

Development of an Interactive E-Module Based on Coastal Potential to Improve Students Environmental Literacy

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Abstract

Students' environmental literacy, particularly regarding the preservation of coastal ecosystems, remains relatively low due to a lack of integration of environmental issues into learning and a scarcity of innovative, contextual learning resources. This situation calls for the development of teaching materials that are relevant to the students' surrounding environment. This study aims to analyze, develop, and test the validity, practicality, and effectiveness of an interactive e-module based on coastal potential as a tool for environmental literacy learning. This is a development study using the 4D model (Define, Design, Develop, Disseminate) involving teachers and students as research subjects. Data were collected through interviews, questionnaires, and tests, using instruments tailored to the aspects being measured. Qualitative data were analyzed using the Miles and Huberman technique, while quantitative data were analyzed using percentage and n-gain calculations. The results indicate that the developed e-module has a very high level of validity based on expert evaluation and is considered highly practical in its application. Furthermore, the e-module has proven effective in enhancing students' interest in learning and their environmental literacy, with significant improvements observed in these areas. These findings indicate that integrating digitized coastal potential into instructional materials can serve as an effective strategy for strengthening environmental literacy. The implications of this research underscore the importance of developing innovative, locally-contextualized learning resources to support sustainable education.

Keywords: E-Module; Coastal Potential; Interactive; Environmental Literacy; Sustainable Education

INTRODUCTION

Education in Indonesia continues to develop in line with the demands of a dynamic era, one manifestation of which is the implementation of the Merdeka (Freedom of Learning) Curriculum. This curriculum concept, established by the Ministry of Education, Culture, Research, and Technology, emphasizes student activity and freedom in exploring their potential, with teachers positioned as facilitators of the learning process. Within this framework, literacy occupies a central role as the capacity to acquire, understand, process, and utilize information. Literacy is not limited to reading and writing, but also encompasses critical thinking, analysis, interpretation, and the evaluation of information from various sources. Through strong literacy skills, students are able to access knowledge effectively, make sound decisions, and adapt to change. Accordingly, the Merdeka Curriculum provides space for literacy development so that students can apply their knowledge to real-life contexts with critical and creative thinking.

Among the various dimensions of literacy, environmental literacy has become increasingly important amid mounting global ecological challenges. Environmental literacy refers to the knowledge, awareness, attitudes, and skills that enable individuals to understand environmental issues and to act responsibly toward the preservation of ecosystems. This dimension of literacy is closely aligned with the Sustainable Development Goals (SDGs), particularly Goal 14 (Life Below Water) and Goal 15 (Life on Land), which emphasize the protection and sustainable use of marine and terrestrial ecosystems. Coastal ecosystems, situated at the interface between land and sea, are among the most productive yet most threatened ecosystems, making them a strategic context for cultivating students' environmental awareness.

Integrating environmental literacy into learning is therefore a strategic step in shaping students who are critical, innovative, and environmentally conscious.

Nevertheless, students' environmental literacy in Indonesia remains relatively low. National and international assessments indicate that Indonesian students' literacy competence is still below the average of participating countries, and environmental literacy in particular has not been systematically developed in schools. Preliminary observations at the school level reveal that a large proportion of students do not adequately understand issues related to coastal ecosystem conservation. This condition is caused by the limited integration of environmental issues into learning, the scarcity of engaging environmental literacy resources, and the inflexible implementation of literacy programs that still emphasize reading skills alone. In addition, teachers often lack sufficient knowledge and readiness to integrate environmental literacy into their instruction, and the local potential of the surrounding coastal environment has rarely been utilized as a learning resource. This situation indicates a gap between the expected integration of environmental literacy within the Merdeka Curriculum and its actual implementation in classroom practice.

The low level of environmental literacy has an impact on students' ability to explore, verify, manage, analyze, and utilize information for solving problems related to coastal ecosystem sustainability. Several factors contribute to this condition, including limited reading interest, restricted access to engaging digital literacy resources, and the inconsistent implementation of literacy activities. Furthermore, the learning process is frequently dominated by conventional approaches that do not actively engage students in critical and contextual problem solving. The lack of contextual learning resources connecting global environmental issues with local environments makes it difficult for students to relate their knowledge to real-life situations. As a result, students' ability to think critically and respond to environmental challenges remains underdeveloped.

