IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Enhancing Student Ecoliteracy through an ESD-Inquiry Website on Mangrove Biodiversity

Fahmie Firmansyah[1], Edi Rosadi[2]
[1,2]Mangku Wiyata University, Banten, Indonesia

Check for updates OPEN ACCESS

DOI : https://doi.org/10.46245/ijorer.v7i1.938

Sections Info

Article history:
Submitted: Juny 15, 2025
Final Revised: July 30, 2025
Accepted: August 05, 2025
Published: January 30, 2026

Keywords:
Ecoliteracy; ESD; Inquiry; Mangrove; Website

ABSTRACT

Objective: This study aims to develop an inquiry-based Education for Sustainable Development (ESD) oriented website that focuses on mangrove in the Pulau Dua Nature Reserve to enhance high school students' ecoliteracy. The research addresses the limited availability of digital learning media that successfully integrate local environmental content with inquiry-driven learning approaches. **Method:** The study applied the ADDIE model, which includes analysis, design, development, implementation, and evaluation phases. Validation was conducted by media and material experts, followed by classroom implementation with selected high school students in Serang Regency. Data collection combined quantitative and qualitative methods. Quantitative data were obtained from pretest and posttest assessments on ecoliteracy indicators, while qualitative data were gathered through expert reviews and teacher interviews. **Results:** The results indicated a significant improvement in students' ecoliteracy, covering cognitive, affective, and behavioral dimensions. All six measured aspects showed positive development, including ecological knowledge, environmental awareness, attitudes and values, ecological skills, critical and reflective thinking, and environmental action. The effectiveness was confirmed through statistical analysis using paired sample t-tests. **Novelty:** The novelty of this research lies in the integration of local environmental issues into a digital learning platform that promotes critical thinking and sustainability-oriented behavior. The website provides a contextual and interactive learning experience that connects ecological content with global sustainability perspectives. These findings demonstrate the potential of localized and inquiry-based digital tools to strengthen students' understanding and commitment to sustainable development.

INTRODUCTION

The global ecological crisis characterized by climate change, environmental degradation, pollution, and loss of biodiversity has become a major challenge to the sustainability of life on earth (Ahmad et al., 2022). This situation impacts the physical environment and affects the social, economic, and health structures of people around the world (Upadhyay & Mishra, 2023). In facing the complexity and urgency of this crisis, environmental education is essential as an effort to build public awareness, knowledge, and skills to understand and respond to ecological problems critically and responsibly.

Environmental education plays a strategic role in shaping sustainability-oriented mindsets and behaviors (Gani et al., 2023). Through education, individuals and communities can develop holistic insights into the relationship between humans and nature, foster concern, and encourage real action to protect the environment (Santos & Coutinho, 2022). In addition, environmental education is also a foundation in building an ecological culture and social justice so that people are able to adapt and contribute to efforts to overcome the global ecological crisis collectively and sustainably (Busygina et al., 2022).

Pulau Dua Nature Reserve has great potential as a source of contextual learning due to its rich biodiversity and unique ecosystem (Elfidasari, 2006; Siska et al., 2016). This area

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

is a habitat for various types of mangroves, water birds, and bivalves, thus providing opportunities for students to learn the concepts of ecosystems, biodiversity, and the relationship between living things and their environment directly in the field (Pertiwi, 2021). Through learning experiences in nature, students can observe and analyze ecological phenomena in real terms so that their understanding of the subject matter becomes deeper and more relevant to everyday life (Wahyuni et al., 2022).

In addition, contextual learning in Pulau Dua Nature Reserve can improve students' mastery of concepts through methods such as field trips and habitat mapping (Kamudu et al., 2024). These activities strengthen theoretical understanding and train observation skills, data analysis, and critical thinking (Noor et al., 2023). Thus, Pulau Dua Nature Reserve plays an important role in supporting active and meaningful learning, as well as fostering environmental awareness in the younger generation.

The lack of digital learning media that integrates Education for Sustainable Development (ESD) and the inquiry approach is a challenge in efforts to improve the quality of 21st-century education (Veckalne & Tambovceva, 2022). Although the need for learning that is relevant to sustainability issues is increasingly urgent, most of the available digital media are still unable to combine ESD content with inquiry methods that encourage students to think critically, actively, and reflectively (Ssossé et al., 2021). This causes ESD learning to often be theoretical and less contextual and meaningful learning experiences for students.

The limitations of integrated digital media also have an impact on the lack of mastery of 21st-century skills, such as problem-solving, collaboration, and digital literacy, which are very important in facing global challenges (Maya & Suseno, 2022). In fact, the integration of ESD and the inquiry approach through digital media can create an interactive, adaptive learning environment and encourage active student involvement in understanding and finding solutions to sustainability problems (Seibert et al., 2020). Therefore, the development of digital learning media that integrates these two aspects is very necessary to support the transformation of education towards sustainable development.

Ecoliteracy is one of the key competencies of the 21st century that is very important in facing global challenges such as climate change, environmental degradation, and the need for sustainable development (Kusumawardani et al., 2023). The ability to understand, appreciate, and interact wisely with natural systems is the foundation for creating a society that is able to maintain a balance between human needs and environmental sustainability (Chiu et al., 2022). Ecoliteracy not only includes knowledge about ecosystems but also involves attitudes, values, and skills to make decisions that support the sustainability of life (Sharma, 2023).

