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# The Effectiveness of E-LKPD Based on Education for Sustainable Development (ESD) to Improve Students' Critical Thinking Skills

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**Abstract**

Critical thinking is a crucial 21st-century skill that must be fostered through contextual and sustainable learning approaches. However, in the Indonesian curriculum, there is still a lack of digital learning tools explicitly designed based on Education for Sustainable Development (ESD), which limits opportunities to cultivate students' critical thinking in environmental contexts. This study aims to examine the effectiveness of ESD-based electronic student worksheets (E-LKPD) in enhancing students' critical thinking skills. The research employed a quasi-experimental design involving 138 senior high school students, divided into an experimental group (ESD-based E-LKPD) and a control group (conventional LKPD). The instrument used was a critical thinking test based on Facione's five indicators: interpretation, analysis, evaluation, inference, and explanation. The results showed that the experimental group achieved a significantly higher normalized gain (N-Gain = 0.63, moderate category) compared to the control group (N-Gain = 0.30, low category), with a statistically significant difference ($p < 0.05$). Furthermore, 50% of students in the experimental group reached the high N-Gain category, while only 7% did so in the control group. These findings indicate that ESD-based E-LKPD is effective in improving students' critical thinking skills and could serve as an innovative digital learning tool in environmental education.

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## INTRODUCTION

Human activities aimed at improving welfare often have negative impacts on the environment, both locally and globally. Development efforts such as deforestation, mining, industrialization, excessive plastic usage, and land-use changes have significantly contributed to environmental degradation (Lozano et al., 2013). The urgency of addressing environmental issues and encouraging preventive action demands strategic solutions, one of which is through the education sector.

Education grounded in the principles of sustainability plays a crucial role in shaping human quality and environmental awareness. Education for Sustainable Development (ESD) emerges as a relevant approach, as it integrates moral values and environmental concern within multidisciplinary learning (Nasibulina, 2015). ESD encourages students to connect learning materials with real world ecological and social problems while fostering a sustainability oriented mindset. Indrati and Hariadi (2016), emphasize that ESD based learning integrates three pillars environmental, social, and economic and promotes critical thinking skills in the context of sustainable development. Nevertheless, global reports indicate that the implementation of ESD, particularly in Southeast Asia, remains fragmented and faces challenges in integrating sustainability across formal education systems (UNESCO, 2023). This highlights a research gap regarding effective strategies and innovative learning tools to strengthen ESD practices in the classroom.

Critical thinking skills refer to the ability to think clearly and rationally, not merely based on collecting data, but more importantly, on the ability to process that data effectively. This competence allows individuals to engage in three complex cognitive processes, starting with gathering diverse information and culminating in decision-making (Chisiu, 2020). One of the initial steps to stimulate critical thinking is by presenting problem-based questions that are connected both to the lesson content and to real-life situations. Students are then given the opportunity to analyze the issues and offer solutions through reasoned argumentation (Donovan et al., 2014). This process encourages a more active learning environment, driven by student engagement in constructing arguments and solving problems.

Critical thinking skills involve students' cognitive processes in systematically analyzing specific problems, distinguishing relevant information, and identifying strategies for problem-solving. Heard et al. (2020), define critical thinking as a reflective and in-depth thinking process used for decision-making and problem-solving, which includes analyzing situations, evaluating arguments, and drawing sound conclusions. This skill is closely associated with High Order Thinking Skills (HOTS), which refers to the ability to critically and creatively manipulate prior knowledge and experience to solve problems in new contexts (Amanda & Karlina, 2022). Facione (1990), proposed six core elements of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation. However, this study focuses on five key dimensions interpretation, analysis, evaluation, inference, and explanation as the foundation for measuring students' critical thinking development.

Electronic student worksheets (E-LKPD) based on ESD are designed to integrate the principles of sustainable development into both the learning process and daily life. One of the major challenges in implementing ESD based worksheets today is the students' awareness of global issues and the complexity of problems currently faced by the world (Nuswowati et al., 2024). Students need to understand that environmental challenges such as climate change, biodiversity loss, and environmental degradation have significant impacts on global sustainability (UNESCO, 2017).

