program Improvements Needed

All participants (P1–P12) agreed that strengthening eco-literacy integration requires substantial improvements within teacher education programs. Participant 4 remarked, “Eco-literacy is present, but teacher education programs need to do more to prepare us for integrating it into our teaching,” while Participant 11 emphasized that “Without curriculum reform and proper training, eco-literacy will always remain secondary.” These responses indicate that although eco-literacy is recognized as an important educational goal, its implementation remains constrained by limited curricular emphasis, insufficient faculty preparation, and the absence of systematic institutional support. Participants highlighted the need for stronger alignment among curriculum, pedagogy, assessment, and faculty development to ensure that

eco-literacy becomes an integral component of science teacher education rather than an isolated instructional initiative. This finding supports Nadiroh et al. (2021), who argued that twenty-first-century teacher education requires curriculum transformation that explicitly embeds eco-literacy competencies. Likewise, Parry Thompson (2023) emphasized that sustainable educational change depends on institutional commitment, policy support, and curriculum reform that collectively promote Education for Sustainable Development within higher education institutions. These findings underscore the critical role of institutional enhancement in establishing coherent and sustainable eco-literacy integration in pre-service science teacher education.

SOP 2. Based on the findings, what conceptual model can be developed to strengthen eco-literacy integration in pre-service science teacher education?

The conceptual model presented in Figure 1 was developed through the synthesis of the six emergent themes identified from the participants' narratives. Rather than functioning as independent findings, these themes collectively illustrate the essential dimensions that influence the successful integration of eco-literacy in pre-service science teacher education. The model demonstrates how curriculum integration, teacher capacity, and institutional enablement interact to promote the development of eco-literate pre-service science teachers. Grounded in the lived experiences of science teacher educators, the conceptual model provides a research-informed representation of the interconnected processes that support sustainability education and serves as a guide for curriculum enhancement, instructional practice, and institutional policy development.

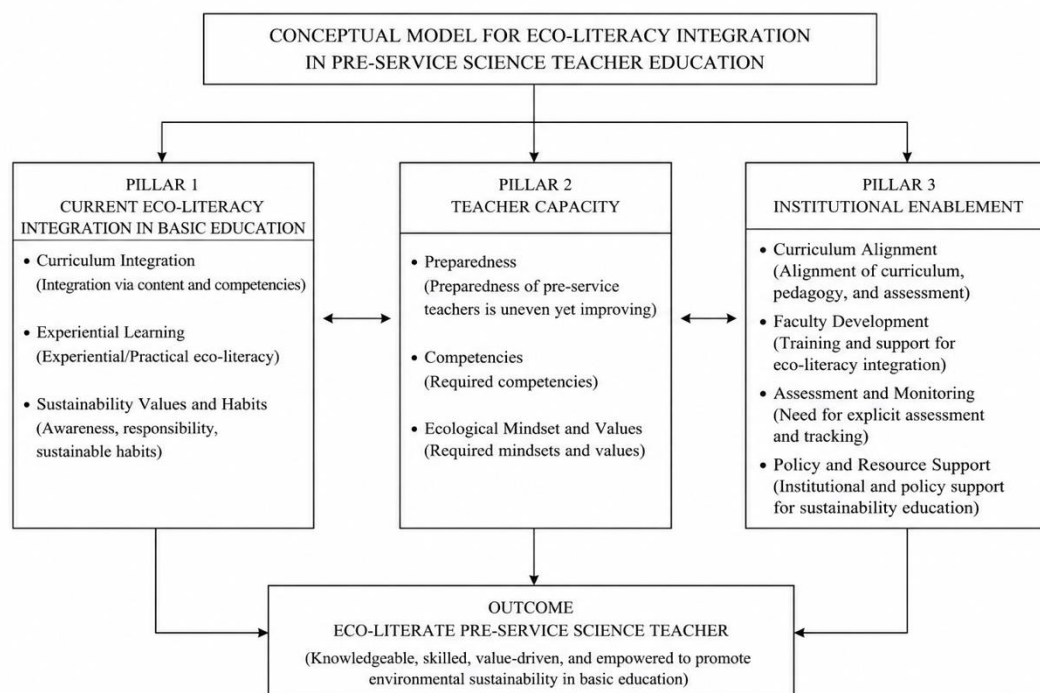


Figure 1. Conceptual Model for Eco-Literacy Integration in Pre-Service Science Teacher Education.

The conceptual model proposes that effective eco-literacy integration is achieved through the dynamic interaction of three major dimensions: curriculum integration, teacher capacity, and institutional enablement. The first dimension, curriculum integration, emphasizes the incorporation of eco-literacy across subject content, experiential learning activities, and sustainability-oriented values. Participants consistently described eco-literacy as being embedded within existing learning competencies rather than taught as a stand-alone subject, allowing environmental concepts to be addressed through interdisciplinary instruction. Likewise, the integration of experiential learning activities, such as fieldwork, community engagement, and environmental projects, reinforces learners' ecological understanding by connecting scientific concepts with authentic environmental experiences. Together, these curricular components establish the foundational learning experiences through which eco-literacy is introduced and contextualized. These findings support the work of Arga and Rahayu (2019), Kelly and Pelech (2020), and Ma and Green (2021), who emphasized that meaningful eco-literacy develops through authentic, context-based, and inquiry-driven learning experiences.

The second dimension, teacher capacity, recognizes that successful eco-literacy integration depends on the preparedness, competencies, and ecological mindsets of future science teachers. Participants emphasized that effective sustainability education extends beyond content knowledge and requires educators who model environmentally responsible behaviors, demonstrate reflective practice, and possess the pedagogical competence to integrate sustainability into science instruction. The model therefore positions teacher preparedness and ecological values as central mechanisms through which curriculum intentions are translated into meaningful classroom practice. This interpretation aligns with Bilianska and Yaroshenko (2020), who highlighted the importance of professional preparation in developing ecological literacy among future teachers, and Haggag (2023), who demonstrated that green pedagogy strengthens both environmental knowledge and value formation among pre-service science educators.