In the modern era, ecoliteracy plays an important role in equipping individuals with critical thinking, problem-solving, and collaboration skills that are relevant to environmental issues (Syofyan & Rachmadtullah, 2019). Learning that emphasizes ecoliteracy, both through formal and non-formal education, can increase awareness, active participation, and innovation in protecting the environment. Thus, ecoliteracy is the main foundation in building a generation that is able to adapt and contribute positively to the sustainability of the earth in the 21st century (Andreou, 2020).

The mangrove diversity-based learning website with the Education for Sustainable Development (ESD) on Inquiry approach has enormous potential in integrating local issues with global learning. By utilizing mangrove diversity as a learning resource,

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

students can understand environmental problems around them while linking them to global sustainability issues. This approach encourages students to think critically, explore, and find solutions to environmental problems through a contextual and relevant inquiry process (Utami & Widiyaningrum, 2020).

In addition, the use of this digital learning website can improve students' ecoliteracy as a whole, covering the cognitive, affective, and psychomotor domains (Trascheev & Kochetova, 2022). Students gain knowledge about mangrove diversity and build an attitude of environmental concern and practical skills in ecosystem conservation. This website can also be a model for effective digital-based environmental learning innovation through an ESD-Inquiry, which is easily accessible and receives positive responses from students and educators, making it worthy of being widely adopted in environmental education (Nurfitria et al., 2022).

Based on the explanation above, the research problem statement is [1] how can a website based on the Pulau Dua Nature Reserve be developed that integrates the Education for Sustainable Development (ESD)-based inquiry approach? [2] what is the feasibility of this website-based digital learning media based on validation results from subject matter and media experts? [3] how effective is the use of this website-based digital learning media in improving high school students' ecoliteracy?

The objectives of this research are [1] to develop a website learning medium that integrates the Education for Sustainable Development (ESD) approach on inquiry with local content on mangrove diversity in the Pulau Dua Nature Reserve. [2] to determine the website's feasibility based on validation results by subject matter experts and media experts. [3] to analyze the effectiveness of the website integrating the Education for Sustainable Development (ESD) approach on inquiry with local content on mangrove diversity in the Pulau Dua Nature Reserve on high school students' ecoliteracy.

RESEARCH METHOD

This study employs a research and development (RnD) methodology, aimed at producing a specific product and evaluating its efficacy (Branch, 2010). This research and development methodology is pertinent to fostering innovation in education, technology, and several other domains. This study employs the ADDIE paradigm (Analyze, Design, Develop, Implement, and Evaluate), a systematic and structured development framework (see figure 1). The initial phase, analysis, discerns issues and requirements fundamental to product development. This phase involves an analysis of current conditions to establish the objectives and criteria that the product must fulfill.

The second step, design, is creating a product informed by prior analytical findings, which includes developing scenarios, requirements, and product frameworks. The third stage, development, is the period in which the conceptual design is actualized as a tangible product. Subsequently, during the deployment phase, the product undergoes testing in a natural context to assess its efficacy and efficiency. The assessment step is conducted to assess product performance and apply adjustments as needed, both throughout the development process and in field use.

The sample population for this study was selected using purposive sampling procedures from all State Senior High Schools in Serang Regency, specifically from State Senior High School 1 Mancak. The selection of classes was conducted using the Cluster Random Sampling approach, resulting in the inclusion of class X pupils. Subsequently, class XI students were picked by Purposive Sampling, resulting in the acquisition of class

IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

XI pupils. The research population comprised all class X IPA, which included five classes. The chosen samples were Class X IPA, consisting of 34 students, and Class X IPA.

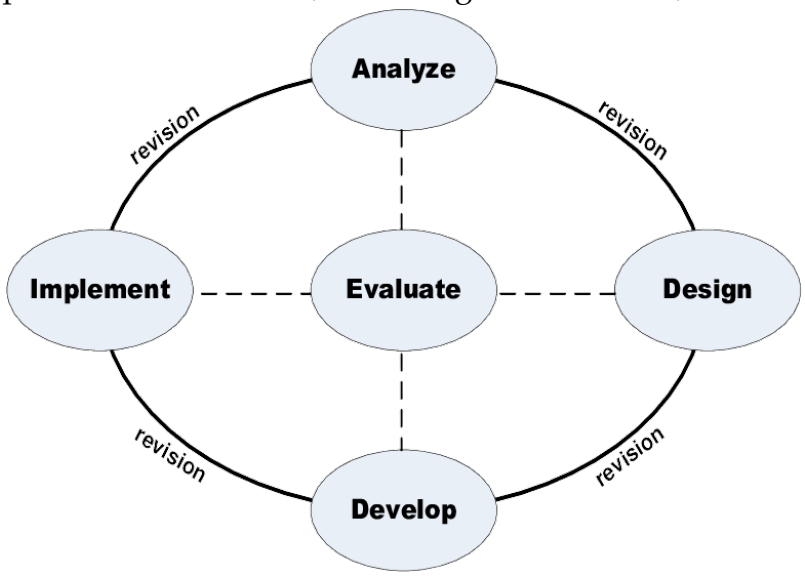

Figure 1. ADDIE model chart (Analyze, Design, Develop, Implement, and evaluate) (Branch, 2010)

The study tool utilized was approved by media and material specialists. The role of media expert validation is to evaluate the viability factors of the product under development. This encompasses an assessment of the media's design, aesthetics, and functionality. The instrument framework used in the media expert evaluation is in Table 1.