Interactive e-modules represent an effective alternative for improving students' environmental literacy. E-modules are able to present material digitally, interactively, and flexibly with attractive visual support, thereby engaging students directly in solving environmental problems encountered in everyday life. An e-module that integrates coastal potential enables students to learn through real contexts related to environmental issues such as mangrove degradation, coastal abrasion, marine pollution, and the loss of coastal biodiversity. Through an approach that utilizes local coastal potential, students not only acquire theoretical knowledge but also gain contextual learning experiences that strengthen their literacy and environmental awareness. Interactive features such as quizzes, surveys, discussions, and problem-solving activities further increase student engagement and support the development of comprehensive literacy skills.

Previous studies have demonstrated that e-modules can enhance students' literacy skills and engagement through interactive and flexible learning environments, and that digital-based learning supports students in solving contextual problems. Other studies highlight that integrating local potential into learning creates meaningful and contextual learning experiences that connect students with real-world issues. However, most of these studies tend to examine digital learning media, environmental issues, and local potential as separate components rather than as an integrated instructional system. Limited research has addressed the integration of coastal-based environmental literacy within a single interactive digital learning platform. This indicates that the potential of e-modules as a comprehensive tool for improving students' environmental literacy has not been optimally explored.

Therefore, the novelty of this study lies in the development of an interactive e-module that combines environmental literacy content, the local potential of coastal ecosystems, and interactive digital learning activities within a single learning platform. Unlike previous studies that generally focused only on students' literacy improvement or the use of local potential separately, this study develops an e-module designed to improve students' environmental literacy and problem-solving skills through contextual coastal issues. The e-module introduces contextual environmental problem-solving activities related to coastal biodiversity conservation

and ecosystem sustainability, enabling students to connect global environmental issues with real local challenges. Thus, this e-module offers a more holistic, contextual, and sustainable learning innovation that supports the implementation of the Merdeka Curriculum. Based on this rationale, this study aims to develop, analyze, and evaluate an interactive e-module based on coastal potential using the 4D model to enhance students' environmental literacy.

RESEARCH METHODS

This study is a research and development study using the 4D model, which consists of four stages: Define, Design, Develop, and Disseminate. The approach employed is a mixed method that combines quantitative and qualitative methods. The mixed-methods design used is sequential exploratory, which begins with a qualitative phase to explore the phenomenon in depth through needs analysis, followed by a quantitative phase to test and generalize the initial findings. This study aims to develop an interactive e-module based on coastal potential to enhance students' environmental literacy. The developed media is an interactive e-module integrating coastal local potential, designed to be accessed digitally through a web-based platform.

The research subjects were teachers and tenth-grade students selected through purposive sampling. The characteristics of the subjects were teachers who actively taught tenth-grade classes and had an interest in environmental literacy learning, as well as tenth-grade students with heterogeneous academic abilities. The data collection techniques used included interviews, questionnaires, and tests. The data collection instruments consisted of 1) interview guidelines, 2) expert validation questionnaires (material, media, and language), 3) student response questionnaires, 4) teacher response questionnaires, 5) student interest instruments, and 6) environmental literacy instruments.

Product validation involved three groups of validators, namely IT/media expert validation, module content validation, and language validation. All research instruments were validated by experts to ensure their content validity, clarity, and alignment with the research objectives. The aspects assessed in IT/media validation were the quality of the product's appearance and system, the technical quality of the product, and the usefulness of the product. Aspects assessed in module content validation included the relevance of the module to the curriculum, learning effectiveness, material quality, suitability with environmental literacy indicators, educational value, module components, worksheet components, module usefulness, and worksheet content.

The data were analyzed using questionnaires administered to validators, teachers, and students, which were interpreted using a Likert scale. Data analysis techniques included percentage analysis for product validation and practicality, as well as N-gain analysis to measure improvements in students' environmental literacy. The results were interpreted into three main categories: validity, practicality, and effectiveness, with the interpretation of each aspect referring to established criteria from previous studies. The effectiveness of the e-module was evaluated based on students' learning interest and outcomes, and improvements in environmental literacy were analyzed using N-gain with interpretation based on established criteria.

