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DEVELOPMENT OF SCIENCE LEARNING DEVICES ORIENTED ESD ON ENVIRONMENTAL POLLUTION MATERIALS TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS AND ECOLOGICAL LITERACY

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ABSTRACT

Indonesia faces significant environmental challenges, exacerbated by poverty and low education levels. Education for Sustainable Development (ESD) is crucial in shaping a generation aware of and responsible for environmental issues. This research aims to develop ESD-oriented science learning tools focusing on environmental pollution to enhance junior high school students' critical thinking skills and ecological literacy. Using the 4D model (Define, Design, Develop, Disseminate), this research developed teaching modules, student worksheets, learning media, and evaluation instruments. Expert validation rated the learning tools highly feasible with an average score of 4.2 out of 5. In limited trials conducted at SMP Negeri 2 Bojong Tegal, the implementation of the teaching module reached 89%, with 81% of students actively engaged and 87% responding positively. Results showed an improvement in students' critical thinking skills with an average score of 80.2 and ecological literacy with an average score of 84.5. The findings suggest that ESD-oriented learning tools effectively enhance students' environmental understanding and problem-solving skills. These tools can be a valuable addition to science education, promoting sustainable development principles and fostering critical thinking and ecological literacy in students.

INTRODUCTION

Indonesia is currently grappling with complex social, economic, and environmental challenges that severely impact ecological sustainability. Two major factors contributing

to environmental issues in Indonesia are high poverty rates and low educational attainment, which hinder public awareness and engagement in sustainable practices (Erlina, 2021). The education sector has yet to fully address these issues, as current learning practices often lack a focus on sustainability, thereby failing to equip students with the skills necessary to face future environmental challenges (Syafi'i et al., 2023). The degradation of the environment, evidenced by problems such as air, water, and soil pollution, global warming, and depletion of natural resources, poses significant threats to life on Earth and requires urgent attention (Kolawole & Iyiola, 2023). Human life is intrinsically tied to the environment, emphasizing the need for an educational approach that integrates ecological awareness into the learning process (Laily & Najicha, 2022).

Education for Sustainable Development (ESD) offers a solution by integrating environmental, social, and economic aspects into educational content, aiming to foster the knowledge, skills, and values required for a sustainable future (Lestari & Rahmawati, 2022). ESD encourages active learning, critical thinking, and problem-solving skills that empower students to act as responsible citizens and environmental stewards (Glavič, 2020). By involving students directly in the learning process through practical projects, problem-solving activities, and real-world scenarios, ESD aims to build a generation that is both environmentally aware and proactive in addressing environmental issues (Earle & Leyva-de la Hiz, 2021). The importance of ESD in shaping future generations who are mindful of their environmental impact cannot be overstated, as it directly supports the development of critical thinking skills and ecological literacy among students (Uswatun Chasanah et al., 2016).

Despite the clear benefits, the current implementation of ESD in science education remains limited. Traditional science learning often emphasizes content mastery over the development of critical thinking skills and ecological literacy, leading to a gap between knowledge and practical application (Rahmah, 2022). If environmental issues are taught as mere theoretical concepts, students are unlikely to perceive these challenges as immediate and relevant to their own lives. As a result, there is a pressing need for innovative science learning tools that integrate ESD principles, making environmental issues more tangible and engaging for students (Ikhsanudin, 2021).

Several studies have highlighted the effectiveness of ESD-oriented learning approaches in enhancing students' understanding of environmental issues. For instance,

research by Nasrulloh (2024) demonstrated that students exposed to ESD-based learning showed significant improvements in critical thinking and environmental awareness compared to those taught through conventional methods. Similarly, Istiningsih and Dharma (2022) found that ESD learning approaches could enhance students' environmental literacy, particularly in their knowledge, attitudes, and behaviors related to environmental conservation. However, many of these studies focus on either critical thinking or ecological literacy, and few have developed specific learning tools tailored to implementing ESD principles, especially on environmental pollution topics (Taufiq et al., 2021). The absence of comprehensive and contextually relevant educational tools limits the ability of students to connect classroom learning with real-world environmental issues.