Table 1. Media expert evaluation instrument

Indicators	Description
Content Accuracy	The degree to which the instructional content is correct, factual, and up to date.
Instructional Design	The appropriateness of content sequencing, learning flow, and alignment with objectives.
User Interface & Usability	The clarity, intuitiveness, and ease of navigation within the media interface.
Multimedia Integration	The effective use and relevance of multimedia elements such as images, audio, and video.
Interactivity	The level of user engagement facilitated by interactive features like quizzes or buttons.
Responsiveness & Compatibility	The ability of the media to function well across various devices, screen sizes, and platforms.
Assessment & Feedback	The availability of assessment tools and constructive feedback mechanisms for learners.

The validation by material experts evaluates the teaching material product, a crucial procedure to guarantee that the generated teaching materials adhere to quality and relevance criteria for educational usage. The evaluation instrument framework used by the subject matter experts is in Table 2.

IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Table 2. Material expert evaluation instrument

Indicators	Description
Alignment with Learning Objectives	The extent to which the material supports and reflects the intended learning goals.
Comprehensiveness of Content	The depth and breadth of information provided across the learning material.
Precision of Information	The factual accuracy and clarity of the scientific content presented.
Pertinence to Local Biodiversity	The relevance of the material to the specific characteristics of local ecosystems.
Thoroughness of Discourse	The degree to which topics are explained in detail and with sufficient elaboration.
Connection to Real-World Applications	How well the content relates to practical, everyday, or societal environmental issues.
Contextualization of Concepts	The ability to link abstract scientific ideas to concrete, meaningful contexts.
Use of Scientific Terminology	The proper and consistent use of appropriate scientific vocabulary throughout the material.
Encouragement for Conservation Efforts	The extent to which the material promotes environmental awareness and proactive actions.

To see the effectiveness of the website in learning, an assessment was carried out using an assessment of students' ecoliteracy knowledge before and after using the website by assessing students' ecoliteracy aspects reviewed from six aspects (table 3), namely 1) ecological knowledge; 2) environmental awareness; 3) attitudes & values; 4) ecological skills; 5) critical & reflective thinking; and 6) environmental action. The questionnaire used a Likert scale with four scales, namely Strongly Agree (S), Agree (S), Disagree (D), and Strongly Disagree (SD).

Table 3. Ecoliteracy knowledge instrument indicators

Indicators	Description
Ecological Knowledge	Understands basic ecological concepts
	Aware of human impact on the environment
Environmental Awareness	Sensitive to environmental issues
	Identifies environmental problems
Attitudes & Values	Displays a caring attitude toward nature
	Values sustainability and ecological responsibility
Ecological Skills	Practices eco-friendly behavior
	Participates in conservation activities
Critical & Reflective Thinking	Analyzes environmental issues critically
	Reflects on personal and collective environmental impact
Environmental Action	Initiates or joins environmental campaigns
	Becomes a change agent for the environment

This website is developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework. Initially, the analysis involves identifying teaching materials, assessing the requirements for these materials, and evaluating the learning objectives related to mangrove diversity. This includes the availability of observation and interview documentation, as well as the presence of teaching material designs alongside the objectives and data concerning mangrove diversity in the Pulau Dua Nature Reserve. Secondly, design involves the creation of teaching materials, websites, and evaluation frameworks, including assessments with achievement indicators that encompass the presence of website designs featuring educational content

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

and graphic elements, as well as the availability of evaluation rubrics and assessment questionnaires.

Third, the development, namely media development and media trials, includes accomplishment indicators for the availability of online teaching materials based on mangrove diversity data in the Pulau Dua Nature Reserve and the outcomes of media trials. The fourth aspect pertains to implementation, specifically the execution of the website via restricted product trials and field trials, accompanied by performance indicators that demonstrate the availability of evidence for both the implementation and evaluation of these limited product trials, as well as the evidence for the assessment of field trials. The fifth aspect is evaluation, namely the assessment of the website through summative and formative evaluations, as well as effectiveness tests, utilizing accomplishment indicators related to the availability of summative and formative assessment findings and the processing of website effectiveness test data.

This study employs qualitative and quantitative data analysis methodologies. Qualitative data were acquired through teacher interviews and recommendations from validators. Quantitative data were collected through the distribution of needs analysis questionnaires and media feasibility evaluations to validators, educators, and students. Qualitative data were examined descriptively by providing a comprehensive account of the collected information. The analysis started with data gathering, followed by descriptive interpretation. This study employed a Likert scale ranging from 1 to 5 for quantitative data. In the Likert score evaluation, a score of 81-100 is classified as highly possible; a score of 61-80 is deemed practicable; and a score of 41-60 is labeled as sufficiently viable. If the evaluation score ranges from 21 to 40, it is classified as not feasible; if the score is between 0 and 20, it is designated as extremely not possible. Table 4 presents the Likert scale. The efficacy of the website on students' ecoliteracy abilities was evaluated using a hypothesis test, namely the t-test.

