

Developing Digital Eco-Mathematics Teaching Materials: A Pathway to Foster Critical Thinking and Environmental Awareness

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Abstract:

The development of digital Eco-Mathematics teaching materials presents a significant opportunity to enhance elementary education by fostering critical thinking skills and environmental awareness among students. Existing mathematics learning materials rarely integrate environmental contexts in a structured and digital format, particularly in border areas, leading to limited opportunities for students to develop both competencies simultaneously. Moreover, students in border areas often experience limited access to contextual and innovative learning resources, which contributes to low levels of critical thinking skills and environmental awareness. This research aims to develop and evaluate these materials for fifth-grade students in elementary schools located in the Indonesia–Malaysia border area. Utilizing the Tesser & Akker framework, the study employs a design research approach consisting of a Preliminary Study and a Formative Evaluation to guide the development process. The analysis focuses on the validity, practicality, and effectiveness of the teaching materials in terms of educational outcomes. The findings indicate that the developed Eco-Mathematics materials meet the criteria for validity, practicality, and effectiveness. These results highlight the contribution of this study in providing an innovative integration of environmental contexts into digital mathematics learning, which effectively supports the enhancement of students' critical thinking skills and environmental awareness, particularly in under-resourced border areas.

Keywords: Border areas, critical thinking skills, digital eco-mathematics, environmental

Introduction

Global challenges today manifest in various aspects of life. Indonesia participates in sustainable programs as a solution to address these global challenges. One such program is known as the Sustainable Development Goals (SDGs). The SDGs consist of 17 interrelated and mutually supportive goals, one of which is environmental



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conservation (Santoso & Raharjo, 2021). Environmental conservation involves the wise use of natural resources to maintain environmental balance.

In reality, environmental conditions in Indonesia continue to deteriorate due to human activities such as improper waste disposal and forest burning. These issues are also evident in Bengkayang Regency, West Kalimantan, where increasing waste accumulation and frequent forest fires indicate a low level of environmental awareness among the community (Jati et al., 2023; Pradiptia et al., 2023).

Preventing environmental problems can be achieved through education, particularly by equipping students from an early age. Students aged between 7 and 12 years begin to enhance their memory, imagination, and thinking functions and start to think critically (Jadidah et al., 2023; Rabillas et al., 2023). This critical thinking ability is essential for developing environmental awareness from a young age. Students with strong critical thinking skills tend to be more responsive to environmental issues and capable of proposing solutions (Kamila et al., 2024). However, previous studies indicate that students' critical thinking skills remain low due to less contextual learning approaches and the limited use of appropriate teaching materials (Sasanti et al., 2024).

The integration of environmental awareness into elementary education can be effectively implemented through mathematics learning. Mathematics has strong potential to be connected with real-life contexts, including environmental issues, although such integration is still rarely applied in practice (Unnithan Kumar, 2024). Through contextual mathematical problems, students can develop ecological knowledge while simultaneously enhancing their analytical and problem-solving abilities (Imomberdiyev, 2023).

Integrating environmental contexts into mathematics learning not only improves students' understanding of mathematical concepts but also encourages them to analyze real-world problems, interpret data, and make decisions related to environmental issues. This process directly supports the development of critical thinking skills while fostering environmental awareness, as students engage cognitively and affectively with meaningful learning contexts (Durmuş & Kınacı, 2021; Hermawan et al., 2022; Kinslow et al., 2019).

One approach to facilitating this integration is through the development of digital Eco-Mathematics teaching materials. These materials incorporate environmental contexts into mathematical content, allowing students to learn mathematics while understanding environmental issues. Furthermore, the use of digital formats in teaching materials can enhance student engagement, provide interactive learning experiences, and support flexible learning environments, especially in elementary education, where learning through interaction and visualization is essential.

Conceptually, digital Eco-Mathematics teaching materials are designed by combining contextual environmental problems with mathematical reasoning activities. This integration enables students to develop critical thinking skills through

processes such as analysing data, evaluating information, and solving problems, while simultaneously fostering environmental awareness through understanding, attitudes, and responsible actions toward environmental issues. In this study, the developed teaching materials are presented in a digital format that integrates interactive features, problem-based learning activities, and contextual environmental cases. The indicators used to assess critical thinking include analysis, evaluation, and problem-solving skills, while environmental awareness is reflected through students' knowledge, attitudes, and responsiveness toward environmental issues.

Despite the increasing attention to environmental education and critical thinking, there is still a lack of teaching materials that systematically integrate environmental contexts into mathematics learning, particularly in digital formats and in border areas. Moreover, previous studies have not clearly demonstrated how digital Eco-Mathematics teaching materials can simultaneously support the development of critical thinking skills and environmental awareness, especially in under-resourced educational contexts such as border regions. Therefore, this study aims to develop and evaluate digital Eco-Mathematics teaching materials that are valid, practical, and effective in fostering critical thinking skills and environmental awareness among elementary school students in border areas.

