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DEVELOPMENT OF AN INTEGRATED ESD EVALUATION MODEL FOR MATTER AND ENERGY LECTURES TO IMPROVE ENERGY AND SCIENCE LITERACY

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ABSTRACT

This study aims to develop an evaluation model for the integrated Energy and Matter lecture in Education for Sustainable Development (ESD) based on energy literacy and scientific literacy for prospective science teachers. The study employed the Research and Development (R&D) method with the ADDIE model, encompassing the stages of analysis, design, development, implementation, and evaluation. The subjects were 30 students from the Science Education Study Program. The research instruments included an expert validation sheet, energy and scientific literacy tests, and a student response questionnaire. Data were analyzed using descriptive statistics and N-gain calculations. The results showed that the developed evaluation model had a very high level of validity and was suitable for use in lectures. The implementation of the integrated ESD evaluation model was able to improve students' energy and scientific literacy with a moderate increase. Furthermore, student responses to the evaluation model were very positive, particularly in terms of relevance to sustainability issues and the development of critical thinking. Therefore, this evaluation model has the potential to be an innovative alternative to support sustainability-oriented science learning and strengthen the competencies of prospective science teachers. Keywords: learning evaluation, Education for Sustainable Development, energy literacy, science literacy, science education.

INTRODUCTION

Higher education plays a strategic role in preparing human resources capable of facing the global challenges of the 21st century, particularly those related to the energy crisis, environmental degradation, and the demands of sustainable development (Arifin, 2020). In the context of science education, prospective science teachers are not only required to master theoretical scientific concepts but also to possess adequate literacy skills to transform this knowledge into meaningful and sustainability-oriented learning practices (Suryani & Nugroho, 2021). Therefore, learning and evaluation processes in higher education need to be systematically designed to align with global demands and national and international education policies (Widodo, 2022).

One of the fundamental courses in science education study programs is the study of matter and energy, which serves as an important foundation for understanding natural phenomena, technology, and various problems in everyday life (Rahmawati, 2020). The concepts of matter and energy are closely related to strategic global issues, such as the use of renewable energy, energy efficiency, climate change, and environmental sustainability (Hidayat, 2023). However, research results show that learning about matter and energy in higher education still tends to be oriented towards cognitive mastery of concepts and has not fully developed students' energy literacy and science literacy comprehensively (Putri, 2021).

Energy literacy is defined as an individual's ability to understand basic energy concepts, recognize the impacts of energy use on the environment and society, and make responsible decisions regarding energy issues (DeWaters & Powers, 2019). Meanwhile, scientific literacy encompasses the ability to use scientific knowledge, identify science-based questions and problems, and draw conclusions supported by scientific evidence in personal and social decision-making (Bybee, 2021). These two forms of literacy are essential competencies that prospective science teachers must possess to equip students with a relevant and contextual understanding of science (Susanti, 2020).

In line with these demands, Education for Sustainable Development (ESD) is seen as a strategic approach to integrating sustainability principles into the education system at all levels, including higher education (UNESCO, 2017). ESD emphasizes the development of knowledge, skills, values, and attitudes that enable individuals to actively contribute to sustainable development (Tilbury, 2020). The integration of ESD in science learning, particularly in the material on matter and energy, is considered highly relevant because it is able to link scientific concepts with real problems faced by the global community (Wiek et al., 2021).

Nevertheless, the implementation of ESD in higher education still faces various challenges, one of which is the limited availability of course evaluation models capable of holistically measuring the achievement of ESD objectives (Lozano, 2022). Learning evaluation in higher education generally focuses on cognitive aspects through written tests, while the dimensions of energy literacy, scientific literacy, and sustainability values and attitudes have not been optimally accommodated (Lestari, 2022). Consequently, the learning outcomes expected from ESD integration are often not measured comprehensively and sustainably (Kurniawan, 2023).

Course evaluation plays a crucial role as a reflection instrument for assessing the effectiveness of the learning process and the achievement of graduate learning outcomes (Sudjana, 2019). A comprehensive evaluation model should not only assess final learning outcomes but also encompass the process, context, and impact of learning on student competency development (Wiggins & McTighe, 2019). Therefore, the development of an evaluation model for lectures on substances and energy that is integrated with ESD and based on energy literacy and science literacy is an urgent need in the education of prospective science teachers (Prasetyo, 2024).

