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Development of an eco-literacy based learning model to promote sustainable practices in elementary schools

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ABSTRACT

This study addresses the limited integration of environmental sustainability and disaster preparedness in primary education, particularly in environmentally vulnerable coastal areas. It aims to develop and evaluate an integrated sustainability learning model implemented through the Sekolah Nyawiji Program. The study employed a research and development design using the define, design, develop, and disseminate stages. Data were collected through expert validation, user responses, and pre-test–post-test assessments.The results show that the model achieved high validity, with expert validation scores ranging from 3.50 to 4.00, indicating strong alignment between design and learning objectives. The model also demonstrated good practicality, reflected in high usability based on teacher and student responses. In terms of effectiveness, the model produced a high N-Gain score of 0.76, indicating substantial improvement in students' learning outcomes. These findings demonstrate that contextual and place-based sustainability learning enhances ecological understanding, environmental responsibility, and disaster preparedness. The study concludes that integrating eco-literacy, responsible consumption, and coastal ecosystem awareness provides an effective and applicable framework for sustainability learning in primary education.

INTRODUCTION

Global environmental crises, including climate change, ecosystem degradation, and increasing levels of pollution and resource exploitation, pose systemic threats to sustainable human life (Baidya & Saha, 2024; Vijaya, 2024). These challenges are closely linked to low ecological awareness and the limited internalization of sustainability values from an early age. In this context, primary education plays a strategic role, as it represents a critical stage for shaping students' values, attitudes, and long-term behavioral patterns (Lamanauskas, 2023; Ludin et al., 2025). Therefore, eco-literacy encompassing ecological knowledge, relational awareness between humans and nature, and environmental responsibility must be positioned as a core component of

holistic education, extending beyond cognitive achievement toward the formation of sustainable behavior.

Previous studies have shown that integrating environmental issues through project-based, contextual, and collaborative learning approaches can improve students' knowledge and pro-environmental attitudes (Azrai et al., 2024; Xi & Wang, 2022). However, these studies predominantly focus on short-term learning outcomes and tend to treat eco-literacy as supplementary content rather than as a guiding framework for instructional design. Moreover, research in primary education, particularly in developing country contexts, often adopts general pedagogical approaches without adapting them to students' developmental characteristics or systematically integrating ecological values into learning design (Murti et al., 2025; Permata & Agung Wibowo, 2023; Sitorus et al., 2025)

More critically, there remains a lack of empirically validated instructional models that explicitly integrate the cognitive, affective, and behavioral dimensions of eco-literacy into a coherent and structured pedagogical framework for primary education. Existing studies tend to address these dimensions in isolation focusing either on knowledge acquisition or attitude development without translating them into a unified and replicable learning model (Lovren & Jablanovic, 2023; Pitaloka et al., 2024; Singh et al., 2025). In addition, limited attention has been given to contextualizing sustainability learning within specific ecological settings, such as coastal areas, which are both environmentally vulnerable and pedagogically rich for experiential learning. This gap highlights the need for a model that is not only integrative but also contextually grounded and operationally applicable.

Based on these gaps, this study aims to develop and evaluate an eco-literacy-based learning model that integrates cognitive, affective, and behavioral dimensions within a systematic and contextual pedagogical design for primary school students in coastal areas. The novelty of this research lies in the formulation of an integrative model that positions eco-literacy as a comprehensive instructional design framework and in its development through structured stages resulting in both conceptual and operational models. The model is articulated through instructional syntax consisting of contextual exploration, value reflection, and ecological action, which are implemented in classroom practice.

Recent developments in sustainability education highlight a growing shift from knowledge-oriented approaches toward integrative and transformative learning models that emphasize the interconnection between cognition, values, and action. Within this trajectory, eco-literacy has evolved from a conceptual framework into a pedagogical orientation that seeks to foster systemic thinking, ethical awareness, and pro-environmental behavior. However, current state-of-the-art studies reveal that most eco-literacy implementations remain fragmented, focusing on isolated dimensions or short-term interventions rather than developing comprehensive instructional models that are both theoretically grounded and empirically validated. In addition, limited research has explored how eco-literacy can be operationalized within specific ecological contexts, such as coastal environments, which offer authentic and dynamic learning spaces for sustainability education.