Table 4. Likert scale

Nu	Score	Category
1	81-100	Very feasible
2	61-80	Feasible
3	41-60	Sufficient feasible
4	21-40	Not feasible
5	0-20	Very not feasible

RESULTS AND DISCUSSION

Results

Media expert validation

The website underwent professional assessment. The website validator was evaluated by several specialists, specifically media and content professionals. The validation outcomes from media experts are displayed in Table 3, while those from material experts are shown in Table 4. Table 5 presents the validity test for media expertise, utilizing eight indications. The mean score was 85.39, within a highly attainable level. All indications were classified as very feasible.

IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Table 5. Validity results by media expert

Indicators	Score	Category
Content accuracy	87.50	Very feasible
Instructional design	85.00	Very feasible
User interface & usability	85.25	Very feasible
Multimedia integration	89.00	Very feasible
Interactivity	80.00	Very feasible
Responsiveness & compatibility	82.00	Very feasible
Assessment & feedback	89.00	Very feasible
Average	**85.39**	**Very feasible**

Media experts suggest that while the website's layout is visually appealing, emphasis must be given to the contrast between the background color and the text to enhance readability. The website's navigation layout is intuitive; nonetheless, incorporating a "return to the main menu" function on each page might enhance user ease. The quizzes and practice questions exhibit commendable engagement; yet, it is imperative to guarantee the absence of technological issues while accessing them across diverse gadgets. The website is compatible with students' digital devices. Nevertheless, it requires more testing to guarantee its look remains uniform across all browsers and operating systems. The website effectively facilitates digital learning; nonetheless, it requires small adjustments to its technical and aesthetic elements to enhance user experience. This aligns with Avra et al., (2022), who assert that effective electronic teaching materials must prioritize readability, navigation, and student engagement with the content.

Material expert validation

The validity assessment conducted by material specialists, as shown in Table 6, utilized nine indicators. The mean score was 85.33, within a highly attainable level. Eight of the nine indications were classified as very fesiable, while one indicator was categorized as feasible.

Table 6. Validity results by material expert.

Indicators	Score	Category
alignment of materials with learning objectives	81	Very feasible
comprehensiveness of content	83	Very feasible
precision of information	89	Very feasible
pertinence to local biodiversity	88	Very feasible
thoroughness of discourse	77	Feasible
connection to real-world applications	89	Very feasible
Contextual presentation of concepts	82	Very feasible
use of scientific terminology	97	Very feasible
encouragement for conservation efforts	82	Very feasible
Average	**85.33**	**Very feasible**

The validity test findings from media and material experts, as presented in table 3 and 4, indicate that the developed website is highly appropriate for use as instructional resources in the educational process. Material specialists indicate that the website's material corresponds with the fundamental competences of the high school biology curriculum. The correlation between sub-chapters and anticipated learning objectives need clarification. The focus on mangrove variety is commendable; nonetheless, several portions require an expanded discourse to offer a more comprehensive perspective. The

IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

use of mangrove variety within the Pulau Dua nature reserve is pertinent to enhancing students' ecoliteracy. The website would be more engaging if it included environmentally-focused activities, such as direct observation or minor projects that connect the content to students' everyday experiences. This result aligns with the assertion of Arsita & Astawan (2022) that the content in electronic teaching materials must correspond with the learning objectives and the abilities that students are expected to attain.

We assess the variations in students' ecoliteracy knowledge by delivering pretest questions before utilizing the internet and posttest questions thereafter. We assess the variations in students' ecoliteracy knowledge employing a paired t-test utilizing the SPSS software. The indicators for assessing students' ecoliteracy encompass five dimensions: 1) ecological knowledge, 2) environmental awareness, 3) attitudes & values, 4) ecological skills, 5) critical & reflective thinking, and 6) environmental action. The study's results indicated a substantial change in students' ecoliteracy understanding before and after utilizing the e-module. This conclusion is corroborated by the paired t-test findings obtained from SPSS 25, which yielded a significant value (2-tailed) of 0.001 (<0.05) for the pretest and posttest. The Pulau Dua nature reserve website augments students' comprehension of ecoliteracy.

Table 7. Average score of students' ecoliteracy

Indicators	Prestest	Posttest	Standard Deviation	
			Prestest	Posttest
Ecological Knowledge	73	82	4.16	3.74
Environmental Awareness	76	88	4.47	4.08
Attitudes and Values	74	89	4.08	4.47
Ecological Skills	77	85	4.69	4.00
Critical & Reflective Thinking	76	88	4.47	4.08
Environmental Action	79	88	3.87	4.08
Average	75.83	86.67	4.29	4.08

Discussion

The study's results demonstrated a substantial enhancement in all ecoliteracy metrics following the execution of the learning intervention. The ecological knowledge indicator shown an increase in score from 73 in the pretest to 82 in the posttest. This indicates that students have enhanced their comprehension of fundamental ecological concepts, encompassing ecosystems, energy flow, and biodiversity (Nursidin et al., 2022). This rise signifies that the content provided throughout the learning process effectively reinforces students' ecological knowledge basis (Lagutenko et al., 2022).