Research Methods

The research methodology for the development of digital Eco-Mathematics teaching materials aimed at enhancing critical thinking skills and environmental awareness among fifth-grade students in the Indonesia–Malaysia border area (Bengkayang District) is based on the design research approach, adopting the Tessmer formative evaluation model integrated with the Van den Akker development framework. This approach consists of two main phases: Preliminary Study and Formative Evaluation. In the Preliminary Study phase, the research focuses on analysing students' learning needs and curriculum alignment through surveys and interviews with teachers and students. The participants were selected using purposive sampling, involving elementary schools with accreditation levels of A or B to ensure the relevance and quality of the data. The Formative Evaluation phase consists of self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field testing, which are systematically conducted to assess the validity, practicality, and effectiveness of the developed teaching materials (Tessmer, 1994; Van den Akker, 1999; Plomp, 2019). Figure 1 illustrates the stages of the development process, adapted from previous design research models (Plomp, 2019; McKenney & Reeves, 2020).

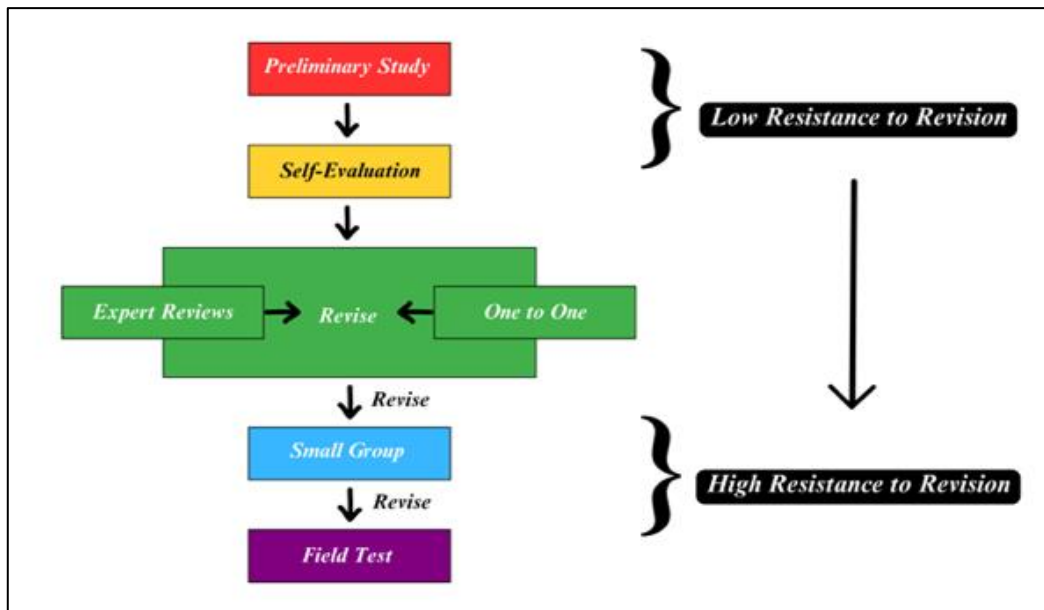


Figure 1. The Development Stage

Research Instruments

The instruments used in this study include: (1) validation sheets, (2) practicality questionnaires, (3) critical thinking skills tests, and (4) environmental awareness questionnaires. The validation sheets were used by experts to assess the content, construct, and language aspects of the developed teaching materials using a Likert scale (1–5). The practicality questionnaire was administered to teachers and students to evaluate ease of use, readability, and engagement. The critical thinking skills test was designed based on indicators such as analysis, evaluation, and problem-solving abilities, while the environmental awareness questionnaire measured students' knowledge, attitudes, and behaviors toward environmental issues. The instruments were developed based on relevant theoretical frameworks and were validated by experts before implementation. Reliability testing was conducted using Cronbach's Alpha to ensure internal consistency of the instruments. The experts involved in this study consisted of three individuals with expertise in mathematics education, instructional design, and elementary education.

Data Analysis

The data analysis techniques in this study focus on three aspects: validity, practicality, and effectiveness. Validity was calculated based on expert judgment scores using the formula: $\text{Validity Score} = (\text{Total Score Obtained} / \text{Maximum Score}) \times 100\%$, with criteria categorized as very valid, valid, fairly valid, and invalid. Practicality was analyzed using questionnaire responses from teachers and students, calculated using percentage scores, and categorized into very practical, practical, fairly practical, and impractical. The effectiveness of the teaching materials was determined based on students' critical thinking test results and environmental awareness questionnaire scores. The materials were considered effective if: (1) at least 75% of

students achieved the minimum mastery criteria (KKM), and (2) the average score exceeded the predetermined standard. The categorization of environmental awareness levels (high, moderate, low) was adapted from established criteria in educational assessment literature (e.g., Azwar, 2012). The effectiveness of the materials in supporting learning was also interpreted based on indicators of usability, student engagement, and learning outcomes, supported by relevant educational evaluation frameworks (Plomp, 2019; McKenney & Reeves, 2020).