Positioning this study within the current scholarly landscape, this research advances the field by proposing a coastal-integrated eco-literacy learning model that systematically connects cognitive, affective, and behavioral dimensions within a structured instructional design. Unlike previous approaches, the proposed model is not only conceptual but also operational, developed through a Research and Development framework and validated through empirical testing. By embedding sustainability learning within local ecological contexts and aligning it with global sustainability agendas, this study bridges the gap between abstract sustainability discourse and context-based pedagogical practice, thereby contributing to the advancement of primary education for sustainable development.

Accordingly, this study is guided by the following research questions: (1) How can an eco-literacy-based learning model integrating cognitive, affective, and behavioral dimensions be developed for primary school students? (2) To what extent is the developed model valid, practical, and effective in improving students' eco-literacy outcomes?

This study is expected to contribute theoretically by strengthening the integration of eco-literacy dimensions within primary education pedagogy and practically by providing an implementable and replicable learning model to support sustainability education in environmentally vulnerable contexts.

METHOD

This study employed a Research and Development (R&D) approach using the 4D model, which consists of the define, design, develop, and disseminate stages. The 4D model was selected because it provides a systematic framework for developing educational products through stages of needs analysis, design, validation, and limited trials prior to broader implementation (Indaryanti et al., 2025). This approach is appropriate for instructional model development as it allows for the integration of conceptual design and empirical testing (Reigeluth et al., 2024). The product developed in this study is an eco-literacy-based learning model integrating cognitive, affective, and behavioral dimensions into a structured pedagogical design. The stages of the research process are presented in Figure 1.

Figure 1. Research Phases

The research population consisted of fifth-grade students in a public primary school, with a sample of 19 students selected through cluster sampling. Additionally, two experts in primary education and one expert in environmental education were involved as validators to assess content and construct validity. The selection of fifth-grade students was based on their cognitive developmental stage, which enables them to understand causal relationships within environmental contexts.

The research was conducted in four stages. In the define stage, curriculum analysis, classroom observations, and semi-structured teacher interviews were conducted to identify the need for eco-literacy integration. The design stage involved developing the conceptual framework and instructional syntax consisting of contextual exploration, collaborative value reflection, and guided ecological action. Learning materials included teaching modules, student worksheets, and assessment instruments aligned with eco-literacy dimensions.

In the develop stage, the model was validated using expert judgment. Content validity was analyzed using Aiken's V, with a threshold of ≥ 0.80 indicating acceptable validity. Instrument reliability for the affective scale was tested using Cronbach's Alpha ($\alpha \geq 0.70$). After revisions, a limited trial was conducted over four learning sessions.

Data were collected using three main instruments. The cognitive dimension was measured using a test of ecological understanding consisting of 15 multiple-choice items covering ecosystem concepts, human–environment interactions, and sustainability principles. A sample item is: "What is the impact of plastic waste on marine ecosystems?" The affective dimension was assessed using a 10-item Likert-scale questionnaire (1–5 scale) measuring environmental care, responsibility, and awareness (e.g., "I feel responsible for keeping the environment clean"). The behavioral dimension was evaluated using an observation checklist with 8 indicators, including waste sorting, participation in environmental activities, and responsible use of natural resources.

The validity of the model was established through expert evaluation of content and construct alignment. Practicality was assessed through teacher and student response questionnaires focusing on usability, clarity, and feasibility. Effectiveness was analyzed through improvements in learning outcomes. Cognitive data were analyzed using a paired sample t-test ($\alpha = 0.05$) after testing statistical assumptions, including normality (Shapiro–Wilk test) and homogeneity. The magnitude of the effect was calculated using Cohen's d, interpreted as small (0.2), medium (0.5), and large (0.8). Learning improvement was also measured using normalized gain (N-Gain). Affective data were analyzed using mean scores and gain indices, while behavioral data were analyzed descriptively based on observed frequency changes. The disseminate stage involved developing an implementation guide based on validation and trial results, ensuring that the model is valid, practical, and effective for classroom application.

Despite its strengths, this study has several limitations. The sample size was relatively small ($n = 19$), which may limit generalizability. In addition, the absence of a control group restricts the ability to attribute causal effects solely to the intervention. The short duration of implementation also limits the assessment of long-term behavioral changes. These limitations suggest the need for further studies using larger samples, experimental designs, and longitudinal approaches to strengthen external validity.

