The Effectiveness of Mobile Learning Teaching Materials for Education on Sustainable Development in Eco-Friendly Technology to Improve Environmental Literacy

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Abstract

This study aimed to develop mobile learning teaching materials based on Education for Sustainable Development (ESD) with the theme of Eco-Friendly Technology and to test their effectiveness in improving Environmental Literacy. The teaching materials were developed using the ADDIE model. A total of 58 9th-grade students participated in the study, divided into an experimental group and a control group. The instruments used for data collection included an Environmental Literacy test and assessment sheets to evaluate the quality of the teaching materials and comprehension. The data were analyzed by calculating the average normalized gain, conducting t-tests, and determining the effect size. The analysis revealed the following findings: 1) The quality test and reading comprehension test scores were good; 2) The Environmental Literacy skills of the experimental group increased with medium criteria, while the control group showed low criteria improvement; 3) There was a significant difference in the increase of Environmental Literacy skills between the experimental and control groups, indicating that the teaching materials were effective in improving Environmental literacy skills with an N-Gain of 0.41, classified as medium; and 4) The effect size test showed a high category score of 1.2, indicating that the teaching materials were effective in enhancing students' environmental literacy skills.

Keywords: Teaching materials; Mobile Learning; ESD; Environmental Literacy; Eco Friendly Technology

INTRODUCTION

Environmental problems are a widely discussed global issue that arises from various causes, including climate change, depletion of natural resources, and human activities such as unsustainable logging practices. The development of technology has brought both positive and negative impacts on the environment, with one of the negative consequences being environmental damage leading to a decline in environmental quality. However, there is a lack of public awareness and understanding of environmental issues, which can be attributed to a low level of environmental literacy among the population. Therefore, it is crucial to integrate environmental literacy into science education.

In the context of science learning, environmental literacy refers to a person's ability to comprehend and actively engage in actions aimed at protecting and improving the environment. According to Roth (1992), environmental literacy involves understanding the surrounding environment and playing an active role in its conservation. Kidman and Casinader (2019) define it as the capacity to comprehend and interpret environmental conditions and take appropriate action to maintain, restore, or enhance those conditions.

However, despite the importance of environmental literacy, there is evidence to suggest that it has not been adequately prioritized. This is evident from research studies that have assessed students' environmental literacy and found an average percentage of only 47%. Previous studies have also identified low levels of environmental literacy among students, classifying it as "sufficient" (Aini et al., 2021; Igbokwe, 2016). This lack of environmental literacy can be attributed to various factors, including a lack of interest in and awareness of environmental issues (Rohweder, 2004). Furthermore, Suryawati et al. (2020) observed that junior high school students' abilities to identify, analyze problems, and devise action plans to solve environmental issues were also low. Their study indicated that students with inadequate environmental knowledge exhibited relatively higher levels of environmental education, attitudes, concerns, and perceptions regarding environmental problems (Saribas et al., 2014).This study demonstrates a gap between the competency standards in junior high school and students' environmental literacy. It is important to note that environmental literacy cannot be naturally developed but rather requires stimulation through various stimuli and environmental conditions. In order to enhance the quality of education, teachers play a crucial role. One aspect of their role is providing appropriate teaching materials that cater to students' needs. Lack of interactivity and interest in teaching materials hinders students' learning experience.

Mobile learning teaching materials offer new opportunities for students, allowing for personalized and contextualized learning experiences without time or environmental constraints (Crompton & Burke, 2018; Farrah & Abu-Dawood, 2018). From a user's perspective, mobile learning has several advantages, particularly as a learning resource (Elfeky & Yakoub Masadeh, 2016). These materials, easily accessible, differ from traditional teaching materials. According to a survey conducted by Insani (2016), 96% of teachers in Indonesia primarily utilize printed materials such as textbooks, modules, and worksheets, while only 4% use electronic school books. To bridge this gap, this research aims to enhance environmental literacy among junior high school students through the use of mobile learning teaching materials.