Results and Discussions

Results

The development of digital Eco-Mathematics teaching materials aimed at enhancing the critical thinking skills of elementary school students in border regions begins with conducting a needs analysis and a curriculum analysis. The needs analysis focuses on the learning characteristics and challenges faced by students during the learning process. In the context of the Indonesian-Malaysian border, particularly in elementary schools in Bengkayang District, the characteristics and challenges include: 1) limited access to learning resources, where students face difficulties in obtaining books and technology, hindering the variety of learning materials; 2) the effectiveness of experiential learning, as students find it easier to grasp concepts when learning is directly related to real-life experiences, especially those connected to their environment; 3) a strong collaborative culture, with students preferring and showing greater productivity in group or collaborative learning activities, reflecting the communal culture prevalent in border regions; 4) limited exposure to critical thinking methods, as the dominance of conventional teaching practices restricts students' ability to fully develop their critical thinking skills; and 5) language limitations affecting the learning process, with some students struggling with the Indonesian language due to the influence of local dialects, resulting in less optimal learning without language adjustments.

From the curriculum analysis perspective, the seven targeted schools have implemented the Merdeka Curriculum. This means that learning outcomes and objectives are tailored to the achievements expected at each phase. In this context, instruction occurs in Grade V, Phase C, focusing on the sub-topic of Data Analysis. The formulated learning objectives state that students should be able to sort, compare, present, and analyze data from various objects and measurement results in the form of images, pictograms, bar charts, and frequency tables to extract information.

The Formative Evaluation phase encompasses several aspects, including Self-Evaluation, Expert Reviews, One-to-One, Small Group, and Field Test. Self-Evaluation is conducted to reassess the initial design of the developed teaching materials. The results of this evaluation include: 1) the appropriateness of the teaching material cover; 2) the alignment of the content within the teaching materials with the implemented curriculum; and 3) the relevance of the context in learning activities to the mathematical problems presented. After this phase is completed, the next step is

Expert Reviews. The developed teaching materials are then validated by three experts, with the average validation results displayed in Table 1.

Table 1 presents the validation results conducted by three experts regarding the developed product, evaluated from the aspects of content, construct, and language. According to the analysis of each aspect, the total score for the content aspect is 49, classified as valid, while the construct aspect received a score of 51, categorized as very valid, and the language aspect scored 49, also considered valid. Based on individual evaluations from each validator, Validator I assigned a total score of 50 for all three aspects, marked as valid; Validator II achieved a score of 49, which is also valid; and Validator III provided a score of 50. The average score from the evaluations of the three validators reached 49.67, categorized as valid. Therefore, based on the assessments from the experts, the developed Eco-Mathematics teaching materials are deemed valid and can be utilized with minor revisions.

Table 1. Expert Validation Analysis Results

Aspects	Validator			Total Score Per Aspect	Criteria Per Aspect
	I	II	III		
Content	18	15	16	49	Valid
Construction	17	16	18	51	Highly Valid
Language	15	18	16	49	Valid
Total Score	50	49	50		
Criteria	Valid	Valid	Valid		
Average		49,67			
Average Criteria		Valid			

The expert validation process not only assessed the quality of the developed teaching materials but also provided constructive recommendations for improvement. These recommendations were used as the basis for revising the initial product. A summary of the validators' suggestions and the corresponding improvement results is presented in Table 2.

Table 2. Validator Recommendations and Improvement Results

Validator Recommendations and Suggestions	Improvement Results
Add contextual environmental examples	Integrated local cases (waste, energy)
Increase HOTS-based questions	Added problem-based and essay items
Simplify dense material	Divided into smaller sections
Increase variation of questions	Added analytical and argument-based tasks
Enhance interactivity	Added quizzes and educational games

The recommendations and suggestions for improvement from the three validators encompass several important points. First, while the material aligns with the learning objectives of Eco-Mathematics, it is necessary to include more concrete examples relevant to the local context in border areas, such as issues related to waste

management and energy conservation. Second, although the content regarding critical thinking skills is deemed adequate, there is a need for additional practice questions that encourage students to analyze and seek creative solutions to environmental problems, including the development of problem-based questions that stimulate discussion. Third, despite the systematic structure of the material presentation, some sections are overly dense, making it difficult for elementary school students to comprehend; thus, it is recommended to divide the content into smaller sub-sections with simpler explanations. Furthermore, while the existing practice questions measure critical thinking skills, more variety in question types is necessary, such as incorporating short essay questions that encourage student arguments. Finally, although the digital media used is interactive, some elements can be strengthened by adding more interactive components, such as quizzes and educational games, to enhance student engagement.

After the instructional materials were validated and revised, a one-to-one evaluation was conducted involving one elementary school teacher with more than five years of teaching experience and familiarity with the Merdeka Curriculum, as well as three students representing high, medium, and low ability levels. This stage aims to evaluate the practicality of the materials in terms of usability, clarity, and implementation feasibility in real classroom settings. This trial aims to assess the practicality of the developed materials as evaluated by classroom teachers. This analysis provides insights into how effectively the instructional materials can be utilized by teachers in real classroom settings, as well as helping to identify areas that may still require further refinement or adjustment. Therefore, the one-to-one trial is a crucial step in ensuring that the instructional materials are not only valid but also practical and effective in supporting student learning. The practicality scores were calculated using a Likert scale (1–5) and categorized based on standard criteria, where scores above 4.20 are classified as “Highly Practical” (Widoyoko, 2018). The results of the analysis of the practicality of the instructional materials are presented in Figure 2.