The third dimension, institutional enablement, represents the organizational conditions necessary to sustain eco-literacy integration. Participants unanimously recognized that curriculum alignment, faculty development, assessment practices, leadership support, and institutional policies significantly influence the consistency and quality of eco-literacy implementation. Without systematic institutional commitment, eco-literacy initiatives remain dependent on individual teachers rather than becoming integral components of teacher education programs. Accordingly, the model identifies institutional enablement as the structural support that strengthens curriculum implementation and teacher capacity, ensuring that eco-literacy is embedded within the broader educational system. This finding is consistent with Nadiroh et al. (2021), who advocated for curriculum transformation that explicitly incorporates eco-literacy competencies, and Parry Thompson (2023), who emphasized that sustainable educational change requires institutional commitment and coherent policy support.

Collectively, the interaction among these three dimensions culminates in the development of eco-literate pre-service science teachers who possess ecological knowledge, environmental values, pedagogical competence, and the capacity to promote sustainable practices through science education. Rather than presenting eco-literacy as a collection of isolated instructional strategies, the conceptual model illustrates it as a holistic educational process in which curriculum, teacher preparation, and institutional support function as mutually reinforcing components. As such, the model contributes a conceptual explanation of eco-literacy

integration that is grounded in empirical evidence and offers practical guidance for higher education institutions seeking to strengthen sustainability education within pre-service science teacher preparation programs.

SUMMARY

The study examined the current integration of eco-literacy in Basic Education Institutions and identified six major themes that characterize existing practices in environmental education. The findings revealed that eco-literacy is primarily integrated through curriculum content and learning competencies rather than as a stand-alone discipline, with experiential and place-based learning serving as effective approaches for strengthening ecological understanding and environmental responsibility. Participants emphasized that eco-literacy aims to cultivate sustainable values and behaviors; however, the extent of implementation varies because of differences in teacher preparedness, instructional practices, and institutional support. The study further highlighted that effective eco-literacy integration requires educators who possess both environmental competencies and ecological mindsets, supported by coherent curriculum alignment, faculty development, and institutional commitment. Drawing from these interconnected themes, the study developed a conceptual model that positions curriculum integration, teacher capacity, and institutional enablement as the fundamental dimensions for strengthening eco-literacy integration in pre-service science teacher education, thereby providing a research-informed framework for enhancing sustainability education within teacher preparation programs.

CONCLUSIONS

This study explored the current integration of eco-literacy in Basic Education Institutions through the perspectives of science teacher educators and identified six interrelated themes that characterize existing practices in sustainability education. The findings indicate that eco-literacy is presently embedded across curriculum content and learning competencies, enriched through experiential learning, and intended to cultivate environmental awareness and sustainable habits among learners. However, its implementation remains inconsistent due to variations in teacher preparedness, ecological competencies, and institutional support. These findings demonstrate that while eco-literacy has gained recognition within the curriculum, its integration continues to depend largely on individual teaching practices rather than on a coherent and systematic educational approach.

Drawing from these empirical insights, the study developed a conceptual model that positions curriculum integration, teacher capacity, and institutional enablement as the three interconnected dimensions essential for effective eco-literacy integration in pre-service science teacher education. The model highlights that meaningful sustainability education extends beyond curriculum content and requires competent educators, supportive institutional structures, and intentional pedagogical practices working together to develop eco-literate future science teachers. As a research-informed representation of eco-literacy integration, the proposed conceptual model contributes to the growing body of sustainability education literature and offers a practical reference for curriculum developers, teacher educators, higher education institutions, and policymakers seeking to strengthen environmental education within teacher preparation programs.

RECOMMENDATIONS

Based on the findings of the study, it is recommended that higher education institutions strengthen the integration of eco-literacy within teacher education curricula by embedding sustainability concepts explicitly across professional education and science courses. Curriculum developers and teacher educators may align learning outcomes, instructional strategies, experiential learning activities, and assessment practices with eco-literacy competencies to ensure that pre-service teachers develop not only environmental knowledge but also the skills, values, and dispositions necessary to promote sustainable practices in their future classrooms.

Teacher education institutions are likewise encouraged to expand experiential and place-based learning opportunities that allow pre-service science teachers to engage directly with environmental issues through field experiences, community-based projects, environmental stewardship activities, and service-learning initiatives. Such authentic learning experiences may deepen ecological understanding while cultivating environmental responsibility, critical thinking, and sustainable decision-making. To support these efforts, institutions may also invest in continuous faculty development programs that equip teacher educators with current pedagogical approaches, instructional resources, and best practices for integrating eco-literacy effectively into science teacher preparation.

At the institutional level, educational leaders and policymakers may consider adopting the proposed conceptual model as a guide for curriculum enhancement, faculty development, instructional planning, and sustainability initiatives within teacher education programs. Institutional policies that explicitly promote eco-literacy integration across instruction, research, extension, and community engagement may further strengthen the consistent implementation of sustainability education. Finally, future researchers are encouraged to validate, implement, and refine the proposed conceptual model in various educational settings to examine its effectiveness in improving eco-literacy integration and to explore additional factors that may influence the preparation of environmentally responsible future science teachers.

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AI DECLARATION STATEMENT

AI-supported tools helped with grammar and structure in creating this article. No AI tools were used to collect, analyze, or interpret data; all authors are credited for their academic contributions.

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