Various national studies have shown that integrating ESD into science learning has the potential to improve students' conceptual understanding, environmental awareness, and sustainability attitudes (Rahmawati, 2020; Widodo, 2022). However, most of this research focuses on the learning aspect and has not yet developed a systematic and applicable evaluation model to simultaneously assess the achievement of energy literacy and science literacy (Putri, 2021). Meanwhile, international research focuses more on ESD curriculum and pedagogy development, while studies on ESD-based course evaluation are relatively limited (Sterling, 2020).

This research gap highlights the need to develop a course evaluation model that is not only valid and reliable but also contextualized to the needs of prospective science teachers in Indonesia (OECD, 2021). The developed evaluation model is expected to serve as a practical guide for lecturers in designing, implementing, and evaluating ESD-oriented courses on matter and energy (Fensham, 2020). In addition, this model is expected to encourage continuous improvement in the quality of science learning in higher education (Holbrook & Rannikmae, 2021).

The development of an integrated ESD (Education for Sustainable Development) model for evaluating energy and science-based lectures on matter and energy has strategic implications for improving the quality of science teacher education (Arends, 2018). Prospective teachers with strong energy and science literacy will be better prepared to face the challenges of 21st-century learning and will be able to instill sustainable values in their students (Miller, 2020). Therefore, this research not only contributes to the development of science education science but also supports the achievement of sustainable development goals at both the national and global levels (UNESCO, 2020).

Based on this description, it can be concluded that the development of an integrated ESD (Education for Sustainable Development) model for evaluating energy and science-based lectures on matter and energy is a strategic step in addressing the challenges of prospective science teacher education in the era of sustainability (Zoller, 2018). This research is expected to provide theoretical and practical contributions to the development of relevant, innovative, and future-oriented science learning evaluations (Creswell, 2018).

RESEARCH METHODOLOGY

This study employed a Research and Development (R&D) approach, aiming to develop an integrated evaluation model for the Education for Sustainable Development (ESD) Substance and Energy course, based on energy literacy and science literacy for prospective science teachers. The R&D approach was chosen because this research not only focused on measuring learning effectiveness but also on producing an educational product in the form of a systematic, valid, practical, and effective evaluation model for use in higher education contexts (Sugiyono, 2020; Creswell, 2018).

The development model used was the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model because it has clear, logical stages and is appropriate for developing competency-based and sustainability-based learning evaluation models (Arends, 2018). The subjects of this study were students of the Science Education Study Program who were taking the Matter and Energy course. The research sample was determined at 30 Science Education students, selected using a purposive sampling technique, with the consideration that all students were taking the same course, using a uniform RPS, and were in a semester relevant to the implementation of ESD. In addition to students, lecturers teaching the course were also involved as users of the evaluation model.

RESULT AND DISCUSSION

The initial phase of the research focused on expert validation of the integrated Energy and Matter lecture evaluation model for Education for Sustainable Development (ESD) based on energy literacy and science literacy. Validation was conducted by three experts: a science education expert, a learning evaluation expert, and an ESD expert.

Aspects assessed included content feasibility, model construction, indicator clarity, ESD integration, and measurability of energy and science literacy.

The validation results showed that the developed evaluation model achieved an average score of 3.62 on a scale of 4, which is categorized as highly valid. Specifically, the ESD integration aspect received the highest score, followed by the clarity of energy and science literacy indicators. This indicates that the evaluation model aligns with the sustainability principles and literacy competencies that are the focus of the research.

Table 1. Expert Validation Results of Evaluation Model

Language Acquisition	Average Score	Category
Rated aspect	3,60	Very Valid
Model construction	3,56	Very Valid
ESD Integration	3,70	Very Valid
Energy literacy	3,63	Very Valid
Scientific literacy	3,61	Very Valid
Average	3,62	Very Valid

These results indicate that the developed evaluation model is suitable for implementation at the limited trial stage in the Matter and Energy lecture. A limited trial was conducted on 30 Science Education students taking the Matter and Energy course. The evaluation model was applied throughout one lecture cycle and used to assess the process and outcomes of ESD-integrated learning.

