



BUILDING SUSTAINABILITY AWARENESS : INTEGRATING ESD INTO HUMAN DIGESTIVE SYSTEM EDUCATION

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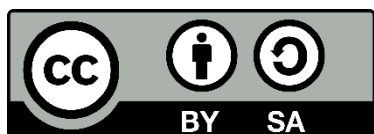
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ARTICLE INFO		ABSTRACT
Article history		<i>This study aimed to develop and evaluate Education for Sustainable Development (ESD)–oriented science learning materials on the human digestive system to enhance students’ sustainability awareness. Employing a Research and Development (R&D) approach and the ADDIE model, the instructional materials were implemented in a quasi-experimental design with two eighth-grade groups at SMP Negeri 2 Tulis during the 2024/2025 odd semester. Sustainability awareness was measured using a 26-item questionnaire administered as a pretest and posttest. The experimental group, which received the ESD-oriented intervention, demonstrated a mean pretest score of 70.55 and a posttest score of 92.06 (mean N-Gain = 0.63). The experimental group showed significantly higher gains in both sustainability awareness—especially in emotional engagement—compared to the control group. These outcomes suggest that integrating ESD into science learning not only improves conceptual understanding but also shaping environmentally responsible and reflective students.</i>
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INTRODUCTION

With the pressing global challenges of climate change, biodiversity loss, pollution, and the depletion of natural resources, the need for sustainability awareness has never been more urgent, particularly among younger generations. Previous studies in Indonesia and abroad have shown that a shift towards sustainable conservation in education can effectively foster environmental awareness and concern in primary schools. It's also been found that while youth in metropolitan areas recognize environmental issues, their eco-

friendly practices are inconsistent. Additionally, a pro-environmental school culture significantly enhances students' environmental awareness and the success of green initiatives (Shutaleva *et al.*, 2022; Pravitasari & Nugraheni, 2024; Tanubrata *et al.*, 2024). Education plays a pivotal role in shaping values, attitudes, and behaviors that support sustainable lifestyles (Mujahidin *et al.*, 2023; Firdaus & Nugraheni, 2024; Ray *et al.*, 2024). However, in practice, the integration of sustainability into science education at schools remains limited mainly to the transmission of cognitive knowledge, without promoting critical reflection or establishing meaningful connections between scientific understanding and environmental, social, and economic issues (Syaiful, 2024). This gap poses a critical challenge in preparing students to become conscious and responsible citizens who are actively engaged in sustainable development. Therefore, strengthening sustainability awareness through science education, particularly on topics closely related to everyday life such as health and dietary habits, is increasingly important (Journal *et al.*, 2025; Octavia *et al.*, 2025; Ristiani *et al.*, 2025).

Previous studies have attempted to address these challenges by implementing ESD principles in interdisciplinary learning, including science subjects. ESD aims to equip students with competencies in critical thinking, problem-solving, and responsible decision-making in the context of sustainability issues (UNESCO *et al.*, 2014; Wahid *et al.*, 2025). Research by Muntamah *et al.* (2024) demonstrates that ESD-based approaches can foster higher-order thinking skills and promote real, sustainable actions. Similarly, Laela *et al.* (2024) reveal that ESD-based learning in schools enhances students' sustainability-oriented attitudes. However, the potential of science topics—such as the human digestive system—remains underutilized as a strategic context for developing sustainability awareness grounded in scientific understanding and interconnected environmental, economic, and socio-cultural dimensions. This untapped potential is a significant area for further research and development.

This study extends and deepens previous findings by developing a comprehensive learning framework that explicitly integrates ESD principles into the topic of the human digestive system. Recent research on senior high school students found that although they had moderate to good understanding of the digestive system and high nutrition knowledge, these were not significantly related to their actual healthy eating habits (Saputra & Nurlim, 2025). The novelty of this research lies in the development of ESD-

based science learning materials that not only emphasize conceptual understanding but also promote sustainability awareness. The digestive system topic was deliberately chosen for its strong relevance to students' daily lives and its potential to serve as an entry point for exploring connections between individual health, food consumption patterns, and environmental sustainability. This unique approach is a significant contribution to the field of science education and sustainability awareness.