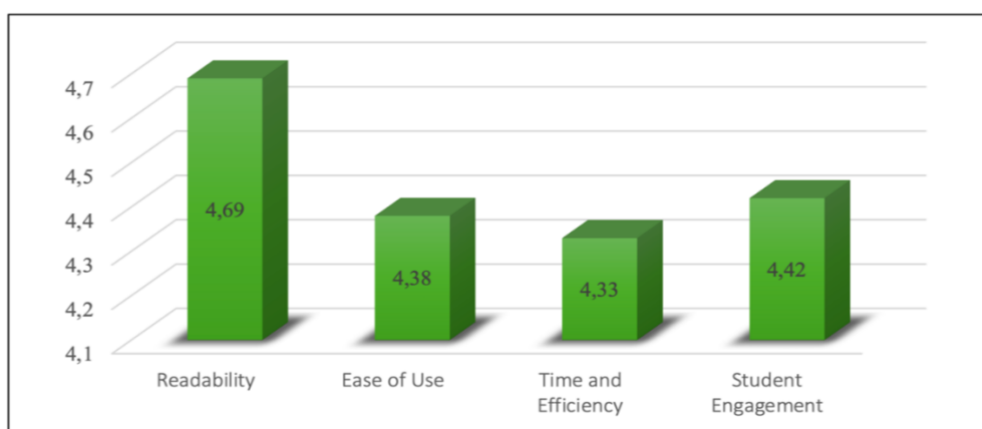


Figure 2. Practicality Analysis

Based on Figure 2, the average ratings for readability, ease of use, time efficiency, and student engagement were 4.69, 4.38, 4.33, and 4.42, respectively, with an overall average score of 4.46, categorized as “Highly Practical.” The overall average for these four assessment aspects was 4.46, also classified as Highly Practical. This indicates that the developed Eco-Mathematics teaching materials are practical for facilitating critical thinking skills and environmental awareness among elementary school students in the border region.

Following the one-to-one testing, the next step involved trialing the teaching materials in small groups, targeting elementary school students with learning characteristics similar to the research subjects. The small group evaluation involved 8–10 students with similar characteristics to the research subjects. The teaching materials were implemented in two learning sessions, and feedback was collected through observation and questionnaires to evaluate practicality and initial effectiveness. The final stage of this research is the Field Test, which aims to evaluate the effectiveness of the developed teaching materials. The effectiveness is assessed through two evaluations: a final test on critical thinking skills and a questionnaire evaluating students' environmental awareness. The results of the critical thinking skills test for elementary school students are presented in Table 2.

Table 2. Critical Thinking Skills Test Results

Description	Score
Highest Score	91,5
Lowest Score	55
Average	80,29
Students who passed number	134
Students who did not pass number	21
Completion Percentage	86%

Table 2 presents the results of the critical thinking skills test for elementary school students after participating in lessons using the developed digital Eco-Mathematics teaching materials. The effectiveness of the teaching materials was determined based on students' critical thinking test results, where a minimum mastery criterion (KKM) of 75% was adopted following national education standards (Permendikbud, 2018). The results showed that 86% of students achieved mastery, indicating that the developed teaching materials are effective. This outcome indicates that the developed digital Eco-Mathematics teaching materials are effective in facilitating the critical thinking skills of elementary school students in the border region. In terms of environmental caring character, the practicality questionnaire was constructed following Azwar's criteria, which includes five-level scale: very high, high, moderate, low, and very low (Azwar, 2012). The results of this questionnaire analysis are presented in Figure 3.