The energy literacy test results showed a significant increase between pretest and posttest scores. The average pretest score for students was 56.4, while the average posttest score increased to 78.6. The N-gain calculation showed a value of 0.51, which is considered moderate.

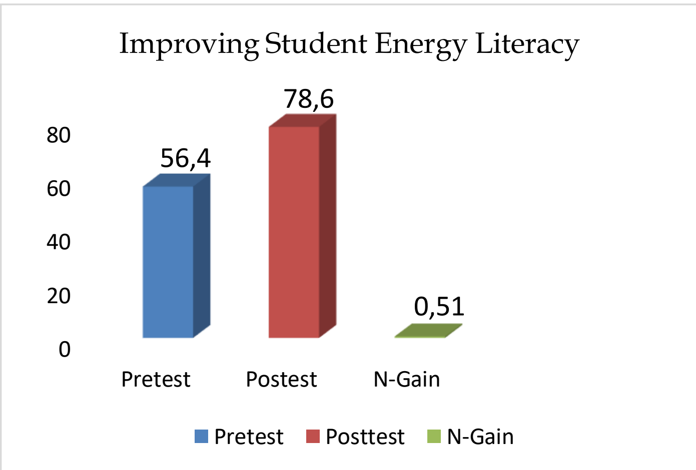


Figure 1. Graph of Increase in Student Energy Literacy Scores

These results indicate that the application of the ESD-based evaluation model not only functions as an assessment tool, but also encourages students to understand energy concepts in a more contextual and sustainable manner.

In addition to energy literacy, students' scientific literacy also improved. The average pretest score for scientific literacy was 58.2, while the posttest score increased to 80.1. An N-gain of 0.53 indicates moderate improvement.

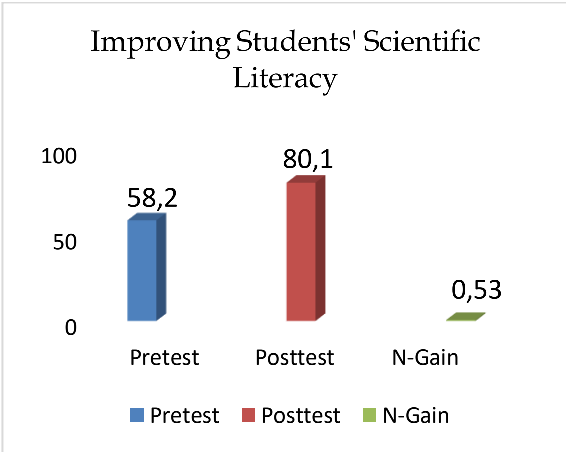
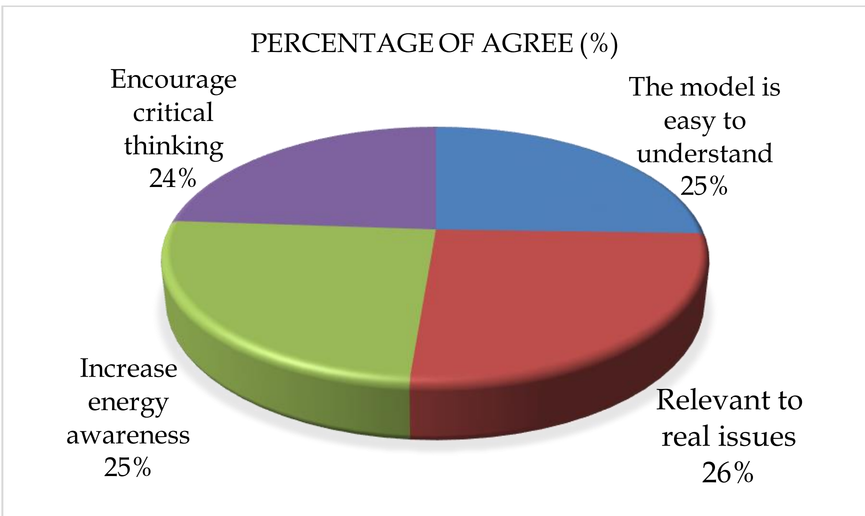


Figure 1. Graph of Student Science Literacy Score Improvement

This increase indicates that the integration of ESD in course evaluation encourages students to use scientific knowledge in analyzing real-world problems related to matter and energy. Student responses to the use of the evaluation model were overwhelmingly positive. 86.7% of students stated that the evaluation model helped them understand the relationship between the concepts of matter and energy and sustainability issues. Furthermore, 83.3% of students stated that the evaluation indicators encouraged them to think more critically and reflectively.