This study is expected to yield two main contributions. First, it offers a set of ESD-based science learning materials that are valid, practical, and effective in supporting the development of students' sustainability awareness. Second, the implementation of these materials is anticipated to strengthen students' understanding of the relationship between the human digestive system, health, and environmental issues. By linking scientific content with real-world challenges, this research aims to foster environmental responsibility and empower learners to make informed decisions that promote healthy and sustainable lifestyles. More broadly, this study contributes to strengthening the practice of ESD in Indonesia by providing a theoretically grounded and practically applicable model of science education.

MATERIALS AND METHODS

This study employed a R&D approach to develop ESD-based science learning materials on the human digestive system, aiming to improve students' sustainability awareness. The development process followed the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). The quasi-experimental pretest-posttest control group design was embedded in the **Implementation** and **Evaluation** stages of the R&D process to empirically test the effectiveness of the developed materials. During these stages, the materials that had passed expert validation were trialed in actual classroom settings. One class (experimental group) received the ESD-based learning materials, while another class (control group) received conventional instruction.

The participants were eighth-grade students at SMP Negeri 2 Tulis, Batang Regency (2024/2025 odd semester). Two classes with similar academic characteristics were purposively selected: one as the experimental group and one as the control group. The research instrument was a Sustainability Awareness Questionnaire (26 items

covering environmental, socio-cultural, and economic dimensions), validated by experts. Data were collected through questionnaires and analyzed with SPSS, including tests for validity, practicality, and effectiveness, N-gain analysis, and independent sample t-tests. Ethical approval was obtained from the institutional ethics committee, and informed consent was secured from all participants. The participants were eighth-grade students at SMP Negeri 2 Tulis, Batang Regency (2024/2025 odd semester). Two classes with similar academic characteristics were purposively selected: one as the experimental group and one as the control group. The research instrument was a Sustainability Awareness Questionnaire (26 items covering environmental, socio-cultural, and economic dimensions), validated by experts. Data were collected through questionnaires and analyzed with SPSS, including tests for validity, practicality, and effectiveness, N-gain analysis, and independent sample t-tests. Ethical approval was obtained from the institutional ethics committee, and informed consent was secured from all participants.

RESULTS AND DISCUSSION

Data on students' sustainability awareness were collected through the administration of a pretest and posttest using a questionnaire consisting of 26 items, developed based on the framework proposed by Hassan *et al.* (2010). The instrument assesses three core dimensions of sustainability awareness: awareness of sustainable practices, awareness of attitudes and habits, and emotional awareness. The average pretest and posttest scores of sustainability awareness among participants in both the experimental and control groups are presented in the following figure, offering a comparative overview of students' levels of sustainability awareness before and after the instructional intervention. Notably, the comparison between the two groups provides insights into the effectiveness of the intervention.

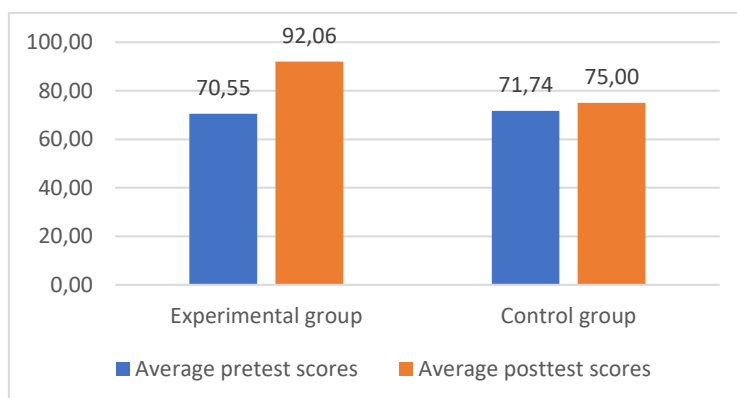


Figure 1. Mean Pretest and Posttest Scores of Sustainability Awareness
in the Experimental and Control Groups

As shown in Figure 1, both groups demonstrated a positive trend in their mean scores, indicating progress. This research, following the ADDIE stages, began with a needs analysis that revealed a limited integration of ESD principles in the topic of the digestive system. We then designed and developed validated learning materials, which were rated as highly feasible by experts. During implementation, the experimental group's mean score increased from 70.55 to 92.06, while the control group's mean score also saw an increase, from 71.74 to 75.00. The evaluation stage confirmed that the developed materials effectively improved students' conceptual understanding and sustainability awareness. This demonstrates that ESD-oriented instruction not only enhances students' cognitive domain but also fosters the development of sustainability-related attitudes and values. As a result, students developed an enhanced awareness of the importance of sustainable living practices and a greater emotional engagement with the environmental and health consequences of their choices (Bonilla-Jurado et al., 2024).