The environmental awareness indicator rose from 76 to 88, signifying a substantial increase in students' cognizance of environmental concerns, including pollution, ecological degradation, and climate change (Arshad et al., 2020). This rise indicates the effectiveness of the educational technique in cultivating students' awareness of their surrounding environmental circumstances (Niswatin et al., 2020). The contextual or problem-based learning method has likely succeeded in enhancing students' sensitivity to environmental phenomena (Amin et al., 2022).

Moreover, the attitudes & values indicator saw a surge from 74 to 89, representing the most significant rise among all indicators. This suggests that learning enhances students' cognitive abilities while simultaneously cultivating good attitudes and robust ecological values (Sueb et al., 2021). Students develop a greater appreciation for the

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

significance of environmental preservation and exhibit a responsible demeanor towards nature (Berame et al., 2022). Enhancements in this emotional dimension are significant markers of the efficacy of environmental education aimed at character development.

Enhancements are observed in the Ecological Skills indicator, rising from 77 to 85, and in critical & reflective thinking, increasing from 76 to 88. This growth indicates that students possess comprehension and awareness, as well as the ability to act and engage in critical thinking when examining environmental issues (Dewi & Erman, 2022). This demonstrates students' active engagement in the learning process, enabling them to apply information both practically and reflectively (Dogani, 2023).

The environmental action indicator rose from 79 to 88. This indicates that students are increasingly engaging in tangible acts such as recycling, conserving electricity, and participating in environmental initiatives (Öktem et al., 2023). These findings underscore the transformative potential of targeted environmental education in fostering not only knowledge but also proactive engagement in sustainability practices among students (Vandaele & Stålhammar, 2022).

Based on the analysis results, there was a significant increase in all ecoliteracy indicators after learning, with an average score increasing from 75.83 to 86.67. The increase includes aspects of ecological knowledge, environmental awareness, attitudes and values, ecological skills, critical thinking, and environmental action. This shows that the designed learning has succeeded in forming students' understanding and concern for environmental issues as a whole, not only in the cognitive domain but also in the affective and psychomotor domains (Huang et al., 2020).

This finding is in line with the principles of Education for Sustainable Development (ESD), which emphasizes the development of critical thinking competencies, values of desire, and responsibility in acting (Merma et al., 2022). The increase in aspects of attitude, skills, and action shows that students are beginning to form awareness and behavior that reflect a commitment to environmental desires (Firmanshah et al., 2023). Thus, strengthening ecoliteracy through contextual learning is an effective strategy in supporting the implementation of ESD in educational environments.

Based on mangrove biodiversity, the creation of a website-based digital learning medium that combines an inquiry-based approach with the concepts of Education for Sustainable Development (ESD) has a lot of promise for growth. This is because digital platforms make it easy for students in different areas to acquire and share information, especially when it comes to learning about ecology that is important both locally and worldwide (Stone & Lowney, 2022). You may also use this website as a guide for making other local environmental themes in other parts of Indonesia, such rainforests, sustainable farming, or saving water (Yulistyorini et al., 2022). So, this method may be used not only on Dua Island, but also across the country with information that is tailored to each location.

But this scaling potential depends a lot on how ready and able the teachers are. A lot of instructors in schools, especially in 3T locations (remote, isolated, and undeveloped), still don't know enough about digital literacy and ESD methods. So, it is very important to train teachers right away. Teachers need to know how to use technology, but they also need to know how to use inquiry-based methods, manage project-based learning in the environment, and teach students about sustainability in a way that makes sense (Cederqvist et al., 2022). Without adequate training, using this

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

media risks becoming merely a passive aid instead of a driver of change in teaching and learning methods.

Also, the primary problem comes up when there is a lot of variety in schools in Indonesia. Schools in cities with superior technology may be able to use this medium more rapidly (Gai Mali et al., 2023). On the other hand, schools that don't have good internet connectivity, ICT gadgets, or energy will have a lot of trouble using it to its full potential (Mariati et al., 2022).

Also, the different degrees of student preparation, such as their ability to think critically and read and write, might determine how well this inquiry-based media works. Taking all of this into account, a comprehensive approach is needed to make this innovation work on a large scale (Smerichevskyi et al., 2023). This includes building teachers' skills, adapting the content to local situations, providing the necessary infrastructure, and making sure that education policies focus on improving ecological literacy and sustainable education (Sá et al., 2023).

CONCLUSION

Fundamental Finding : The implementation of ecoliteracy-oriented learning demonstrated a meaningful improvement in students' understanding, awareness, and engagement with environmental issues. This enhancement extended beyond cognitive gains to include affective and behavioral dimensions. **Implication :** These findings underscore the relevance of integrating Education for Sustainable Development (ESD) principles into classroom practices. Contextual and value-based instructional approaches have proven effective in cultivating environmentally responsible attitudes and actions among students. **Limitation :** The study was limited in scope, focusing on a specific group of participants within a particular educational context. As such, the generalizability of the findings may be constrained. Moreover, long-term behavioral impacts were not examined. **Future Research :** Future research should look at how ecoliteracy learning affects students in the long term, how it may be used in different types of schools, and how students learn to value the environment. To make things more relevant and academically rigorous, teachers need to be more involved and essential concepts need to be defined more clearly.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the school community and students who participated in this study for their valuable time and engagement. Special thanks are extended to the teachers and school administrators for their support and cooperation throughout the research process. The authors also acknowledge the constructive feedback provided by peer reviewers and colleagues, which greatly contributed to the refinement of this work.