RESULTS

The results present the development and testing of the "Nyawiji Program" as a coastal-based learning model. The findings are systematically organized to include: (1) product validity, (2) practicality, and (3) program effectiveness based on improvements in students' learning outcomes. This presentation aims to demonstrate the feasibility of the model both conceptually and empirically following the completion of the Four-D development stages.

1. Product Validity

The validity of the "Nyawiji Program" was assessed by three expert validators using a structured validation sheet covering five main aspects: program relevance, instructional design, innovation, pedagogical components, and alignment with coastal environmental characteristics. The validation instrument employed a Likert-type rating scale, which, following common practice in educational research, was treated as interval data to allow for quantitative analysis.

Table 1. Score Product Validity

Aspect	Validator 1	Validator 2	Mean Score	Category
Program Relevance	4	4	4.00	Highly Valid
Instructional Design	4	3	3.50	Highly Valid
Innovation	4	3	3.50	Highly Valid
Pedagogical Components	4	3	3.50	Highly Valid
Contextual Alignment	4	4	4.00	Highly Valid

The validity of the "*Nyawiji Program*" was assessed by two expert validators using a structured validation sheet covering five main aspects: program relevance, instructional design, innovation, pedagogical components, and alignment with coastal environmental characteristics. As presented in Table 1, the validation results show that all aspects achieved high scores, with mean values ranging from 3.50 to 4.00 on a four-point scale, indicating a high level of validity.

Minor variations between validators' ratings were observed, particularly in aspects of instructional design, innovation, and pedagogical components, where Validator 2 assigned slightly lower scores compared to Validator 1. However, these differences remain within the "highly valid" category, reflecting consistent expert agreement on the overall quality of the model.

These findings indicate that the developed model demonstrates strong conceptual consistency across its objectives, instructional design, and pedagogical components. The integration of eco-literacy, Sustainable Development Goals (SDGs) 12 and 14, and disaster mitigation elements is considered appropriate and well aligned with the characteristics of primary education in coastal contexts.

2. Practicality of the Program

The practicality of the program was assessed through questionnaires administered to teachers, school principals, and students following a limited implementation involving 19 fifth-grade students. The results of the practicality assessment are presented in Table 2.

Table 2. Practicality of the Program

Respondent	Percentage (%)	Category
Teacher	97.33	Very Practical
School Principal	96.00	Very Practical
Student	91.22	Very Practical
Average	94.85	Very Practical

An average practicality level of 94.85% indicates that the program is easily understood and implemented within the existing curriculum structure. The very high responses from teachers and school principals suggest that the program does not impose additional administrative burdens or require complex resources. From the students' perspective, the high responses indicate that experiential learning in the coastal environment enhances engagement, active participation, and learning motivation. Contextual activities such as field observations, disaster mitigation simulations, and processing coastal waste materials such as shells, leaves, and twigs into reusable items provide meaningful learning experiences that are directly relevant to students' daily lives.

3. Effectiveness of the Program

The effectiveness of the program was analyzed by comparing pre-test and post-test scores to assess the improvement in student learning outcomes following implementation. This analysis aims to quantitatively measure the impact of the learning intervention by comparing students' initial competencies before the treatment with their achievements after participating in a series of coastal-based learning activities. The differences in scores represent the program's contribution to enhancing students' conceptual understanding in an objective and measurable manner, as shown in Table 3:

Table 3. Effectiveness of the Program

Indicator	Pre-test	Post-test
Average Score	47.89	84.74
Mastery Learning (%)	26.31	94.73
Number of Students Mastered	5	18
Total Number of Students	19	19

From the table, it can be observed that the average score increased by 36.85 points, while mastery learning improved by 68.42%. This improvement indicates that the program had a significant impact on students' conceptual understanding of coastal ecosystems, environmental sustainability, and disaster mitigation. The increase in the number of students achieving mastery from 5 to 18 demonstrates that the learning intervention effectively reached almost all participants, not only those with high academic abilities.