When developing teaching materials to improve specific skills, it is essential to have a well-defined approach. The Education for Sustainable Development (ESD) framework can be applied to science education. ESD is closely linked to sustainable development, emphasizing the integration and balance of the pillars of sustainability: society, environment, economy, and culture (Unesco, 2017). Its objective is to cultivate human character and competence through education in schools (Oh et al., n.d.). However, in Indonesia, ESD has yet to be included and implemented in the school curriculum, resulting in a lack of learning resources and appropriate teaching materials from the government to support the implementation of ESD-focused learning activities.Moreover, the author conducted a brief analysis of the ESD values in the 2013 science curriculum textbook published by the government, specifically focusing on the study of Eco Friendly Technology. The analysis revealed several findings: (1) the material discussed did not contain any ESD aspects and did not align with the goals of sustainable education, (2) the material did not specifically address the goals of sustainable education, and (3) the material lacked environmental, socio-cultural, and economic aspects. It is essential to emphasize these aspects in learning resources to support ESD-based learning (Mahaffy et al., 2019; O'Flaherty & Liddy, 2018).

Previous studies have examined the use of interactive media in mobile learning applications. Another study conducted by Widodo et al. (2020) developed gadget-based interactive multimedia. Various studies have explored environmental literacy and the implementation of ESD, specifically focusing on students' sustainability awareness through the integration of ESD in the teaching and learning process (Berglund et al., 2014). The difference between this study and previous research lies in its specific focus on improving environmental literacy within certain topics. The development of teaching materials, such as e-books or e-modules, currently involves simply transferring traditional books into digital formats and does

not fully meet the demands of education in the 21st century. By incorporating appropriate teaching materials and engaging students in activities that involve their surroundings, literacy skills, including identity formation, agency, and the use of environmental literacy, can be enhanced (Häggström & Schmidt, 2020). In this study, teaching materials in the natural sciences were developed for junior high school students, and their effectiveness was evaluated. The process of developing these materials followed the model used in writing science textbooks (Sinaga et al., 2017).

Meanwhile, the objective of this study is to develop ESD-based mobile learning teaching materials to enhance environmental literacy skills in junior high school students, specifically focusing on the topic of eco friendly technology. Based on the aforementioned details, the research problem can be formulated as follows: "What is the effectiveness of developing ESD-based mobile learning teaching materials to improve junior high school students' environmental literacy skills in the area of Eco Friendly Technology?"

METHOD
Study Design
The study utilized a research and development method. The focus of the development research was on a specific product, program, process, or instructional tool (Richey & Klein, 2005). The chosen development model was ADDIE, a systematic learning design model that was selected because it is based on a theoretical foundation of learning design and structured programming with systematic activities to address learning problems related to student needs. This model consists of five steps: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation.

The analysis stage included three components: needs analysis, student analysis, and material analysis. Data was collected through surveys, questionnaires, interviews, and discussions with science teachers and students. The needs analysis involved interviews and questionnaires with science teachers to determine the need for teaching materials in schools. In the design stage, the process of designing teaching materials involved five stages: designing learning objectives, sequencing, designing learning strategies, and designing product evaluation strategies. The development stage included content development, storyboarding, and the development of teaching materials.

During the implementation stage, the effectiveness of the developed teaching materials was tested. The final stage involved evaluating student learning outcomes and making improvements to the products based on student needs as a basis for further research.

Participants
The participants in this study were ninth-grade students at a junior high school in West Bandung, West Java Province. Purposive sampling was employed, considering certain characteristics of the population based on the researcher's considerations. This technique is suitable when attempting to control for specific variables (Singh, 2006). Considerations included the students' use of smartphones, as well as their relatively similar level of academic skill based on their previous exam results. The ninth-grade students were divided into an experimental group and a control group, with 29 students in each group.

Treatment
This study implemented the treatment stage of the ADDIE model. The treatment was carried out in both the experimental and control groups, with a focus on the natural sciences. The treatment consisted of five meetings, each with two sessions lasting 45 minutes. The experimental group used mobile learning teaching material based on ESD, while the control group used standard textbooks published by the government. The content of the teaching material focused on eco-friendly technology, which is closely related to ESD.

The first session of the first meeting was dedicated to explaining the learning process and objectives, while the second session included a pre-test for both groups. The learning process

took place in the second to fourth meetings, with the teacher serving as the instructor. The last meeting included a summary of what had been learned, followed by a post-test for both groups.