Fatiyah et al. (2021), shows that the use of ESD based student worksheets (E-LKPD) is effective in enhancing students' problem-solving skills and environmental awareness. The implementation of ESD through digital student worksheets (E-LKPD) also aligns with Indonesia's educational reform initiatives, such as the Profil Pelajar Pancasila (Pancasila Student Profile), which emphasizes values of environmental concern, collaboration, and real-

world problem solving (Kemendikbudristek, 2022). The demand for critical thinking skills has become increasingly urgent, especially with the emergence of 21st century challenges that require mastery of the 4Cs critical thinking, communication, collaboration, and creativity (Thornhill-Miller et al., 2023).

Preliminary findings in secondary schools indicate that many students rarely encounter tasks that require higher-order thinking skills (HOTS), either in learning activities or assessments (Kopnina et al., 2025). This condition has the potential to limit students' critical reasoning and problem-solving abilities, which are crucial for facing 21st-century challenges (Bağ & Gürsoy, 2021). Therefore, the use of instructional materials that are specifically designed to stimulate analytical, evaluative, and creative thinking becomes urgent. Integrating Education for Sustainable Development (ESD) principles into E-LKPD serves as one alternative to bridge this gap, as it not only enriches environmental relevance but also creates meaningful contexts for students to practice higher-level thinking (Singer-brodowski, 2025).

The integration of digital learning media has also become an essential component of modern education, particularly because technology increasingly shapes how knowledge is accessed and processed (Khasanah et al., 2021). Compared to printed worksheets, E-LKPD provides more accessible, interactive, and cost-efficient features that can foster learner engagement. Digital learning environments are proven to enhance students' active participation, support diverse learning styles, and improve comprehension when combined with well-structured pedagogical design (Handayani & Rahayu, 2020). Hence, the shift towards digital-based worksheets aligns with global educational trends that emphasize flexibility, inclusivity, and sustainability.

Furthermore, the application of E-LKPD that integrates ESD aligns with the principle of "think globally, act locally," where students are encouraged to analyze and address local issues as part of global sustainability challenges (Fan, 2025). This approach does not merely focus on knowledge acquisition but also promotes values, attitudes, and behaviors that support long-term sustainable practices (Huang & Pagano, 2024). By embedding real-life contexts into digital worksheets, students develop a deeper sense of responsibility toward the environment while simultaneously strengthening their critical thinking competencies. Such educational innovations are consistent with calls to transform learning into a platform for cultivating both cognitive and socio-emotional skills necessary for global citizenship (Christodoulou, 2023).

Based on these considerations, this study aims to analyze the effectiveness of E-Worksheets based on Education for Sustainable Development (ESD) in enhancing the critical thinking skills of senior high school students. To the best of the researchers' knowledge, this is the first study that combines ESD principles with digital worksheets (E-LKPD) in Indonesian high schools, thus offering a novel contribution to the field of sustainable education.

## METHODS

This study is a quantitative research employing a quasi-experimental method. Klassen et al. (2012), state that quantitative research refers to methods used to test specific theories by examining the relationships among variables. These variables are measured so that the data, consisting of numbers, can be analyzed using statistical procedures (Sugiyono, 2013).

The population of this study consisted of 759 students from two different high schools. The sample was selected using purposive sampling, which involves selecting specific subjects based on particular criteria relevant to the research objectives. Two classes from each school were chosen as samples: one experimental class (Class A) with 70 students and one control class (Class B) with 68 students.

This study utilized a pretest-posttest control group design, where the experimental group received instruction using the E-LKPD based on Education for Sustainable Development (ESD) (X1), while the control group received instruction without the E-LKPD intervention (X2). Both groups were given a pretest (Q1) and a

posttest (Q2). The research design is presented in Table 1.