RESULTS AND DISCUSSION

Results

The results of this study are presented based on four main aspects: product characteristics, validity, practicality, and effectiveness. Product development began with analyzing the needs of students and teachers regarding media to improve environmental literacy through interviews, observations, and needs surveys. A needs and task analysis was then conducted to formulate learning tasks for students in order to strengthen their understanding of coastal environmental

literacy. Furthermore, a concept analysis was carried out to determine the core concepts to be integrated into the e-module based on the local potential of coastal ecosystems, which were compiled by identifying the main points of the material. The developed e-module integrates interactive digital elements to create an engaging and structured learning environment.

To ensure the quality and feasibility of the developed product, a validation process was conducted involving media experts, material experts, and language experts. The results of the media expert validation are presented in Table 1.

Table 1. Media Expert Validation Results

No	Aspect	Expert Evaluation
1	Quality of appearance (aesthetics) and system developed	3.80
2	Technical quality of product use	4.15
3	Product benefits	4.50
Total Percentage		83.00% (valid)

Based on Table 1, the e-module is categorized as valid, indicating that it is feasible for use with minor revisions. The highest score was obtained in the product benefits aspect, suggesting that the e-module provides meaningful support for the learning process. The technical quality and system performance aspects also received positive evaluations, indicating that the product functions properly and is user-friendly. These results demonstrate that the integration of interactive digital elements within the e-module has been effectively implemented. Module content validation results are shown in Table 2.

Table 2. Module Content Validation Results

No	Aspect	Expert Evaluation
1	Curriculum linkage	4.00
2	Learning effectiveness	4.50
3	Material quality	4.00
4	Suitability to environmental literacy	4.33
5	Educational values	4.50
6	Module components	4.00
7	Worksheet components	4.17
8	Module usefulness	4.33
9	Worksheet content	4.33
Total Percentage		85.30% (very valid)

The module content validation indicates that the e-module is highly valid and appropriate for learning implementation. The evaluation results show that the material is relevant to the curriculum and aligned with environmental literacy indicators. In addition, the quality of the material and the structure of the module components are considered well-organized and systematic. The inclusion of worksheets and supporting components also enhances students' engagement in learning activities. Overall, these findings suggest that the e-module content is suitable for facilitating effective and meaningful learning experiences. Language validation results are shown in Table 3.

Table 3. Language Validation Results

No	Aspect	Expert Evaluation
1	Conformity with language rules	3.90
2	Clarity and communicativeness of language	4.50
3	Suitability of language to student level	4.20
Total Percentage		84.00% (valid)

The language validation results indicate that the e-module is valid and supports effective communication of the learning content. Based on the assessment results from the validators, the interactive e-module based on coastal potential was declared highly valid for use as a medium for improving students' environmental literacy. The practicality of the product was subsequently assessed based on the responses of teachers and students to the use of the e-module, reflecting the ease of use, clarity of instructions, and effectiveness of integrating coastal local potential as a useful learning resource. The results of the practicality assessment are presented in Table 4.

Table 4. Product Practicality

No	Aspect	Score (%)
Teacher Response		
1	Ease of use	85.00
2	Meaningfulness of learning	88.00
3	Relevance to the curriculum	89.00
4	Understanding of environmental literacy	87.50
Total Percentage		87.38% (Very Practical)
Student Response		
1	Ease of use	70.00
2	Display quality	72.00
3	Material quality	77.00
4	Focusing attention	78.50
5	Engagement	79.00
6	Developing environmental literacy	78.50
Total Percentage		75.83% (Practical)
AVERAGE		81.61% (Very Practical)

The practicality of the product was assessed based on the responses of teachers and students to the use of the interactive e-module. These responses reflect the ease of use, clarity of instructions, and relevance of the content to learning needs. Teachers reported that the e-module was easy to implement and supported the delivery of environmental literacy materials effectively. Meanwhile, students indicated that the module was engaging and helped them better understand the learning content. The integration of coastal local potential also contributed to making the learning experience more meaningful and contextual. Overall, these findings indicate that the e-module is practical and suitable for classroom use.