REFERENCES

Ahmad, F., Saeed, Q., Shah, S. M. U., Gondal, M. A., & Mumtaz, S. (2022). Environmental sustainability: Challenges and approaches. In *Natural Resources Conservation and Advances for Sustainability* (pp. 243–270). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00019-3

Amin, S., Sumarmi, S., Bachri, S., Susilo, S., Mkumbachi, R. L., & Ghozi, A. (2022). Improving Environmental Sensitivity through Problem-Based Hybrid Learning

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

(PBHL): An Experimental Study. *Jurnal Pendidikan IPA Indonesia*, *11*(3), 387–398. https://doi.org/10.15294/jpii.v11i3.38071

Andreou, N. (2020). *Towards a Generation of Sustainability Leaders: Eco-Schools as a Global Green Schools Movement for Transformative Education* (pp. 31–45). https://doi.org/10.1007/978-3-030-46820-0_3

Arshad, H., Saleem, K., Shafi, S., Ahmad, T., & Kanwal, S. (2020). Environmental Awareness, Concern, Attitude and Behavior of University Students: A Comparison Across Academic Disciplines. *Polish Journal of Environmental Studies*, *30*(1), 561–570. https://doi.org/10.15244/pjoes/122617

Arsita, G. A. M. L., & Astawan, I. G. (2022). Improving Student Learning Outcomes in Online Learning by Using Electronic Teaching Materials. *Journal for Lesson and Learning Studies*, *5*(2), 199–209. https://doi.org/10.23887/jlls.v5i2.48067

Avra, T. D., Le, M., Hernandez, S., Thure, K., & Ulloa, J. G. (2022). Readability assessment of online peripheral artery disease education materials. *Journal of Vascular Surgery*, *76*(6), 1728–1732. https://doi.org/10.1016/j.jvs.2022.07.022

Berame, J. S., Lumaba, N. W., Delima, S. B., Mercado, R. L., Bulay, M. L., Morano, A. B., Mar G. Parohing, & Christine, D. (2022). Attitude and behavior of senior high school students toward environmental conservation. *Biodiversitas Journal of Biological Diversity*, *23*(10). https://doi.org/10.13057/biodiv/d231036

Branch, R. M. (2010). Instructional design: The ADDIE approach. In *Instructional Design: The ADDIE Approach*. https://doi.org/10.1007/978-0-387-09506-6

Busygina, A. L., Bakulina, S. Y., Lizunova, E. V., Vershinina, L. V., & Bondareva, V. V. (2022). The concept of ecological culture in the professional training of pedagogical university students. *Samara Journal of Science*, *11*(4), 247–252. https://doi.org/10.55355/snv2022114303

Cederqvist, A.-Marie., von Otter, A.-Marie., Kavai, Portia., & Khoza, Samuel. (2022). Digital competence with respect to ESD for science and technology student teachers. In *Science and Technology Teacher Education in the Anthropocene* (pp. 170–190). Routledge. https://doi.org/10.4324/9781003190158-12

Chiu, W.-K., Fong, B. Y. F., & Ho, W. Y. (2022). The Importance of Environmental Sustainability for Healthy Ageing and The Incorporation of Systems Thinking in Education for A Sustainable Environment. *Asia Pacific Journal of Health Management*. https://doi.org/10.24083/apjhm.v17i1.1589

Dewi, S. O., & Erman, E. (2022). Analysis of students critical thinking ability based on gender in science learning environmental pollution topics. *Jurnal Pijar Mipa*, *17*(4), 480–485. https://doi.org/10.29303/jpm.v17i4.3612

Dogani, B. (2023). Active learning and effective teaching strategies. *International Journal of Advanced Natural Sciences and Engineering Researches*, *7*(4), 136–142. https://doi.org/10.59287/ijanser.578

Elfidasari, D. (2006). Prey diversity for Three Species Herons in Pulau Dua Nature Reserve Serang Distrik, Banten Province. *Biodiversitas Journal of Biological Diversity*, *7*(4). https://doi.org/10.13057/biodiv/d070412

Firmanshah, M. I., Abdullah, N., & Fariduddin, M. N. (2023). The Relationship of School Students' Environmental Knowledge, Attitude, Behavior, and Awareness toward the Environment: A Systematic Review. *International Journal of Academic Research in Progressive Education and Development*, *12*(1). https://doi.org/10.6007/IJARPED/v12-i1/15707