The pretest and posttest were meticulously conducted to evaluate students' sustainability awareness using a 26-item questionnaire. The instrument was developed based on the categorization proposed by Hassan et al. (2010), which classifies sustainability awareness into three key dimensions: awareness of sustainable practices, awareness of attitudes and habits, and emotional awareness. Each item in the questionnaire was carefully designed to reflect one of these three categories, ensuring a thorough evaluation of students' understanding and internalization of sustainability concepts. The average pretest and posttest scores for each indicator in the experimental group are presented in the following figure, providing a comprehensive view of the

progression of students' sustainability awareness after participating in ESD-oriented learning.

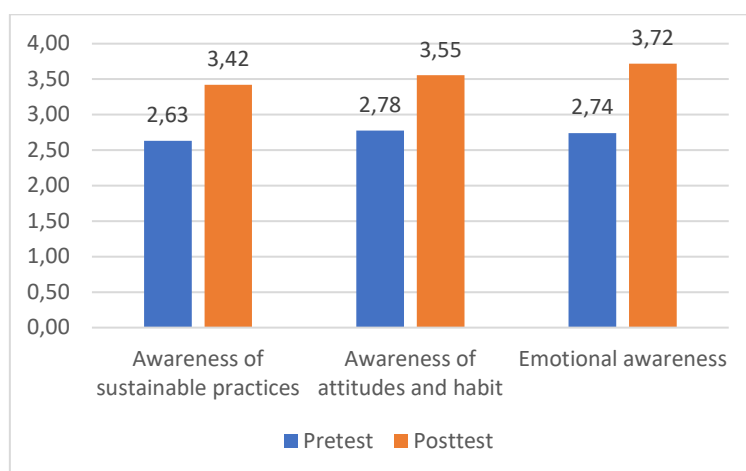


Figure 1. The mean scores of the pretest and posttest per sustainability awareness indicator in the experimental groups

Based on the figure above, the experimental group demonstrated an increase in pretest to posttest scores across all indicators of sustainability awareness. For the awareness of sustainable practices indicator, the average score increased by 0.79, indicating that students not only gained a better understanding of actions that support sustainability in their daily lives, but also the ability to identify and implement these practices. In the awareness of attitudes and habits category, there was a score increase of 0.78, reflecting a positive shift in students' behaviors and attitudes toward sustainable living. The highest improvement was observed in the emotional awareness indicator, with an average gain of 0.98, suggesting that students developed a stronger emotional engagement with sustainability issues and showed increased empathy toward the environmental and health consequences of human actions (AlQallaf et al., 2024; Carmona et al., 2024; Liga et al., 2024).

The 'Emotional Awareness' indicator, which showed the most significant increase in scores among the three indicators, is of particular importance. This improvement not only manifests in the test results but also in the observed behavioral changes in students post-intervention. A notable example of this change is the students' proactive measures to reduce plastic waste. They began bringing their own food from home and carrying their own eating utensils and drinking containers when purchasing food at the school canteen. This behavior, which is a direct application of their sustainability knowledge,

demonstrates their commitment to sustainability. This is clearly depicted in the image below, which shows students practicing the habit of bringing their own meals and utensils.



Figure 2. Students bring their own meals as well as their own eating utensils and drinking containers when purchasing food at the school canteen (Source: Author's personal documentation, 2025).