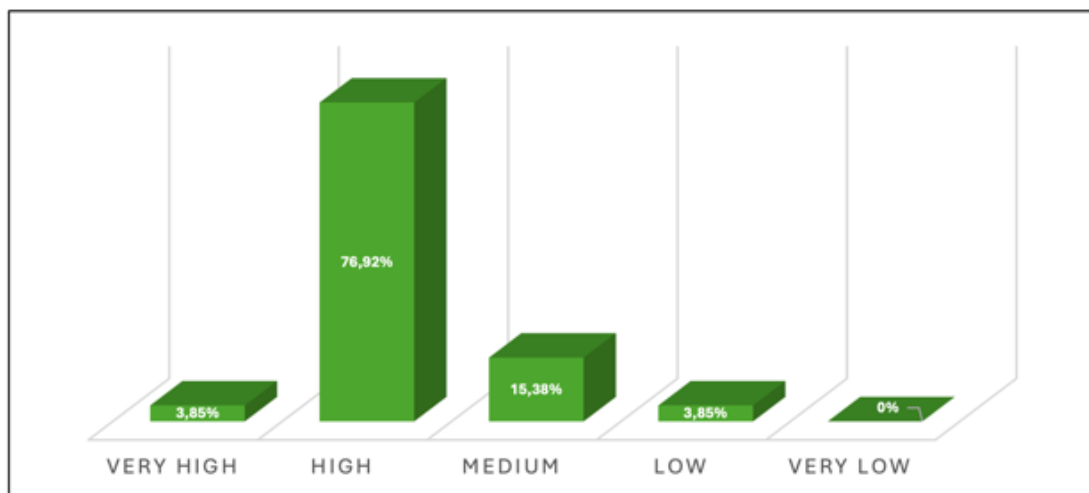


Figure 3. questionnaire Analysis Results

Figure 3 shows that 76.92% of students fall into the “high” category, with an average score of 69.85, indicating a strong level of environmental awareness. These results indicate that the developed teaching materials are effective in facilitating environmental caring characteristics among elementary school students in border areas. In conclusion, it can be stated that the digital Eco-Mathematics teaching materials are effective in promoting both critical thinking abilities and environmental awareness among elementary school students in border regions. Based on the stages of the research, the results of the development of digital eco-mathematics teaching materials aimed at facilitating critical thinking skills and environmental awareness among elementary school students in border regions are illustrated in Figure 4. This figure encapsulates the overall findings and effectiveness of the developed materials in enhancing both critical thinking abilities and environmental caring attitudes among students.

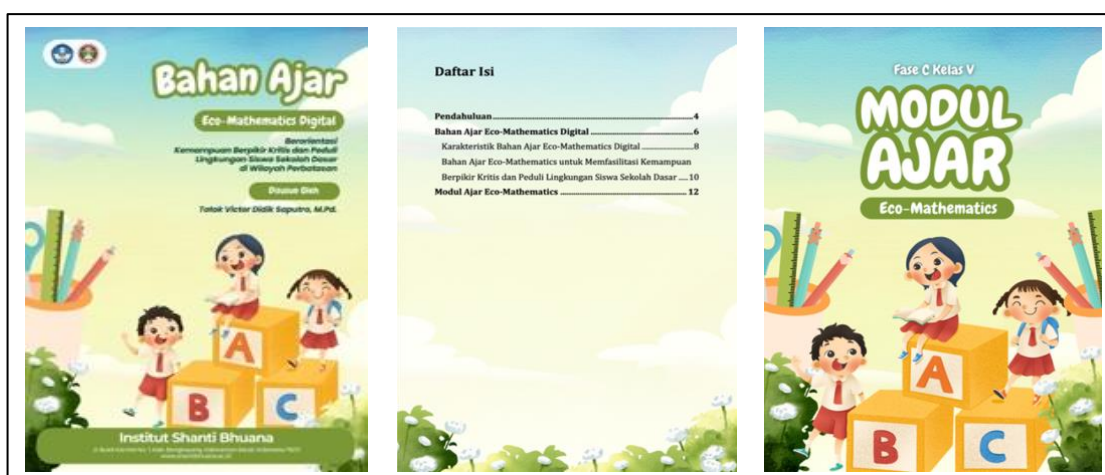


Figure 4. Eco-Mathematics Teaching Materials

Based on Figure 4, the core content of the eco-mathematics teaching materials includes an introduction, the characteristics of digital eco-mathematics teaching materials, eco-mathematics materials designed to facilitate critical thinking skills and environmental awareness among elementary school students, and an eco-mathematics teaching module. The eco-mathematics teaching module is a detailed lesson plan (RPP+) tailored to the implementation of the "Merdeka" curriculum, aligned with the formulated learning outcomes. This module ensures that the teaching materials are not only relevant to the curriculum but also effectively engage students in critical environmental issues. The developed digital Eco-Mathematics teaching materials consist of interactive modules that integrate environmental contexts with mathematical concepts. The digital components include interactive tasks, contextual problem scenarios, visual data representations, and quizzes. The eco-mathematics principles are reflected in the use of real environmental data (e.g., waste, energy, and natural resources), while critical thinking is fostered through problem-solving and data analysis activities. Environmental awareness is developed through reflective questions and contextual case discussions. An example of the teaching material is presented in Figure 4, illustrating how students analyze environmental data using mathematical representations to propose solutions.

Discussion

The development of eco-mathematics teaching materials represents a significant advancement in educational approaches, integrating both critical thinking skills and environmental awareness into elementary school curricula. The findings of this study indicate that the developed teaching materials meet the criteria of validity, practicality, and effectiveness, as reflected in the validation score (49.67), practicality score (4.46), and effectiveness result (86% student mastery). These results provide a strong empirical basis for discussing the theoretical and practical contributions of the study.

Integration with Curriculum and Learning Context

A key contribution of this study lies in the alignment of Eco-Mathematics teaching materials with the Merdeka Curriculum, which emphasizes student-centered learning and contextual understanding. The integration of environmental contexts into mathematics learning enables students to connect abstract mathematical concepts with real-world environmental issues, such as waste management and resource conservation. This finding supports previous studies indicating that contextual and interdisciplinary learning enhances students' engagement and understanding by linking knowledge to real-life situations (Bouckaert, 2023; Amin et al., 2023). By situating mathematical problems within environmental contexts, students are encouraged to actively construct knowledge rather than passively receive information.