**Table 1.** Research Design

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| A | $Q_1$ | $X_1$ | $Q_1$ |
| B | $Q_1$ | $X_2$ | $Q_2$ |

The treatment administered to the experimental group (A) consisted of learning activities using E-LKPD based on Education for Sustainable Development (ESD) (X1), whereas the control group (B) received conventional LKPD-based learning. The critical thinking skills test instrument used in this study was administered to both the experimental and control groups, and it referred to the critical thinking skill indicators proposed by Facione, (1990), namely: interpretation, analysis, evaluation, inference, and explanation. The test instrument consisted of 25 items, including 20 multiple-choice questions and 5 essay questions. The distribution of critical thinking skill indicators within the test items is presented in Table 2.

**Table 2.** Profile of the Instrument

| Critical Thinking Indicator | Number of Item |
|---|---|
| Interpretation | 5 |
| Analysis | 5 |
| Evaluation | 5 |
| Inference | 5 |
| Explanation | 5 |

The purpose of using this data collection instrument was to determine the effect of E-LKPD implementation on students' critical thinking skills. The research instruments were validated by ten validators, considering both content and media aspects. Several revisions were made to the E-LKPD following the validation process. Data analysis techniques were conducted using statistical tests. The prerequisite tests included normality and homogeneity tests. Meanwhile, the hypothesis test was carried out using the Normalized Gain (N-Gain) test to measure the improvement in students' critical thinking skills after the treatment. This improvement was evaluated based on students' pretest and posttest scores.

Normalized Gain (N-Gain) is defined as the ratio between the actual score improvement and the maximum possible score improvement (Hake, 1999). It is used to evaluate the effectiveness of learning by comparing pretest and posttest scores. The N-Gain score categories are presented in Table 3.

**Table 3.** N-Gain Score Criteria

| Gain Factor (Scale 0–1) | Criteria |
|---|---|
| $\langle g \rangle \geq 0.7$ | High |
| $0.3 \leq \langle g \rangle > 0.7$ | Medium |
| $\langle g \rangle < 0.3$ | Low |

If the N-Gain result of the experimental group is higher than that of the control group, it can be interpreted that the experimental group experienced greater improvement than the control group. This indicates that the use E-LKPD based on Education for Sustainable Development (ESD) had a significant effect on students' critical thinking outcomes.

## RESULTS AND DISCUSSION

The effectiveness of the ESD based E-LKPD media in enhancing students' critical thinking skills was measured using pretest and posttest scores obtained during the large-scale trial. The research employed a pre-post group design to collect data. The large-scale trial was conducted over four meetings in both the experimental and control classes. The effectiveness of the ESD based E-LKPD media was tested on four classes, comprising two control and two experimental classes from two different schools. The instrument used consisted of pretest and posttest questions aligned with critical thinking skill indicators.

The effectiveness of the ESD based E-LKPD was evaluated by comparing the critical thinking skill scores between the experimental and control classes using the normalized gain (N-Gain) test. The N-Gain results are presented in Table 4.

**Table 4.** N-Gain Test Results on Critical Thinking Skills

| Description | Control | % | Experimental | % |
|---|---|---|---|---|
| Average N-Gain Score | 0.30 | 30 | 0.63 | 63 |
| Highest N-Gain Score | 0.77 | 77 | 0.93 | 93 |
| Lowest N-Gain Score | 0.00 | 0 | 0.08 | 8 |

Based on Table 4, the average N-Gain score in the experimental class was 0.63 (63%), indicating that the ESD based E-LKPD media was moderately effective in enhancing students' critical thinking skills (Hake, 1999). In contrast, the control class had a lower average N-Gain score of 0.30 (30%), suggesting that learning without the ESD based E-LKPD media was less effective in improving students' critical thinking.