Further analysis using the N-Gain score yielded a value of 0.76, which is categorized as high. This indicates that the learning model contributes substantially to students' learning improvement, suggesting that the observed gains are not merely incremental but reflect meaningful conceptual understanding.

This study confirms that the integration of eco-literacy, reinforcement of Sustainable Development Goals (SDGs) 12 and 14, and disaster mitigation education within the Nyawiji

School Program produces a systemic, contextual, and effective sustainability learning model for primary schools in coastal areas. The developed model not only significantly enhances students' cognitive achievements but also fosters ecological awareness and disaster preparedness through authentic, environment-based learning experiences. By utilizing coastal areas as learning laboratories, global sustainability concepts are translated into locally relevant practices that are meaningful for students' daily lives. The quality of the developed model is reflected in three key indicators, namely validity, practicality, and effectiveness, as summarized in Table 3.

Table. 3 Research Findings

Aspect	Indicator	Result	Category
Validity	Expert validation (2 validators)	Mean: 3.50 – 4.00	Highly Valid
Practicality	Teacher & student response	High usability	Practical
Effectiveness	N-Gain	0.76	High

DISCUSSION

The "Nyawiji Program", as a coastal-based learning model, integrates eco-literacy, global sustainability values, and disaster mitigation within a single multidimensional framework. This study demonstrates that the "Nyawiji Program" is not only statistically effective but also represents a conceptual shift in sustainability education at the primary school level in coastal regions. By integrating eco-literacy, Sustainable Development Goals (SDGs) 12 and 14, and disaster mitigation into a unified pedagogical design, the program establishes a systemic rather than additive learning model. Sustainability is positioned not as supplementary content but as a structural framework that connects knowledge, values, and practices within an authentic ecological context. The high N-Gain score (0.76) indicates a substantial improvement in students' conceptual understanding, suggesting that contextual coastal-based learning environments are effective in facilitating meaningful cognitive engagement. This finding aligns with prior studies that emphasize the importance of contextual learning in enhancing conceptual understanding, yet extends them by demonstrating a higher magnitude of improvement within an integrated eco-literacy framework.

Theoretically, these findings extend the perspectives of constructivism and experiential learning in the context of primary education. Current literature emphasizes that eco-literacy is most effective when learners interact directly with authentic environments and engage in structured reflective processes (Murti et al., 2025; Prasetyo et al., 2024). In this study, the coastal environment functions as an ecological epistemic space, enabling students to build causal relationships between human activities, ecosystem degradation, and disaster risks. Compared to previous findings, which often report improvements limited to cognitive or affective domains, this study demonstrates that integrating experiential activities such as waste reuse practices and disaster simulations can simultaneously influence cognitive understanding, environmental attitudes, and observable behaviors. This indicates that the integration of reflection and action components strengthens the transformative potential of eco-literacy learning beyond knowledge acquisition.

Compared to previous studies that often treated environmental education and disaster education separately, this research shows that integrating both within a single learning framework generates synergistic effects. Earlier studies typically emphasized environmental awareness or technical preparedness independently, without designing a structured model that combines eco-literacy, global SDG agendas, and disaster mitigation in a locally grounded development framework (Giyono & Suyitno, 2024; Muyed et al., 2025). In contrast, the findings of this study suggest that such integration enhances learning coherence and relevance, allowing students to perceive sustainability issues as interconnected rather than fragmented. This result supports and extends prior research Di Vaio, 2024; Scott, 2022 by demonstrating that global sustainability concepts can be more effectively internalized when embedded in localized and experiential learning contexts.

These findings also reinforce the argument that primary education for sustainability must be rooted in learners' localities and geographic contexts. Coastal areas, as ecologically and disaster-vulnerable zones, provide authentic and relevant learning spaces (Barrable & Barrable, 2024). When students study marine pollution while observing the conditions of their local beaches, empirical experience is integrated with normative awareness (Mustami'ah et al., 2023). This finding is consistent with place-based education theory, which posits that direct engagement with local environments strengthens emotional connection and promotes long-term pro-environmental behavior. However, this study further contributes by structuring such experiences into a systematic instructional model, thereby moving beyond incidental contextual learning toward a replicable pedagogical design.