The research results indicate that the integrated ESD-based evaluation model for the "Matter and Energy" course, based on energy literacy and scientific literacy, has a very high level of validity and is capable of improving the literacy competency of prospective science teachers. This finding aligns with the view that learning evaluation serves not only as a tool for measuring learning outcomes but also as a learning tool in itself (Wiggins & McTighe, 2019).

The improvement in students' energy literacy demonstrates that the integration of ESD principles into evaluations can guide students toward a more meaningful and contextual understanding of energy concepts. According to DeWaters and Powers, energy literacy relates not only to conceptual understanding but also to awareness and decision-making regarding sustainable energy use. The evaluation model developed in this study explicitly incorporates these indicators, encouraging students to reflect on the impact of energy use in their daily lives.

The results of the improvement in scientific literacy also support Bybee's scientific literacy theory, which states that scientific literacy encompasses the ability to apply scientific knowledge to solve real-world problems. The integration of ESD in the evaluation of matter and energy lectures provides an authentic context for students to relate science concepts to environmental and social issues, making learning more meaningful.

The findings of this study align with Tilbury's research, which asserts that ESD, which interacts systematically in learning and evaluation, can foster the development of desired competencies in students. Furthermore, the results of this study support Lozano's view, which emphasizes the importance of holistic evaluation in assessing the achievement of ESD goals in higher education.

Students' positive responses to the evaluation model indicate that prospective science teachers welcomed the evaluation approach, which assesses not only cognitive aspects but also attitudes and awareness of desired values. This is important because prospective teachers play a role in transforming desired values into students at school. Therefore, this developmental evaluation model holds long-term promise for improving the quality of science education.

Theoretically, the results of this study reinforce the authentic evaluation theory proposed by Wiggins and McTighe, which emphasizes the importance of assessment based on real and meaningful contexts. The evaluation model developed by Wiggins and McTighe measures not only what students know but also how they use that knowledge in desired contexts.

From an ESD perspective, this research supports the sustainability competency framework proposed by Wiek et al., which encompasses systems thinking, critical thinking, and sustainable decision-making. The indicators in the evaluation model are explicitly designed to measure these competencies in the context of matter and energy.

The practical implication of this research is the availability of an evaluation model that can be used by science education lecturers as a guide in assessing ESD-based courses. This model can also serve as a basis for developing evaluations for other courses relevant to sustainability issues. Thus, this research contributes to the development of innovative science learning evaluation practices that are relevant to the demands of the 21st century.

Overall, the results and discussion of this study indicate that the development of an ESD-integrated evaluation model for the Matter and Energy course based on energy literacy and science literacy is effective in improving the competencies of prospective science teachers. These findings emphasize the importance of integrating ESD not only in teaching but also in the evaluation system as an integral part of sustainability education in higher education.

CONCLUSIONS AND SUGGESTIONS

Based on the research results and discussion, it can be concluded that the integrated Energy and Matter lecture evaluation model developed by Education for Sustainable Development (ESD) based on energy literacy and scientific literacy has a very high level of validity and is suitable for implementation in Science Education courses. The implementation of this evaluation model has been proven to improve the energy and scientific literacy of prospective science teacher students, as demonstrated by the increase in pretest to posttest scores for both aspects. The integration of ESD principles into learning evaluation not only serves as a measure of learning outcomes but also encourages students to understand the concepts of matter and energy contextually, critically, and with a sustainability orientation. Thus, this evaluation model significantly contributes to supporting the achievement of 21st-century competencies and strengthening the role of science education in sustainable development.

Based on these research findings, it is recommended that this integrated ESD lecture evaluation model be applied more broadly to other courses relevant to sustainability issues in Science Education study programs and other science fields. Furthermore, further research is needed involving a larger sample size and different institutional contexts to test the consistency and effectiveness of this evaluation model. Further development can also be directed at integrating digital technology into the evaluation system and measuring the long-term impact on the pedagogical and professional competencies of prospective science teachers in implementing ESD in schools.

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