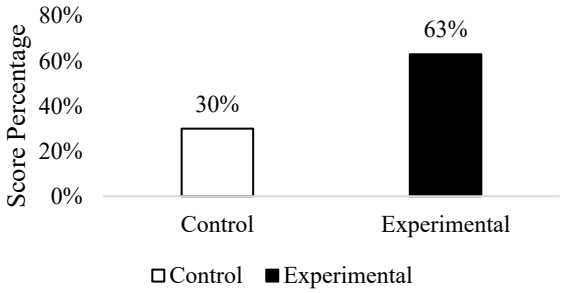


**Figure 1.** Comparison of Average N-gain of Students' Critical Thinking Skills

Figure 1 presents a comparison of the average N-Gain scores between the control and experimental classes, revealing a significant difference. Furthermore, the N-Gain score distribution in both groups was categorized into three levels high, medium, and low as shown in Table 5.

**Table 5.** N-Gain Category Distribution for Critical Thinking Skills

| Category | Control | % | Experimental | % |
|---|---|---|---|---|
| High N-Gain | 5 | 7 | 35 | 50 |
| Medium N-Gain | 26 | 38 | 30 | 43 |
| Low N-Gain | 37 | 54 | 5 | 7 |

Table 5 shows that 50% of students in the experimental class achieved a high N-Gain score, while 54% of students in the control class were in the low N-Gain category. These findings indicate that the use of ESD based E-LKPD media was effective in improving students' critical thinking skills. A comparison of the N-Gain categories between the two groups is illustrated in Figure 2.

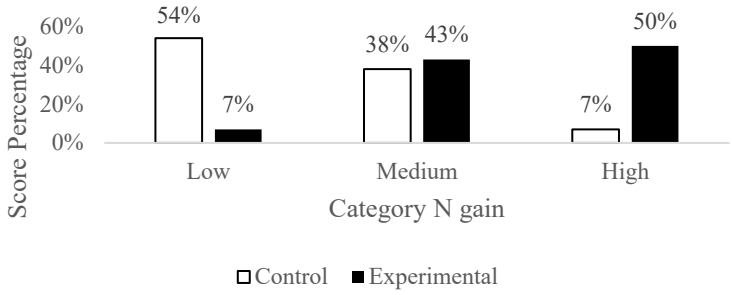


**Figure 2.** Comparison of N-gain Categories of Students' Critical Thinking Skills

Figure 2 demonstrates a clear contrast the experimental class showed dominant high N-Gain scores (50% of 70 students), whereas the control class was dominated by low N-Gain scores (54% of 68 students). These results reinforce the conclusion that the ESD based E-LKPD media had a significant impact on enhancing students' critical thinking.

The average posttest score in the experimental class was 83, substantially higher than the control class, which scored 70. The average N-Gain score of 0.63 (63%) falls into the "moderately effective" category (Hake, 1999). This improvement reflects students' active engagement with contextual and interactive learning media, which positively influenced their higher-order thinking, especially critical thinking.

These findings align with UNESCO's (2017) theory on critical thinking development within Education for Sustainable Development (ESD), which emphasizes the importance of equipping students with critical, reflective, and decision-making skills to address complex issues. Similarly, Saavedra & Opfer, (2012) argue in Educational Leadership that critical thinking can only be effectively developed through authentic learning experiences that connect knowledge to real life problems a principle reflected in the design of the ESD based E-LKPD content and activities (Felix, 2023).

Radeloff et al. (2020), emphasize that learning instruments centered on environmental and sustainability issues not only raise awareness but also foster students' reflective and analytical thinking. These skills include evaluating environmental problems, analyzing cause effect relationships, and formulating solutions, which are core elements of critical thinking indicators such as interpretation, analysis, inference, and evaluation (Facione, 1990).

The indicators used to measure critical thinking in this study referred to Facione's (1990) framework interpretation, analysis, evaluation, inference, and explanation. The achievement of each indicator based on posttest scores is presented in Table 6.