The effectiveness of the e-module was evaluated based on the improvement in students' learning interest and environmental literacy before and after using the e-module. To measure the effectiveness of using the e-module in improving student literacy, an analysis of student interest

was conducted before and after its use. The improvement of students' interest in learning is shown in Figure 3.

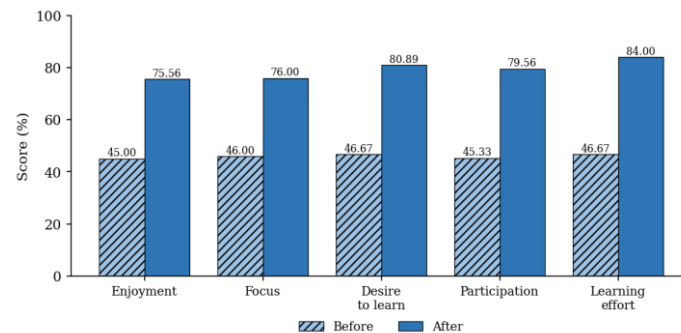


Figure 3. Improvement of Students' Interest in Learning

The results indicate that the use of the e-module successfully enhances students' engagement and motivation in learning. Figure 3 shows the difference in students' learning interest before and after learning using the e-module based on coastal potential. Before using the e-module, the aspects of enjoyment, focus, desire to learn, participation, and learning effort were in the fairly good category. After learning using the e-module, all aspects of learning interest increased to the good and very good categories. This finding demonstrates that the contextual and interactive nature of the e-module effectively stimulates students' interest in exploring environmental issues related to coastal ecosystems. The improvement of students' environmental literacy based on the pretest and posttest analysis is presented in Figure 4.

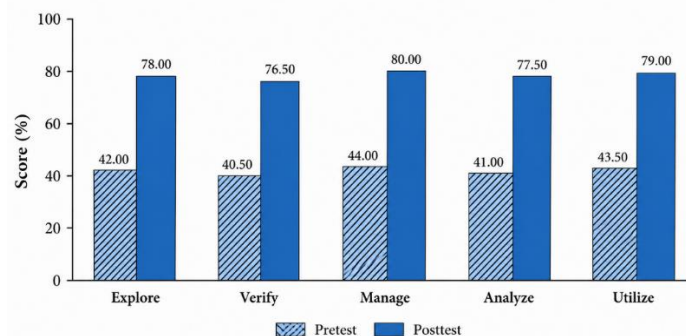


Figure 4. Improvement of Students' Environmental Literacy (Pretest Posttest)

Figure 4 illustrates the improvement in students' environmental literacy across five indicators, namely exploring, verifying, managing, analyzing, and utilizing information related to coastal ecosystem sustainability. The results of the pretest and posttest analysis show an increase in learning outcomes after using the e-module in all indicators. Based on the N-gain analysis, the average students' environmental literacy score increased with an N-gain value of 0.62, which is in the moderate to high category. These results indicate that the use of the interactive e-module is effective in improving students' environmental literacy. The improvement observed suggests that the e-module is particularly effective in strengthening students' understanding of coastal ecosystem conservation and in developing meaningful environmental literacy skills.

DISCUSSION

The interactive environmental literacy e-module is developed by integrating the local potential of coastal ecosystems as a contextual learning resource. The diversity of coastal flora, fauna, and ecosystems—such as mangrove forests, seagrass beds, and estuarine habitats—provides authentic learning materials that support students' understanding of the importance of

preserving coastal ecosystems. The utilization of local potential through the e-module functions not only as a learning medium but also as a means of developing literacy skills and environmental awareness. Through this approach, students are able to connect theoretical knowledge with real environmental conditions, making learning more meaningful and relevant. The integration of environmental, social, and economic aspects within the module also strengthens students' holistic understanding of sustainability.