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Gai Mali, Y. Calvin., Kurniawan, Daniel., Januardi, J. Ilona., Swara, S. Jati., Lokollo, N. C. Emy., Picauly, I. Amy., Paramitha, N. G., Tanore, J. A., Dewani, M. S., & Pakiding, R. W. (2023). Issues And Challenges of Technology Use in Indonesian Schools: Implications for Teaching and Learning. *IJIET (International Journal of Indonesian Education and Teaching)*, *7*(2), 221–233. https://doi.org/10.24071/ijiet.v7i2.6310

Gani, S., Muthalib, K., Yusuf, T. R., & Gani, B. (2023). The Environment Education Policy in Behavior Commitment of Stakeholders for the Environmental Sustainability. *Polish Journal of Environmental Studies*, *32*(2), 1491–1505. https://doi.org/10.15244/pjoes/158147

Huang, Z., Peng, A., Yang, T., Deng, S., & He, Y. (2020). A Design-Based Learning Approach for Fostering Sustainability Competency in Engineering Education. *Sustainability*, *12*(7), 2958. https://doi.org/10.3390/su12072958

Kamudu, B., Rollnick, M., & Nyamupangedengu, E. (2024). Investigating what students learnt about biodiversity following a visit to a nature reserve using Personal Meaning Maps. *Journal of Biological Education*, *58*(3), 570–587. https://doi.org/10.1080/00219266.2022.2092190

Kusumawardani, E., Nurmalasari, Y., & Rofiq, A. (2023). Ecoliteracy Competence Assessment to Improve Innovation Capability in a Rural Community. *Journal of Education Research and Evaluation*, *7*(1), 61–69. https://doi.org/10.23887/jere.v7i1.54103

Lagutenko, O., Shevchenko, V., Nasteka, T., & Nikolenko, T. (2022). Scientific and Methodological Aspects of The Ecological Content Formation Problem for Senior School Students. *Academic Notes Series Pedagogical Science*, *1*(204), 173–178. https://doi.org/10.36550/2415-7988-2022-1-204-173-178

Mariati, Pance., Anlianna, Anlianna., Sakbana Kusuma, Rendra., Sunanto, Sunanto., Suryanti, Suryanti., & Wiryanto, Wiryanto. (2022). Problems of Using Innovative Learning Media in the Digitalization Era of the Merdeka Program in Basic Education. *Education and Human Development Journal*, *7*(03). https://doi.org/10.33086/ehdj.v7i03.3769

Maya, L., & Suseno, M. (2022). Investigating the Incorporation of Digital Literacy and 21st-Century Skills into Postgraduate Students' Learning Activities. *ELE Reviews: English Language Education Reviews*, *2*(1), 13–27. https://doi.org/10.22515/elereviews.v2i1.5121

Merma, M. G., Gavilán, M. D., Baena, M. S., & Urrea, S. M. (2022). Critical Thinking and Effective Personality in the Framework of Education for Sustainable Development. *Education Sciences*, *12*(1), 28. https://doi.org/10.3390/educsci12010028

Niswatin, Wasino, Suyahmo, & Arsal, T. (2020). Education of Environmental Awareness Based on Larung-Sesaji Ritual in Coastal Community of Bluru Village, Sidoarjo Sub-District, Sidoarjo District. *Proceedings of the International Conference on Science and Education and Technology (ISET 2019)*. https://doi.org/10.2991/assehr.k.200620.039

Noor, A. F., Yunus, R., Suyidno, S., & Fahmi, F. (2023). Development of Predict-Observe-Explain (POE) Based Authentic Problems' Instructional Package to Improve Students' Critical Thinking Skills. *Jurnal Pendidikan Matematika Dan IPA*, *14*(1), 69. https://doi.org/10.26418/jpmipa.v14i1.53932

Nurfitria, M. A., Hariyanto, D., & Widihastuti. (2022). *Website-Based Green School on Fashion Education and Training*. https://doi.org/10.2991/assehr.k.220129.035

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Nursidin, N., Rusman, R., & Dewi, L. (2022). Improved Understanding of Biodiversity Concepts through Environmentally Based Biology Learning Models. *Bioeduscience*, *6*(1), 1–7. https://doi.org/10.22236/j.bes/618016

Öktem, A. G., Ara, A. S., & Özturk, S. (2023). Investigating the Determinants of University Students' Recycling Behaviour. *Sosyoekonomi*, *31*(56), 129–149. https://doi.org/10.17233/sosyoekonomi.2023.02.06

Pertiwi, H. J. (2021). Diversity of Bird Species in the Dua Island Nature Reserve, Banten. *Biosel: Biology Science and Education*, *10*(1). https://doi.org/10.33477/bs.v10i1.1641

Sá, Patrícia., Silva, P. Christine., Peixinho, Joana., Figueiras, Ana., & Rodrigues, A. V. (2023). Sustainability at Play: Educational Design Research for the Development of a Digital Educational Resource for Primary Education. *Social Sciences*, *12*(7), 407–419. https://doi.org/10.3390/socsci12070407

Santos, E. S. B. dos, & Coutinho, D. J. G. (2022). The Importance of Environmental Education A Man-Nature Relationship. *Revista Ibero-Americana de Humanidades, Ciências e Educação*, *8*(4), 423–432. https://doi.org/10.51891/rease.v8i4.4853