The research instruments used in this study were tests to measure ecological knowledge and questionnaires adapted from the Middle School Environmental Literacy Survey (MSELS) developed by McBeth (2010) to measure cognitive skills, actions, and sensitivity to the environment. Before using the questionnaires and tests, they were adapted from MSELS and then validated by experts and tested on students. The environmental literacy skills instrument was tested on 33 ninth-grade students in one public junior high school. The validity of the instrument was evaluated using the Pearson product-moment technique, and its reliability was evaluated using the Kuder-Richardson (KR-21) technique (Arikunto, 2013). The environmental literacy skills test consisted of 12 multiple-choice questions. The Pearson product-moment correlation coefficient for each item ranged from 0.40 to 0.69, and the reliability coefficient was 0.62.

Data Analysis

Data analysis involved determining the average normalized gains to assess improvement in environmental literacy skills, using Hake's (1999) criteria for interpretation. The normalized gain test was used to measure the average increase in students' environmental literacy before and after receiving the treatment. The impact of the mobile learning teaching material based on ESD in improving environmental literacy skills compared to standard textbooks was measured using the independent t-test. Additionally, due to the small sample size, effect size measurement was determined using Cohen's d (Coe, 2002).

RESULTS AND DISCUSSION
Teaching Material Feasibility

The instrument used to evaluate the quality of Mobile Learning Teaching materials based on Education for Sustainable Development (ESD) consists of a reading comprehension test and a score for teaching material quality and reading comprehension. Teaching material quality is assessed based on material relevance, media suitability, and ESD components. Material relevance is determined by the alignment between Basic Competencies and Indicators, as well as the appropriateness of Content Writing. Each aspect is evaluated separately.

The validation results of the teaching material quality test indicate that the mobile learning teaching materials based on ESD are of sufficient quality, with an average score of 80.00. This suggests that the teaching material quality, particularly in terms of material relevance, is suitable for use in schools. In addition, the media suitability aspect consists of two components: 1) the presentation of mobile learning, and 2) the use of mobile learning. The average score for media suitability is 89%, which falls within the adequate category.

The third aspect to be considered is the ESD components, which encompass the environment, social aspects, and economic aspects. The average score for the ESD components is 80.5%. The reading comprehension test employed in this study utilized an instrument that contained texts on various sub-topics. Each text was accompanied by four questions, which assessed the understanding of the main idea, supporting sentences, difficult sentences, and unknown words within the text. The analysis of the developed mobile learning teaching materials revealed that out of the 24 texts tested, 21 texts exhibited a high level of understanding, while 3 texts demonstrated a medium level of understanding.

Environmental Literacy Improvement

In this research study, indicators of environmental literacy were developed based on the Middle School Environmental Literacy Survey (MSELS). To measure students' environmental literacy regarding the theme of eco-friendly technology, a descriptive test consisting of 12 questions was used as an assessment instrument. The analysis of the enhancement in environmental literacy skills, specifically in ecological knowledge, was conducted by

evaluating the increase in N-gain. The research findings demonstrate a disparity in the improvement of environmental literacy between the experimental class and the control class.

The data analysis revealed that the N-gain value for the experimental class was 0.41, whereas the control class had a value of 0.18. Based on Hake's classification (1999), the environmental literacy skills of the experimental group exhibited a medium level improvement, while the control group demonstrated a low level improvement. There was a statistically significant distinction in the enhancement of environmental literacy between the experimental class and the control class.

Table 1. The average normalised gains in students' environmental literacy skills

Class	Pre Test	Post Test	$<g>$	Category
Experiment	48.55	69.79	0.41	Medium
Control	47.72	57.41	0.18	Low