Practicality and Usability of Digital Teaching Materials

The practicality results, with an average score of 4.46 categorized as "Highly Practical," indicate that the developed materials are easy to use, efficient, and engaging for both teachers and students. The integration of digital features such as interactive

content, contextual tasks, and visual representations contributes to increased usability and learning motivation. These findings are consistent with previous research showing that digital learning materials improve student engagement and facilitate flexible learning, particularly in elementary education settings (Putri Hapsari et al., 2022). The high practicality score also reflects that the materials are adaptable to classroom conditions, including those in border areas with limited resources.

Effectiveness in Enhancing Critical Thinking Skills

The effectiveness of the developed teaching materials is demonstrated by the 86% student mastery rate, exceeding the minimum completion criteria (KKM). This result indicates that integrating environmental contexts into mathematics learning can significantly improve students' critical thinking skills. This finding aligns with studies emphasizing that problem-based and contextual learning approaches enhance higher-order thinking skills, including analysis, evaluation, and problem-solving (Pertwi et al., 2024; Lombardi et al., 2024). By engaging students in analyzing real environmental data and solving contextual problems, the teaching materials provide opportunities for meaningful cognitive development.

Impact on Environmental Awareness

In addition to cognitive outcomes, the developed teaching materials also positively influence students' environmental awareness. The results show that 76.92% of students fall into the "high" category of environmental awareness, indicating that the materials effectively foster students' sensitivity toward environmental issues. This supports the concept of eco-pedagogy, which emphasizes the integration of knowledge, attitudes, and behaviors in environmental education. Learning activities that involve real-world environmental problems encourage students to reflect on their roles and responsibilities toward environmental sustainability.

Pedagogical Innovation and Local Relevance

The novelty of this study lies in the integration of eco-mathematics, digital learning, and contextual problem-solving within a single instructional framework. The developed materials incorporate local environmental issues from the Indonesia–Malaysia border area, making learning more relevant to students' lived experiences. This place-based approach strengthens the connection between learning and students' social and environmental contexts, which has been shown to enhance both cognitive and affective learning outcomes (Yemini et al., 2023). Furthermore, the use of digital platforms allows for interactive and flexible learning, addressing the challenges of limited educational resources in border regions.

Theoretical and Practical Contribution

The findings of this study contribute theoretically by strengthening the conceptual linkage between eco-mathematics, critical thinking, and environmental awareness within mathematics education. The results provide empirical evidence that integrating environmental contexts into mathematics learning can simultaneously enhance cognitive and affective learning outcomes. Practically, this study offers an alternative digital teaching material that can be implemented by elementary school

teachers, particularly in under-resourced areas such as border regions. The developed materials provide a model for integrating environmental education into mathematics learning in a structured and engaging manner.

Conclusions and Suggestions

This study demonstrates that the developed Eco-Mathematics teaching materials have met the criteria of validity, practicality, and effectiveness in facilitating critical thinking skills and fostering environmental awareness among elementary school students in the border region. The findings indicate that the developed materials achieved a validation score of 49.67 (valid), a practicality score of 4.46 (highly practical), and an effectiveness level reflected in 86% student mastery exceeding the minimum criteria. Expert validation confirmed the appropriateness of content, construction, and language, while the practicality test indicated ease of use and high student engagement. Furthermore, the effectiveness test demonstrated that the majority of students (86%) achieved mastery learning criteria, indicating that the materials effectively enhance both students' critical thinking skills and environmental awareness. These findings highlight the importance of integrating environmentally based instructional materials into elementary mathematics learning to promote students' critical awareness of environmental issues and contextual understanding. Digital Eco-Mathematics teaching materials can serve as an effective alternative to address the limitations of conventional mathematics learning, particularly in under-resourced border areas.

Based on the findings of this study, several recommendations can be proposed. Practically, the developed teaching materials can be utilized by elementary school teachers as an alternative resource to integrate environmental contexts into mathematics learning. Schools are encouraged to support the implementation of eco-based digital learning through adequate facilities and teacher professional development. Curriculum developers and policymakers may consider integrating environmentally oriented mathematics learning into the curriculum to strengthen students' competencies. For future research, it is recommended to improve the interactivity of digital content, expand the sample size, and explore the integration of project-based or collaborative learning models in diverse educational contexts.