The figure above illustrates that ESD-oriented learning not only enhances students' cognitive aspects but also plays a crucial role in shaping their sustainability-related attitudes and values. Educators, through their guidance and support, are instrumental in this process. They facilitate students in not only acquiring knowledge about sustainability concepts but also in developing a deeper comprehension of the value of embracing environmentally responsible living (Windiyani et al., 2025). Moreover, this learning approach fosters emotional awareness, as students become more mindful of the long-term consequences of their choices on both the environment and their health. Students exhibit greater emotional engagement with the impact of their daily actions, reflecting a more profound commitment to sustainability. Implementing differentiated instruction, learner-centered strategies, reflective practices, and encouraging self-directed learning through resource utilization are suggested methods to enhance students' habits of mind, which further supports this transformative process (Bariroh et al., 2024). This change suggests that ESD effectively integrates cognitive and affective dimensions, encouraging students

not only to understand but also to feel the urgency of adopting more sustainable lifestyles (Lamidi et al., 2022; Huang et al., 2024; Hung & Pan, 2025).

The N Gain value serves as an indicator of the effectiveness of the learning materials in enhancing students' sustainability awareness. It is calculated by subtracting the pretest score from the posttest score, and then dividing the result by the difference between the maximum attainable score and the pretest score. This calculation provides a standardized measure of improvement, enabling a clearer understanding of the educational intervention's impact. The mean N Gain values for both groups – experimental and control – are presented in the following figure, providing a comparative analysis of the extent to which the learning materials facilitated growth in sustainability awareness across both groups.

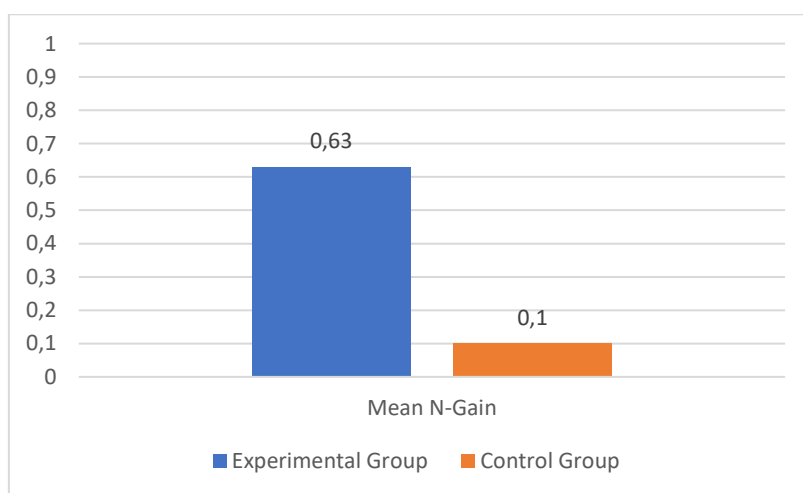


Figure 3. Mean N-Gain Values for Both the Experimental and Control Groups

According to that figure, the experimental group achieved a mean N-Gain of 0.63, whereas the control group's mean N-Gain was 0.10. In the experimental group, 11 students were classified as having a high N-Gain, 19 as medium, and one as low. In the control group, 31 students fell into the low N-Gain category. This suggests that ESD-oriented science learning materials serve not only as a vehicle for delivering instructional content but also as a tool for embedding sustainability values into students' attitudes and mindsets (Guo et al., 2024; Smelkova, 2024). As Ki Hajar Dewantara asserted, education extends beyond the classroom to foster student autonomy and active participation, thereby catalyzing positive change in Indonesia (Nasarudin et al., 2024; Yusuf, 2024; Ferliza et al., 2025). This underscores the significant role that students can play in shaping a sustainable future.

CONCLUSION

This study demonstrates that integrating ESD principles into science learning, particularly on the topic of the human digestive system, is effective in enhancing students' awareness of sustainability. The ESD-oriented learning materials developed in this research were not only found to be valid and effective but also highly practical, ensuring their applicability in diverse educational settings. These materials were instrumental in helping students understand the connections between health, the environment, and sustainable lifestyles. Students demonstrated increased awareness of sustainable dietary practices and environmental responsibility. Significant improvements in posttest scores and high N-gain values, especially in emotional awareness, indicate that students not only gained conceptual understanding but also actively practiced sustainable values in their day-to-day activities. These findings highlight that integrating ESD into science education not only contributes significantly to improving students' conceptual grasp but also plays a vital role in fostering a reflective and environmentally responsible generation committed to sustainable development. Future research may further investigate the long-term effects of such materials and their applicability across various scientific disciplines and educational levels.

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