The increase in students' environmental literacy skills and ecological knowledge was found to be higher among those who utilized the teaching materials compared to those who relied on common textbooks. The improvement in both overall scores and per-item mean scores was evident. A more detailed analysis of the N-gain reveals the percentage differences in the level of improvement in environmental literacy for each category, as depicted in Figure 1.
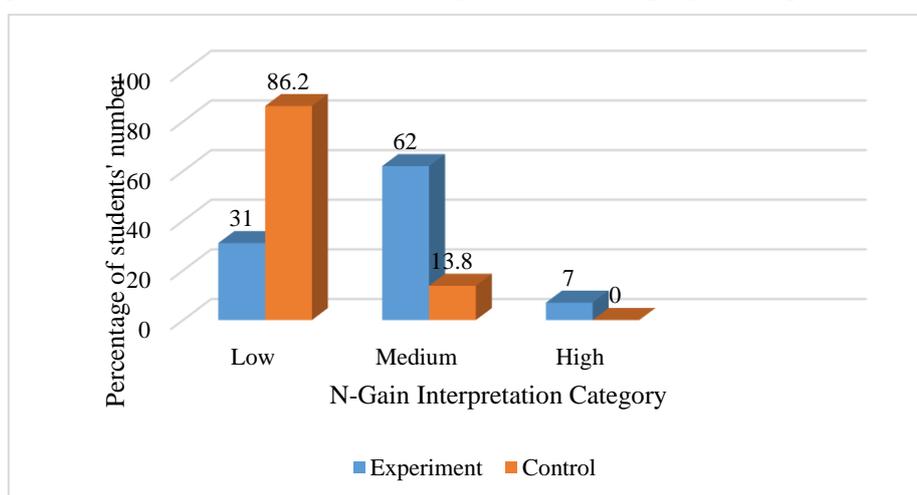

Figure 1. Percentage of the students number based on Environmental Literacy Improvement Category

Furthermore, in addition to enhancing students' ecological knowledge, the developed teaching materials stimulate students' environmental sensitivity. The awareness gained through learning promotes an increased sensitivity to the environment, which in turn leads to responsible behavior and the development of students' character (Wirdianti et al., 2019). Another strategy employed is the integration of environmental content into the secondary school curriculum, thereby strengthening the learning resources available to students. This integration fosters attitudes and behaviors that are essential components of environmental literacy (Varoglu et al., 2018). Moreover, various activities are implemented to heighten students' environmental sensitivity through the school's literacy movement, utilizing appropriate learning resources. The integration of developed teaching materials based on Education for Sustainable Development (ESD) is expected to facilitate activities such as issue identification, analysis, evaluation, and action planning in response to local environmental problems. It has been found that environment-based learning effectively enhances students' attitudes and knowledge (Schmitz & Da Rocha, 2018).

The Effectiveness of Using Teaching Materials on Environmental Literacy

In order to assess the effectiveness of the teaching materials, an effect size was utilized. The effect size analysis was employed to determine the magnitude of the impact that the use of mobile learning teaching materials based on Education for Sustainable Development (ESD) had on students' environmental literacy skills, in comparison to standard textbooks. The results of this analysis are presented in Table 2.

Table 2. Results analysis of the mobile learning teaching material impact on environmental literacy compared to standard textbooks.

ME	MC	SDE	SDC	NTotal	Cohen d	Criteria
41.58	18.57	19.94	16.58	58	1.2	Very High

The effect size yielded a value of 1.2, which is categorized as very high according to Cohen (2018). This indicates that the utilization of mobile learning teaching materials had a significant impact on enhancing students' environmental literacy skills when compared to the use of standard textbooks. The results of the statistical hypothesis test and impact measures further demonstrate that the mobile learning teaching materials were more effective in improving students' environmental literacy skills compared to the use of standard textbooks.

Based on the analysis of the results, an improvement in students' environmental literacy skills was observed. Specifically, the experimental class displayed a higher improvement compared to the control class. Consequently, the use of the developed teaching materials has the potential to enhance students' environmental literacy skills in contrast to the commonly adopted textbooks used in schools. There are several factors that contribute to the higher score of the teaching materials in terms of quality. Firstly, the teaching materials were developed based on the principles of Education for Sustainable Development (ESD). ESD aims to cultivate competencies that empower individuals to consider personal actions in light of present and future social, cultural, economic, and environmental impacts (Klarin, 2018; Perello-Marín et al., 2018). Therefore, in the process of learning, a teacher should be capable of applying ESD values to foster students' character and nurture a sense of environmental care (Didham & Ofei-Manu, 2020). An indicator of environmental care can be assessed through the level of environmental literacy (Hermawan, 2018).