Methodologically, the Research and Development approach using the 4D model strengthens the internal validity of this study. The needs analysis phase ensures that program design is grounded in actual challenges faced by coastal schools, while the design and development phases facilitate systematic integration of eco-literacy, SDGs, and disaster mitigation (Lestari et al., 2023). The high validity results indicate strong alignment between the model's components and pedagogical principles. However, it is important to note that the limited sample size and absence of a control group may introduce potential bias in estimating the model's effectiveness. Therefore, while the results indicate positive learning gains, caution is required in generalizing the findings beyond the study context.

Scientifically, this study contributes to the development of multidimensional, context-based sustainability learning models. By integrating three dimensions ecological knowledge, understanding of global agendas, and disaster preparedness the scope of eco-literacy expands from awareness to transformative practice (Badawi, 2025; Martinenco et al., 2025). Compared to previous studies that focused on isolated outcomes, this research demonstrates that a structured and validated model can produce more comprehensive learning impacts. This finding reinforces the argument that sustainability education is more effective when designed as an integrated system rather than a collection of discrete learning activities.

Practically, this study indicates that primary schools in coastal regions can implement sustainability education without major curriculum restructuring, leveraging the surrounding environment as a learning resource. The model's practicality suggests that it is adaptable within

existing educational structures. However, implementation may vary depending on teacher readiness, school resources, and local environmental conditions, which should be considered in future applications. From a policy perspective, the findings support the importance of locality-based education as a preventive strategy against ecological crises and disaster risks, while reinforcing SDG internalization at the primary education level (Bangay, 2022; Martinez Gutierrez et al., 2024).

Nonetheless, this study has limitations, including a sample restricted to a single school and a relatively short implementation period. Measurement of changes in ecological behavior remains short-term and has not yet been conducted longitudinally. Additionally, potential observer bias in behavioral assessment and self-report bias in attitude measurement may influence the results. Therefore, further research is recommended to test this model through quasi-experimental designs across multiple coastal regions and to conduct long-term studies to assess the sustainability of students' ecological dispositions.

In conclusion, this study confirms that the systemic integration of eco-literacy, SDGs, and disaster mitigation in coastal-based learning produces a pedagogical model that is effective, relevant, and contributes to advancing sustainability education theory at the primary school level. The novelty of this research lies not in the individual concepts employed but in the empirically validated, locality-based integrative design. Therefore, the Nyawiji School Program can be positioned as a prototype of an integrated sustainability learning model for ecologically and disaster-vulnerable coastal areas.

CONCLUSION

These results indicate that the model is not only theoretically sound but also practically applicable and empirically effective in improving multidimensional learning outcomes. The integration of ecological knowledge, value internalization, and pro-environmental behavior demonstrates that sustainability education can be implemented as a coherent and transformative learning system. The quality of the developed model is reflected in three key indicators, namely validity, practicality, and effectiveness, as evidenced by expert validation scores ranging from 3.50 to 4.00 (highly valid), high usability responses from teachers and students (practical), and a high N-Gain score of 0.76 (effective), indicating that the model is theoretically sound, practically applicable, and empirically effective in improving multidimensional learning outcomes. The integration of ecological knowledge, value internalization, and pro-environmental behavior demonstrates that sustainability education can be implemented as a coherent and transformative learning system. The primary contribution of this study lies in formulating a locality-based, integrated sustainability learning model validated both conceptually and empirically through a Research and Development approach, positioning primary education as a strategic platform for developing comprehensive sustainability literacy and expanding environmental education discourse by placing geographic context as the central axis for integrating knowledge, values, and action. Practically, this study provides operational guidance for teachers to implement sustainability learning through structured instructional syntax consisting of contextual exploration, reflective discussion, and ecological action, supported by the use of local environmental resources

and simple assessment instruments aligned with cognitive, affective, and behavioral outcomes. Schools can adopt this model without major curriculum restructuring by integrating it into existing thematic learning, while policymakers are encouraged to incorporate locality-based sustainability and disaster education into primary curricula, teacher training programs, and school-based environmental initiatives. However, this study is limited to a single implementation context and short-term measurement of outcomes. Therefore, future research is recommended to conduct broader studies across multiple coastal regions, apply quasi-experimental and longitudinal designs, and explore policy-level integration to strengthen the model's scalability and long-term impact on students' ecological behavior and environmental resilience.

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