Seibert, J., Schmoll, I., Kay, C. W. M., & Huwer, J. (2020). Promoting Education for Sustainable Development with an Interactive Digital Learning Companion Students Use to Perform Collaborative Phosphorus Recovery Experiments and Reporting. *Journal of Chemical Education*, *97*(11), 3992–4000. https://doi.org/10.1021/acs.jchemed.0c00408

Sharma, A. (2023). Eco-Literacy: For the Well-being of the Earth. *International Journal of Environment and Climate Change*, *13*(8), 2217–2219. https://doi.org/10.9734/ijecc/2023/v13i82180

Siska, F., Sulistijorini, S., & Kusmana, cecep. (2016). Litter Decomposition Rate of Avicennia marina and Rhizophora apiculata in Pulau Dua Nature Reserve, Banten. *Journal of Tropical Life Science*, *6*(2), 91–96. https://doi.org/10.11594/jtls.06.02.05

Smerichevskyi, Serhii., Mykhalchenko, Oleksii., Poberezhna, Zarina., & Kryvovyazyuk, Igor. (2023). Devising a systematic approach to the implementation of innovative technologies to provide the stability of transportation enterprises. *Eastern-European Journal of Enterprise Technologies*, *3*(13 (123)), 6–18. https://doi.org/10.15587/1729-4061.2023.279100

Ssossé, Q., Wagner, J., & Hopper, C. (2021). Assessing the Impact of ESD: Methods, Challenges, Results. *Sustainability*, *13*(5), 2854. https://doi.org/10.3390/su13052854

Stone, Suzanne., & Lowney, Rob. (2022, June 14). Learning ecology theory as a tool to support student digital competences in higher education. *8th International Conference on Higher Education Advances (HEAd'22)*. https://doi.org/10.4995/HEAd22.2022.14718

Sueb, Muhdhar, M. H. I. Al, & Zahroh, V. R. A. (2021). The Effect of Inquiry-Based Ecosystem Learning Module from Fishponds as a Learning Resource on Students' Cognitive Ability. *Journal of Physics: Conference Series*, *1842*(1), 012041. https://doi.org/10.1088/1742-6596/1842/1/012041

Syofyan, H., & Rachmadtullah, R. (2019). Increasing ecoliteracy on the impact of organic waste management using a problem a problem-solving the model. *International Journal of Scientific and Technology Research*, *8*(9).

Trascheev, S. V., & Kochetova, N. G. (2022). The Website "Pedagogical Communication" as a Means of Developing a Teacher's Communicative Skills in the Setting of

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 7, No. 1, January 2026
Page 260-273

Digitalisation of Educational Processes. *Pedagogy. Theory & Practice*, *7*(2), 234–239. https://doi.org/10.30853/ped20220023

Upadhyay, M., & Mishra, S. (2023). Environmental, social and economic impacts due to the COVID-19 outbreak. *Desafíos: Economía y Empresa*, *003*, 111–125. https://doi.org/10.26439/ddee2023.n003.5716

Utami, A. B., & Widiyaningrum, P. (2020). The Effectiveness of School Environment-Based Inquiry Model in the Ecosystem Material Towards Critical Thinking Ability and Environmental Caring Attitudes of High School Students. *Journal of Biology Education*, *8*(3), 367–374. https://doi.org/10.15294/jbe.v8i3.31660

Vandaele, M., & Stålhammar, S. (2022). "Hope dies, action begins?" The role of hope for proactive sustainability engagement among university students. *International Journal of Sustainability in Higher Education*, *23*(8), 272–289. https://doi.org/10.1108/IJSHE-11-2021-0463

Veckalne, R., & Tambovceva, T. (2022). The Role of Digital Transformation in Education in Promoting Sustainable Development. *Virtual Economics*, *5*(4), 65–86. https://doi.org/10.34021/ve.2022.05.04(4)

Wahyuni, I., Ranisah, R., Fani, F. N., & Aini, Q. Q. (2022). Bird Inventory in the Mangrove Forest Area of Pulau Dua Serang Nature Reserve, Banten. *Biodidaktika: Jurnal Biologi Dan Pembelajarannya*, *17*(1).

Yulistyorini, Anie., Ar Rosyid, Harits., Haratama, K. Refa., Rousseau, Diederik., & Al Ansyorie, M. Musthofa. (2022). Raising Environmental Awareness in Kampong Tridi and Kampong Warna-Warni (Malang, Indonesia) through Digital-Based Workshop on Constructed Wetlands. *Jurnal Pengabdian Kepada Masyarakat (Indonesian Journal of Community Engagement)*, *8*(2), 65. https://doi.org/10.22146/jpkm.54607

***Fahmie Firmansyah (Corresponding Author)**
Department of Elementary School Teacher Education, Faculty of Teacher Training and Education,
Mangku Wiyata University,
Jl. Al-Ishlah No.1, Jombang Wetan, Kota Cilegon, Banten, Indonesia
Email: fahmieeefirmansyah@gmail.com

Edi Rosadi
Department of Informatics Engineering, Faculty of Engineering and Computer Science,
Mangku Wiyata University,
Jl. Al-Ishlah No.1, Jombang Wetan, Kota Cilegon, Banten, Indonesia
Email: edirosadie@gmail.com