The e-module is implemented through an interactive digital platform that facilitates student learning in a structured and flexible manner. The platform provides interactive features such as discussions, reflections, quizzes, and assignments, which support active engagement and independent learning. This finding is consistent with previous studies which state that digital learning platforms enhance student engagement and learning outcomes through interactive and flexible environments. In addition, the integration of local potential into environmental literacy learning enables students to analyze real environmental problems and develop problem-solving skills. Thus, coastal local potential serves as an authentic and contextual learning resource that fosters environmental responsibility.

In terms of validity, the results indicate that the developed e-module meets the criteria for feasible implementation. Expert validation confirms that the content, media design, and language are appropriate and aligned with the learning objectives. This suggests that the integration of environmental literacy, coastal local potential, and interactive digital platforms has been systematically designed to support both teaching and learning processes. The alignment between curriculum content and contextual materials strengthens the relevance of the module in real classroom settings.

From the practicality aspect, the positive responses from teachers and students indicate that the e-module is easy to use and supports meaningful learning experiences. Teachers reported that the platform has a high level of usability due to its accessibility and user-friendly navigation. Although some students required more time to adapt to the digital learning environment, the intuitive design of the system and continuous guidance were able to minimize these challenges. These findings reinforce previous research that emphasizes the importance of usability and accessibility in digital learning environments.

In terms of effectiveness, the improvement in environmental literacy demonstrates that the e-module successfully enhances students' learning outcomes. The integration of coastal local potential makes abstract environmental concepts more concrete and easier to understand. Through contextual teaching and learning, students are able to connect learning materials with real-life environmental issues related to coastal ecosystems. The use of contextual problems encourages students to analyze, evaluate, and propose solutions to environmental challenges such as coastal abrasion, mangrove degradation, and marine pollution. This finding supports previous studies which show that contextual and problem-based learning can improve environmental literacy and critical thinking skills.

The structured activities within the module, including exploration, discussion, and reflection, help students develop comprehensive literacy skills. The implementation of problem-based learning within the e-module further strengthens students' critical thinking, collaboration, and problem-solving abilities. Students were able to propose relevant solutions to environmental problems, demonstrating meaningful learning outcomes. The integration of real-world issues into learning activities also increases students' motivation and engagement. Furthermore, students showed increased interest in learning due to the relevance of the material to their daily lives, as contextual learning that integrates local potential has been proven to enhance motivation and participation.

The interactive features within the e-module, such as visuals and activities, create a dynamic learning environment that reduces boredom and promotes active participation. As a result, students become more engaged in exploring information and participating in discussions. The

findings also indicate that the e-module successfully stimulates students' intrinsic motivation to learn, as students actively seek additional information from various sources and demonstrate curiosity toward environmental issues. This aligns with the characteristics of modern learners who rely on digital resources for knowledge acquisition, and highlights the crucial role of technology in supporting independent and lifelong learning.

These findings imply several important contributions to educational practice and theory. The integration of environmental literacy, coastal local potential, and digital technology provides an innovative approach to contextual learning in the digital era. For students, the e-module supports the development of literacy skills, environmental awareness, and critical thinking. This study also contributes to the development of instructional models that combine sustainability education with technology-based learning. However, this study has several limitations. The scope of local potential explored is limited to coastal ecosystems, which may not fully represent broader environmental contexts. Technical constraints such as internet access also become challenges in implementation. Therefore, future research is recommended to involve more diverse contexts, expand the scope of local potential, and examine the long-term impact of e-module implementation on environmental literacy across different educational levels and technological environments.

CONCLUSION

Based on the findings, the development of an interactive e-module integrating coastal local potential demonstrates strong feasibility, practicality, and effectiveness in enhancing students' environmental literacy. The integration of contextual environmental resources with an interactive digital learning platform enables students to engage in meaningful and relevant learning experiences. For students, the e-module fosters learning interest, critical thinking, and a deeper understanding of environmental sustainability, particularly related to the preservation of coastal ecosystems. Overall, this study highlights that the integration of local potential and digital technology constitutes an effective strategy for strengthening environmental literacy in educational settings. This approach not only bridges the gap between theoretical knowledge and real-world contexts but also supports the development of environmentally responsible and critically literate learners.

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