**Table 6.** Achievement of Critical Thinking Indicators

| Indicator | Control | Experimental |
|---|---|---|
| Interpretation | 73 | 86 |
| Analysis | 67 | 76 |
| Evaluation | 69 | 82 |
| Inference | 71 | 84 |
| Explanation | 71 | 82 |

As shown in Table 6, students in the experimental class outperformed those in the control class in all critical thinking indicators. The highest achievement in both groups was in interpretation. The experimental group consistently showed higher scores across all indicators, suggesting that the ESD based E-LKPD media successfully supported the development of diverse critical thinking competencies. The comparison of average indicator achievement is illustrated in Figure 3.

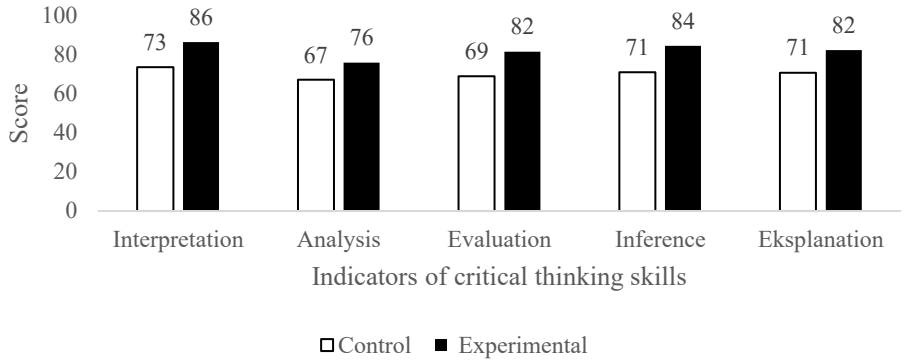


**Figure 3.** Comparison of Average Achievement of Critical Thinking Indicators

Figure 3 further confirms that the experimental class attained higher average scores across all critical thinking indicators. Interpretation was the strongest indicator in both groups, while analysis showed the lowest scores. However, the experimental group still outperformed the control group in the latter, demonstrating more balanced and comprehensive critical thinking development.

These findings are consistent with Hashemi (2011), who asserts that problem-based learning approaches enhance critical thinking by engaging students in information evaluation and evidence-based reasoning. Saido et al. (2015) also emphasize that interactive and contextual learning media like the ESD based E-LKPD enable students to develop higher-order thinking skills including analysis and inference through reflective and collaborative tasks. This highlights the role of ESD principles, such as sustainability, critical reflection, and active engagement, in reinforcing critical thinking.

The high scores in interpretation may stem from the fact that this indicator reflects basic level critical thinking skills more accessible to students, especially at the lower cognitive levels. Interpretation involves understanding and explaining information from texts or data, a skill frequently practiced in everyday learning. In contrast, analysis demands deeper engagement, requiring students to organize, compare, and evaluate complex information tasks that necessitate more time, scaffolding, and teacher support Saido et al. (2015).

The results show that the experimental group scored higher (86) compared to the control group (73) on the interpretation indicator. This demonstrates that the use of ESD-based E-LKPD effectively enhances students' ability to comprehend and interpret information. Interpretation skills involve the capacity to understand meaning, translate data, and connect information to specific contexts. By embedding real life environmental and sustainability issues in learning tasks, ESD-based E-LKPD provides meaningful contexts that foster deeper interpretation. Students are encouraged to relate given information to their own experiences and surroundings, which supports stronger understanding and sense making. As noted by (Bezanilla et al., 2019), embedding authentic contexts in learning stimulates students' interpretive thinking and fosters conceptual understanding.

In the analysis indicator, the experimental group (76) scored higher than the control group (67), suggesting that the integration of ESD-based E-LKPD effectively enhances students' analytical thinking. Analytical skills require learners to break down information, identify relationships, and examine patterns or causes. By presenting sustainability-related, problem-based scenarios such as waste management, environmental change, or resource consumption students are encouraged to dissect complex issues, investigate causal factors, and explore interrelated variables. The structured inquiry provided in ESD-based E-LKPD also scaffolds students to analyze data step by step, preventing them from engaging only at a superficial level.