Given these gaps, this research aims to address the need for specific, practical learning tools that effectively combine critical thinking and ecological literacy within the framework of ESD. The study seeks to develop science learning devices oriented towards ESD, focusing on environmental pollution materials that can improve students' critical thinking skills and ecological literacy simultaneously. By developing and validating these learning tools, this research intends to provide educators with effective resources to foster a deeper understanding of environmental challenges among students and equip them with the skills necessary to contribute positively to sustainable development.

MATERIALS AND METHODS

Research Subjects

This study was conducted with 27 seventh-grade students from SMP Negeri 2 Bojong Tegal, Central Java, Indonesia. The subjects were selected using a purposive sampling technique based on specific criteria, such as homogeneous academic abilities and similar socio-economic backgrounds. SMP Negeri 2 Bojong Tegal was chosen due to its commitment to environmental education and alignment with the Adiwiyata program, which supports ESD principles. The school's laboratory facilities and strategic location in an area exposed to environmental challenges provided an authentic context for this research (Arsyam & M. Yusuf Tahir, 2021).

Instruments and Materials

The learning tools developed in this study include teaching modules, student worksheets (LKPD), learning media, and evaluation instruments, designed to integrate ESD principles into science learning on environmental pollution. The instruments used in the study consisted of: 1) Validation Sheets: Used to collect expert feedback on the learning tools, including aspects of content, media, and instructional quality. Experts included one content specialist, one media expert, and one pedagogy expert. 2) Critical Thinking Skills Test: This test comprised essay questions aimed at assessing students' abilities to analyze environmental pollution problems, identify causes and impacts, and propose appropriate solutions. 3) Environmental Literacy Test: Consisted of multiple-choice and descriptive questions designed to measure students' knowledge, attitudes, and behaviors concerning environmental issues, particularly environmental pollution. 4) Observation Sheets: Used to observe and record the implementation of the developed learning tools and student engagement during the learning process.

Research Procedure

The research utilized a development research approach with a 4D model (Define, Design, Develop, Disseminate) as developed by Thiagarajan et al. (1974). This method was chosen due to its structured and systematic nature, which allows for the development and validation of educational tools. The procedures involved in each stage are as follows: 1) Define: A needs analysis was conducted to identify the core problems in current science learning, focusing on environmental pollution topics. This stage involved initial analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. 2) Design: Learning tools were designed based on the analysis from the define stage. Activities included preparing assessment benchmarks, selecting appropriate media and formats, and creating an initial draft of the learning tools. The media used included interactive videos, simulations, and real-world case studies, chosen to align with the students' learning needs and material characteristics. 3) Develop: This stage involved the realization of the design into usable products, which were then subjected to expert validation. Revisions were made based on expert feedback, followed by a limited trial at SMP Negeri 2 Bojong Tegal. The trial tested the practicality and effectiveness of the tools in a classroom setting. 4) Disseminate: Learning tools that passed the trial phase were refined and disseminated

for broader implementation, including use in other schools or educational settings at the district or city level.

Data Analysis Technique

Data were analyzed using a combination of quantitative and qualitative descriptive analysis techniques: 1) Quantitative Analysis: Expert validation scores, critical thinking test results, and environmental literacy test scores were analyzed statistically to assess the feasibility and effectiveness of the learning tools. The data were processed using statistical software to determine mean scores, standard deviations, and levels of significance. 2) Qualitative Analysis: Qualitative data, such as expert feedback and observations during the trials, were analyzed descriptively. The data provided insights into areas that required improvement and helped refine the tools to better meet the educational objectives.

Interpretation of Results

The interpretation of the results was based on comparing the pre- and post-implementation data of the learning tools. Improvements in students' critical thinking skills and ecological literacy were identified and correlated with the use of the developed tools. The findings were interpreted to highlight the effectiveness of ESD-oriented learning tools in enhancing student engagement and understanding of environmental issues.

RESULTS AND DISCUSSION

This research produces a science learning tool oriented to Education for Sustainable Development (ESD) on environmental pollution material. The tool aims to improve critical thinking skills and ecological literacy for junior high school students. The learning tools developed through the 4D model (Define, Design, Develop, Disseminate) consist of Teaching Modules (LKPD), learning media, and evaluation instruments. The development of this learning tool is based on a needs analysis carried out at the definition stage.