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References

- Adhelacahya, K., Sukarmin, S., & Sarwanto, S. (2023). The impact of problem-based learning electronics module integrated with STEM on students' critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, 9(7), 4869–4878. DOI: 10.29303/jppipa.v9i7.3931
- Agusningtyas, D., Erika, F., & Qadar, R. (2024). Analysis of Teachers' Needs for Interactive e-Module to Train Critical Thinking Skills in the Merdeka Curriculum Era. *International Journal of STEM Education for Sustainability*, 4(1), 79–96. <https://doi.org/10.53889/ijses.v4i1.342>
- Alam, L. (2020). Interpretasi aksi teo-ecology dan transendentalisme terhadap pelestarian lingkungan. *Humanika*, 20, 83–102. DOI:10.21831/hum.v20i2.33482
- Amin, H., Zaman, A., & Tok, E. (2023). Education for sustainable development and global citizenship education in the GCC: a systematic literature review. *Globalisation, Societies and Education*, 1–16. <https://doi.org/10.1080/14767724.2023.2265846>
- Anudiwanti, P., & Ahmad, H. (2022). Edukasi perlindungan pelestarian lingkungan hidup di masyarakat desa melalui penguatan pengaturan tentang ekosida. *Jurnal Dedikasi Hukum*, 2(3), 317–328. <https://doi.org/10.22219/jdh.v2i3.23463>
- Azwar, S. (2012). *Penyusunan skala psikologi*. Yogyakarta: Pustaka Pelajar
- Bafadal, M. F., & Hestiantini, A. P. (2023). Kebijakan Pemerintah Kalimantan Barat Dalam Isu Lingkungan Kebakaran Hutan Dan Lahan (Karhutla) Tahun 2023. *Innovative: Journal Of Social Science Research*, 3(6), 4528–4538. Retrieved from <https://j-innovative.org/index.php/Innovative/article/view/6785>
- Bouckaert, M. (2023). *The assessment of students' creative and critical thinking skills in higher education across OECD countries: A review of policies and related practices*. Retrieved from https://www.oecd.org/en/publications/the-assessment-of-students-creative-and-critical-thinking-skills-in-higher-education-across-oecd-countries_35dbd439-en.html
- Dakabesi, D., & Luoise, I. S. Y. (2019). The effectiveness of problem-based learning model to increase the students' critical thinking skills. *Journal of Education and Learning (EduLearn)*, 13(4), 543–549. <https://doi.org/10.11591/edulearn.v13i4.12940>
- Durmuş, E., & Kınacı, M. K. (2021). Opinions of social studies teacher education students about the impact of environmental education on ecological literacy. *Review of International Geographical Education Online*, 11(2), 482–501. <https://doi.org/10.33403/rigeo.825516>

- Gule, Y., Limbong, N. L. B., Tarigan, P. P. B., & Tarigan, F. A. (2023). Edukasi pentingnya menjaga lingkungan hidup sejak dini. *Jurnal Abdidas*, 4(1), 75–81. <https://doi.org/10.31004/abdidas.v4i1.756>
- Hebebcı, M. T., & Usta, E. (2022). The effects of integrated STEM education practices on problem solving skills, scientific creativity, and critical thinking dispositions. *Participatory Educational Research*, 9(6), 358–379. <http://dx.doi.org/10.17275/per.22.143.9.6>
- Hermawan, I., Suwono, H., Paranit, A. A. I., & Wimuttipanya, J. (2022). Student's Environmental Literacy: An Educational Program Reflections for a Sustainable Environment. *Journal of Biological Education Indonesia (Jurnal Pendidikan Biologi Indonesia)*, 8(1), 1–9. <https://doi.org/10.22219/jpbi.v8i1.16889>
- Imomberdiyev, S. S. (2023). Use of problems with ecological content in mathematics lessons in primary grades. *Web of Teachers: Inderscience Research*, 1(7), 36–39. <https://webofjournals.com/index.php/1/article/view/196>
- Jadidah, I. T., Annisah, R., Melinda, M., Padiman, P., & Anggılin, K. (2023). Analysis of the Implications of Learning Elementary Mathematics According to Jean Piaget's Theory. *Journal Of Dehasen Educational Review*, 4(02), 139–144. DOI:10.33258/joder.v4i02.4256
- Jati, D. R., Fitriarningsih, Y., Utomo, K. P., & Sulastri, A. (2023). Identifikasi Potensi Asap Akibat Kebakaran Hutan terhadap Rencana Pembangunan Tapak PLTN Kabupaten Bengkayang: Identification of Potential Smoke Due to Forest Fires on the Bengkayang Regency Nuclear Power Plant Site Development Plan. *Jurnal Teknologi Lingkungan*, 24(1), 28–35. <https://doi.org/10.55981/jtl.2023.245>
- Kamila, K., Wilujeng, I., Jumadi, J., & Ungirwalu, S. Y. (2024). Analysis Of Integrating Local Potential In Science Learning And Its Effect On 21st Century Skills And Student Cultural Awareness: Literature Review. *Jurnal Penelitian Pendidikan Ipa*, 10(5), 223–233. DOI: 10.29303/jppipa.v10i5.6485
- Kementerian Pendidikan dan Kebudayaan Republik Indonesia. (2016). Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nmor 23 Tahun 2016 tentang Standar Penilaian Pendidikan
- Kinslow, A. T., Sadler, T. D., & Nguyen, H. T. (2019). Socio-scientific reasoning and environmental literacy in a field-based ecology class. *Environmental Education Research*, 25(3), 388–410. <https://doi.org/10.1080/13504622.2018.1442418>
- Lombardi, L., Thomas, V., Rodeyns, J., Mednick, F. J., De Backer, F., & Lombaerts, K. (2024). Primary school teachers' experiences of teaching strategies that promote pupils' critical thinking. *Educational Studies*, 50(5), 683–701.