In this manner, students not only acquire knowledge in the field of science, but also develop a deeper understanding of environmental issues, eco-friendly technologies for sustainable living, as well as non-eco-friendly technologies and their impact on sustainability. The findings of Suryawati et al. (2020) demonstrate that learning through the lens of environmental issues could significantly enhance students' environmental literacy. This study also supports the notion that students require learning experiences and activities related to the environment, as highlighted by Dian Pratiwi & Komala (2019). Engaging in environmental education practices directly contributes to one's ability to acquire, modify, and apply environmental knowledge, ultimately leading to an appropriate attitude towards the environment (Zheng et al., 2017).Secondly, the utilization of developed teaching materials is focused on student-centered and contextually relevant materials. These materials are designed to be user-friendly, so that students can effectively comprehend the content without solely relying on teacher explanations. Additionally, the materials and exercises are organized in a contextual manner, for instance, incorporating exercises that promote environmentally friendly actions by students. The exercises are carefully selected based on the appropriateness of the content and environmental literacy indicators, aiming to provide the necessary information to students. Moreover, the materials are specifically tailored to relate to the students' lives. Research conducted by Doyan and Sukmantara (2014) and Ilhami et al. (2019) indicates that the application of contextual teaching materials in science education helps students reinforce their scientific concepts and enhance their environmental literacy. The development of teaching materials that integrate environmental issues must be both accurate and efficient in order to

maximize students' learning outcomes (Azhary et al., 2020). Therefore, the use of learning resources that utilize the surrounding environment can significantly enhance environmental literacy, as proven by studies conducted by Fajeriadi et al. (2019) and Hekmah et al. (2019).

Thirdly, the developed teaching materials are seamlessly integrated with technology. Various visual media and concept representations such as pictures, videos, and graphics are included to create an engaging and accessible learning experience. The incorporation of technology in teaching materials not only makes them more interesting, but also facilitates easy access at any location. The use of visual media in learning has been proven to enhance learning outcomes by presenting information in a more interesting and interactive manner (Chao, 2019). Furthermore, incorporating multiple representations in learning encourages students to engage in reasoning and reflection, enabling them to better comprehend the subject matter (Azhary et al., 2020; Sinaga et al., 2022). Technology also allows for the simulation of natural phenomena, providing a more accurate representation compared to traditional learning methods using textbooks (Setiawan, et al., 2021). Moreover, research by Höffler et al. (2019) highlights the importance of students' active involvement and understanding of the material through suitable teaching materials to enhance their interest in the learning process.Fourth, the development of questions to measure students' environmental literacy extends beyond mere inquiries into their memory. Instead, it incorporates stimuli that reflect aspects of Education for Sustainable Development (ESD) and are relatable to students' daily lives. These stimuli derive from real-life problems that encompass economic, social, and environmental issues. They may also involve challenges pertaining to the eco-friendly technologies present in students' immediate surroundings. In the creation of assessment instruments, it is crucial to select stimuli that are both contextual and captivating (Putranta & Supahar, 2019).

Consequently, the outcomes of this study indicate that mobile learning materials, which employ various forms of representation (both static and dynamic) and are built upon the foundation of ESD, effectively enhance students' thinking skills. These findings align with prior research conducted by Abdurrahman et al. (2019) and Wiyarsi et al. (2018).

CONCLUSION

This study investigated the effectiveness of mobile learning teaching materials that were centered around eco-friendly technology and implemented on students' individual smart phones for the purpose of developing environmental literacy skills in junior high school students. The teaching materials employed a variety of instructional methods that were rooted in Education for Sustainable Development (ESD). ESD emphasizes the importance of integrating knowledge, skills, values, and action competencies in order to foster a deeper understanding of the interconnections between society, environment, and economy.

Environmental literacy skills were taught alongside instruction on eco-friendly technology in both the experimental and control groups. The results of the data analysis indicate that the experimental group demonstrated a significant improvement in environmental literacy skills, achieving a medium level of proficiency. In contrast, the control group only showed a minor improvement, reaching a low level of proficiency. The students who used the mobile learning teaching materialsexhibited a greater increase in both overall environmental literacy scores and individual item scores compared to those who used traditional textbooks.

To further assess the impact of the mobile learning teaching materials, an effect size test was conducted. The analysis revealed a medium effect size of 0.71, indicating a substantial influence of the mobile learning materials on the development of environmental literacy skills.

RECOMMENDATION

Through further studies, it was anticipated that other research topics related to Education for Sustainable Development would be explored. The development of integrated science learning materials on the topic of eco-friendly technology, with a focus on environmental literacy, continues to be limited to a specific concept. However, there is potential to expand

and develop materials to encompass other concepts. Additionally, there is an opportunity to further develop learning materials that are aligned with other skills, such as problem-solving skills.

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