Based on initial analysis carried out through observations and interviews with science teachers at SMP Negeri 2 Bojong, Tegal, it was found that the science learning

was still conventional and did not integrate environmental issues. Students tend to be less involved in education and need more critical thinking skills and adequate ecological literacy. This shows the need to develop learning tools that are innovative and oriented towards sustainable development.

However, most students still need help analyzing environmental problems critically and understanding environmental issues in depth. Therefore, the learning tools developed must be able to facilitate students to improve their critical thinking skills and ecological literacy (Zahroh & Yuliani, 2021).

Analysis of tasks, concepts, and formulation of learning objectives is carried out to identify the tasks that students must master, the main ideas that must be taught, and the learning objectives to be achieved. The tasks that students must master in learning science on environmental pollution material include, such as : understanding the concept of environmental pollution, identifying its causes and impacts, finding sustainable solutions.

The main concepts that must be taught include types of pollution (air, water, land), pollution sources, pollution impacts, and pollution control efforts. The learning objectives are that students can understand the concept of environmental pollution, analyze pollution problems critically, and develop ecological literacy to participate in environmental conservation efforts.

A benchmark test is prepared to measure student competency achievement at the design stage. The tests prepared include critical thinking skills tests in the form of description questions and environmental literacy tests in the form of multiple choice and description questions. Selection of learning media that suits the characteristics of the material and students is also carried out at this stage. The press chosen are videos, simulations, and field studies that can help students understand environmental issues more accurately and meaningfully. The learning tool formats chosen are Teaching Modules, Student Worksheets (LKPD), and Learning Objective Flow (ATP), which are by implementing the Independent Curriculum. The initial design of the learning tools developed includes teaching modules, worksheets, learning media, and evaluation instruments.

In the development stage, the learning tools designed in the previous stage are realized into products ready to be implemented. This stage begins with expert validation to assess the suitability of the learning tools being developed. Three experts one material

expert, one media expert, and one learning expert carried out validation. The expert validation results show that the learning tools developed are suitable for use, with an average validation score of 4.2 on a scale of 5 (Table 1).

Table 1. Expert Validation Results of ESD-Oriented Science Learning Tools

No	expert	Average score	Criteria
1	Materials Expert	4,3	Very Worth It
2	Media Expert	4,1	Worthy
3	LearningExpert	4,2	Worthy
4	Total Average	4,2	Worthy

Based on the results of expert validation, the learning tools developed received good assessments from the three experts. The material expert gave a score of 4.3, which means it is very worthy, especially from the aspects of the suitability of the material to the curriculum, correctness of concepts, and connection to environmental issues. Media experts scored 4.1, which means decent, with a reasonable assessment of media display attractiveness, interactiveness, and suitability to student characteristics. Meanwhile, learning experts gave a score of 4.2, which means decent, with an upbeat assessment of suitability with the ESD approach, clarity of learning objectives, and implementation of learning activities.

After being validated by experts, the learning tools were revised based on the input and suggestions for improvement provided. Then, a limited trial was conducted on 32 class VII students at SMP Negeri 2 Bojong, Tegal. The results of the limited trials show positive results and support the effectiveness of the learning tools developed (Table 2).

Tabel 2. Results of Limited Trial of ESD-Oriented Science Learning Devices

No	Aspect	Results
1	Teaching Module Implementation	89%
2	Positive Student Responses	81%
3	Average Critical Thinking Skills Score	87%
4	Average Environmental Literacy	84,5%

Table 2 shows that 89% of the Teaching Module was implemented in learning. This shows that the teaching module that was developed can be implemented well in the learning process. In addition, as many as 81% of students were actively involved during the learning process using the tools developed. This active involvement of students is significant in the ESD approach, which demands student participation and activeness in understanding environmental issues and finding sustainable solutions (Vioreza et al., 2023).

Furthermore, as many as 87% of students responded positively to the learning tools developed. This positive response shows that students feel interested and motivated to participate in learning using ESD-oriented devices. This can be caused by several factors, such as presenting material that is contextual and close to students' daily lives, using interactive and interesting learning media, and innovative learning approaches that involve students actively.