Recent studies confirm this potential engaging students in critical reading of academic

texts fosters higher-order analytical tasks by requiring them to identify arguments, evaluate reasoning, and distinguish evidence (Izzatullaevna, 2024; Taufiq et al., 2024). Similarly, problem-based worksheets designed around environmental issues have been shown to strengthen students' critical and analytical skills by encouraging them to investigate, compare alternatives, and understand underlying causes of sustainability challenges (Fadilah & Aloysius, 2024). These findings highlight that well designed ESD-based digital worksheets can serve as effective tools for cultivating students' analytical thinking within authentic and meaningful learning contexts.

Students in the experimental group scored notably higher (82) than those in the control group (69) on the evaluation indicator, indicating that ESD-based E-LKPD strengthens their capacity to assess information critically. Evaluation entails judging the credibility of sources, weighing evidence, and making reasoned judgments. Through ESD based learning tasks such as comparing alternative sustainable practices, evaluating environmental policies, or assessing business impacts students are encouraged to critically analyze information and justify their conclusions. ESD implementations found that inquiry based, interdisciplinary learning significantly fosters students' critical thinking, including evaluative skills, by requiring them to assess evidence within sustainability contexts (Sihombing et al., 2024). Similarly, interactive ESD learning website for global warming and renewable energy reported that the tool enabled learners to visualize complex phenomena and evaluate environmental solutions more effectively, thereby enhancing their critical evaluative reasoning (Shobah et al., 2025).

In the Inference indicator, the experimental group's higher score 84 and 71 for the control group underscores how ESD-based E-LKPD improves students' ability to draw logical conclusions and anticipate outcomes. By engaging with sustainable development scenarios such as modeling environmental impacts or projecting future conditions students practice reasoning beyond immediate data and develop predictive thinking (Uddin et al., 2020). This aligns with findings from SDGs-based STEM learning contexts, where students demonstrated more advanced critical thinking including inferential skills when tackling environmental issues compared to those in traditional learning environments (Yennita et al., 2025).

Regarding the Evaluation indicator, the use of ESD-based E-LKPD effectively cultivates students' capacities to assess credibility, weigh evidence, and make informed judgments. This arises naturally when students compare sustainable practices, analyze policy alternatives, or evaluate interventions within environmental contexts. These abilities are consistent with the broader framework of Education for Sustainable Development, where critical thinking is essential for questioning norms and engaging authentically with sustainability challenges showcased in systematic reviews emphasizing ESD's role in fostering critical and evaluative capacities (Felix et al., 2025).

For the Explanation indicator, the experimental group outperformed the control group, revealing that ESD-based digital worksheets support stronger reasoning articulation and justification. When learners are encouraged to clearly explain their conclusions such as rationalizing a sustainable strategy or communicating environmental causesthey hone their ability to construct coherent and grounded arguments. This resonates with conceptual models of sustainability education, which stress critical thinking and reflective competencies including explanation as core outcomes of ESD-integrated teaching (Strakov & Cimermanov, 2018)

Saido et al. (2015) found that students generally struggle with higher-order thinking, particularly analysis and evaluation, due to a lack of explicit practice in those areas. Hashemi (2011), also observed that while students often succeed in interpreting texts, they face challenges in connecting that information to broader contexts or constructing logical arguments.

The ESD based E-LKPD developed and used in this study can be considered an effective learning medium for enhancing students' critical thinking skills (Zhou & Lee, 2022). It meets

pedagogical characteristics that are both theoretically grounded and empirically supported within the framework of 21st century learning and sustainability-based education (Kocak et al., 2021).

## CONCLUSION

Based on the research conducted, it can be concluded that the E-LKPD based on Education for Sustainable Development (ESD) on the topic of environmental change and conservation is effective in improving students' critical thinking skills, as evidenced by the results of the pretest and posttest, with improvements achieved across all indicators evaluated in the study. In light of these findings, it is recommended that ESD-based E-LKPD be integrated into national teacher training programs and classroom practices as an innovative digital learning tool to enhance critical thinking and environmental awareness among students.

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