<https://doi.org/10.1080/03055698.2021.1990017>

- Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing Critical Thinking Skills through STEM Problem-Based Contextual Learning: An Integrated E-Module Education Website with Virtual Experiments. *Journal of Baltic Science Education*, 23(4), 739–766. <https://doi.org/10.33225/jbse/24.23.739>
- Pradiptia, A., Agung, P. A. M., Pramusandi, S., Hasan, M. F. R., Suropto, A. bin Z., & Ahmad, M. A. (2023). In-Situ Stabilization Analyses of Peaty Clay Soil Layers using Solid Waste from of Biomass Power Plant. *Journal Homepage: Http://Iieta.Org/Journals/Ijdne*, 18(6), 1299–1313. <https://doi.org/10.18280/ijdne.180603>
- Purnasari, P. D., Saputro, T. V. D., & Sadewo, Y. D. (2023). Primary Teacher Working Group Assistance in the Indonesia-Malaysia Border Area to Design the Annual Work Program. *Dinamisia: Jurnal Pengabdian Kepada Masyarakat*, 7(3), 636–643. DOI:10.31849/dinamisia.v7i3.14519
- Purnasari, P. D., Sumarni, M. L., & Saputro, T. V. D. (2023). Application of Concrete Learning Media to Improve Mathematics Learning Outcomes of Elementary School Students. *Journal of Education Policy Analysis*, 1(1), 24–30. Retrieved from <https://businessandfinanceanalyst.com/index.php/JEPA/article/view/53>
- Putra, E. D., Utomo, K. P., & Sulastri, A. (2023). Optimalisasi Sistem Pengangkutan Sampah Di Kabupaten Bengkayang Berbasis Geographic Information System (GIS). *Jurnal Teknologi Lingkungan Lahan Basah*, 11(2), 321–328. <https://doi.org/10.26418/jtllb.v11i2.64824>
- Putri Hapsari, I., Victor Didik Saputro, T., & Damas Sadewo, Y. (2022). Mathematical Literacy Profile of Elementary School Students in Indonesia: a Scoping Review. *Journal of Educational Learning and Innovation (ELIa)*, 2(2), 279–295. <https://doi.org/10.46229/elia.v2i2.513>
- Rabillas, A., Kilag, O. K., Cañete, N., Trazona, M., Calope, M. Lou, & Kilag, J. (2023). Elementary Math Learning Through Piaget’s Cognitive Development Stages. *Excellencia: International Multi-Disciplinary Journal of Education (2994-9521)*, 1(4), 128–142. <https://risejournals.org/index.php/imjrise/article/view/678>
- Rodriguez-Domenech, M. A., Bello-Bravo, J., & Pittendrigh, B. R. (2019). Scientific animations without borders (SAWBO): an innovative strategy for promoting education for sustainable development. *Sustainability Science*, 14(4), 1105–1116. <https://doi.org/10/1007/s11625-018-0624-8>.
- Sadewo, Y. D., Wibawa, B., Hanafi, I., Purnasari, P. D., & Saputro, T. V. D. (2025). Enhancing the GROW syntax in GAARANTUNG: a study on the coaching model development in education. *Journal of Education and Learning (EduLearn)*, 19(1), 34–

45. <https://doi.org/10.11591/edulearn.v19i1.21211>
- Santoso, M. B., & Raharjo, S. T. (2021). Diskursus Corporate Social Responsibility (CSR) dalam Mewujudkan Sustainable Development Goals (SDGS). *Share: Social Work Journal*, 11(2), 100–121. <https://doi.org/10.24198/share.v11i2.37076>
- Saputro, T. V. D., & Mahmudi, A. (2020). Reflective pedagogical paradigm approach in mathematics learning. *Journal of Physics: Conference Series*, 1613(1), 12007. DOI:10.1088/1742-6596/1613/1/012007
- Sasanti, W., Hemptasin, C., & Thongsuk, T. (2024). The Effectiveness of Inquiry-Based Learning to Improve the Analytical Thinking Skills of Sixth-Grade Elementary School Students. *Anatolian Journal of Education*, 9(1), 37–56. DOI:10.29333/aje.2024.913a
- Tessmer, M. (1994). Formative evaluation alternatives. *Performance Improvement Quarterly*, 7(1), 3–18. <https://doi.org/10.1111/j.1937-8327.1994.tb00613.x>
- Unnithan Kumar, S. (2024). Towards an ecological mathematics. *Interdisciplinary Science Reviews*, 03080188241232766. <https://doi.org/10.1177/03080188241232766>
- van den Akker, J. (1999). Principles and Methods of Development Research. In: van den Akker, J., Branch, R.M., Gustafson, K., Nieveen, N., Plomp, T. (eds) *Design Approaches and Tools in Education and Training*. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-4255-7_1
- Widoyoko, E. P. (2018). *Teknik penyusunan instrumen penelitian*. Yogyakarta: Pustaka Pelajar
- Yemini, M., Engel, L., & Ben Simon, A. (2023). Place-based education—a systematic review of literature. *Educational Review*, 1–21. <https://doi.org/10.1080/00131911.2023.2177260>