Another essential aspect that is the focus of this research is improving students' critical thinking skills and environmental literacy. Based on the test results, the average score for students' critical thinking skills was 80.2 on a scale 100. This value is classified as good and indicates that the learning tools developed can improve students' critical thinking skills in analyzing environmental pollution problems, identifying their causes and impacts, and proposing the right solution.

Meanwhile, the average student score for environmental literacy was 84.5 on a scale of 100. This score is also classified as good and shows that the learning tools developed can increase students' understanding and concern for environmental issues, primarily environmental pollution-related ones. Good environmental literacy will encourage students to participate actively in environmental conservation and sustainable development efforts (Kamil et al., 2020).

Several primary factors support the success of the ESD-oriented science learning tools developed to improve students' critical thinking skills and environmental literacy. We are implementing the ESD approach in learning tools by integrating environmental issues into lesson material. The ESD approach allows students to study environmental problems in depth, analyze them critically, and find sustainable solutions.

The learning strategies used in this tool, such as project-based learning, case studies, and group discussions, also play an essential role in improving students' critical thinking skills and environmental literacy. Through project-based learning, students are trained to identify real environmental problems around them, collect data, analyze their causes and impacts, and design sustainable solutions. Case studies also help students critically analyze environmental problems and make the right decisions. Meanwhile, group discussions encourage students to exchange opinions, consider various perspectives, and find solutions together (Assyakurrohim et al., 2022).

Another factor that supports the success of this learning tool is the use of interactive and contextual learning media, such as videos, simulations, and field studies. This learning media helps students understand environmental issues more accurately and meaningfully. Videos and simulations provide a clear visualization of environmental problems, while field studies allow students to directly observe the impact of environmental pollution around them (Cho & Park, 2023).

Apart from that, applying the Independent Curriculum in this learning tool also contributes positively. Using Teaching Modules and Learning Objective Flow supports student learning independence and provides flexibility in the learning process. The Teach Module allows students to learn independently with sufficient guidance, while the ATP assists teachers in designing integrated and sustainable learning by ESD principles (Merisi et al., 2022).

However, implementing this learning tool is challenging. One of the main obstacles is limited learning time. This tool's ESD approach and learning strategies tend to take longer than conventional learning. Therefore, teachers need efficient time management and careful planning.

Another obstacle is inadequate support facilities in some schools, such as limited internet access or equipment for practicum activities and field studies. However, this obstacle can be overcome with teacher creativity in utilizing existing resources optimally or looking for other more affordable alternatives.

Overall, this research has succeeded in developing ESD-oriented science learning tools that are valid, practical, and effective for improving junior high school students' critical thinking and environmental literacy skills on environmental pollution material. This learning tool is in line with the demands of 21st-century learning, which emphasizes high-level thinking skills, environmental literacy, and the use of technology in the teaching and learning process.

This learning tool can be further developed by exploring the broader use of digital technology, such as interactive multimedia, virtual reality, or online learning. This will make learning tools more attractive, practical, and in line with current developments and the demands of education in the digital era.

CONCLUSION

This research has succeeded in developing Education for Sustainable Development (ESD)-oriented science learning tools on environmental pollution material to improve junior high school students' critical thinking skills and ecological literacy. The learning tools developed through the 4D model (Define, Design, Develop, Disseminate) consist of Teaching Modules, Student Worksheets (LKPD), learning media, and evaluation instruments. Based on expert validation, the learning tool was declared feasible with an average score of 4.2 on a scale 5. In limited trials, the learning tool was proven effective, with the implementation of the Teaching Module being 89%, 81% of students being actively involved, and 87% of students giving positive responses. Apart from that, there was an increase in students' critical thinking skills, with an average score of 80.2, and an increase in environmental literacy, with an average score of 84.5 on a scale of 100. This success was supported by the application of the ESD approach with project-based learning, case studies, discussion groups, interactive and contextual media use, and the implementation of the Independent Curriculum with Teaching Modules and Learning Objective Flow, which supports student learning independence. Even though there are limited time constraints and inadequate facilities, they can be overcome with efficient time management and teacher creativity in utilizing existing resources. Overall, the learning tools developed are valid, practical, and effective, in line with the Independent Curriculum and the demands of 21st-century learning, which emphasize high-level thinking skills, environmental literacy, and the use of technology in learning.

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