Vol 11 No 2 2025 DOI : https://doi.org/10.24036/jppf.v11i2.23 Page : 223-234
JURNAL PENELITIAN PEMBELAJARAN FISIKA (JPPF)
Journal of Physics Learning Research
ISSN 2252-3014 (Print) | ISSN 2746-8445 (Electronic)

The Importance of Integrating Education for Sustainable Development in Global Warming Assessments to Improve Students' Critical Thinking Skills

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ARTICLE INFORMATION

Received : 2025-10-14
Revised : 2025-10-28
Accepted : 2025-10-31

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KEYWORDS :

Assessment, Critical thinking skills, ESD, Physics, Wizer.me

ABSTRACT

This research was motivated by the fact that the assessments used in physics education still do not facilitate students' critical thinking skills. The purpose of this study was to analyze the need to develop critical thinking skills assessments integrated with Education for Sustainable Development (ESD) in physics education to support Sustainable Development Goal (SDG) 13: Climate Action. In the 21st century, students need not only conceptual understanding but also critical thinking skills to address global environmental challenges. Using a descriptive quantitative approach, this study involved 33 Grade X Phase E students through Ennis-based critical thinking tests, student questionnaires, and teacher interviews. The results showed that students' critical thinking skills were mostly in the moderate to low range, with the lowest performance on the "advanced clarification" indicator, indicating difficulty in connecting physics concepts with real-life phenomena. However, students demonstrated good sustainability awareness (71.9%–75.17%) and strong technological skills (80.57%), indicating readiness for digital-based assessment. ESD dimension analysis showed effective integration between environmental, cultural, economic, and social aspects in promoting climate action. Teacher interviews confirmed that existing assessments were inadequate in measuring critical thinking and its relationship to ESD. Therefore, the development of electronic assessments is essential to improve critical thinking and sustainability awareness on the topic of global warming. This innovation supports transformative and holistic learning that empowers students to actively contribute to achieving Sustainable Development Goal (SDG) 13 Climate Action.

INTRODUCTION

In the 21st century, the development of science and technology (IPTEK) is increasing and will continue to develop over time. Therefore, as human resources (HR) who will directly engage with these developments, students are not sufficient if they are only equipped with

knowledge alone, but must also be equipped with supporting skills (Agusti, Wijaya, and Tarigan 2019).

Several educational institutions and international organizations have attempted to formulate and articulate the competencies and skills required to meet the demands of the 21st century. These so-called *21st-century skills* encompass a set of core abilities that enable individuals to adapt, innovate, and thrive in a rapidly changing world. Among these, four skills are often emphasized as fundamental: (1) critical thinking and problem-solving, (2) communication, (3) creativity and innovation, and (4) collaboration (Pusmenjar 2020). Of these competencies, critical thinking plays a particularly vital role as it directly supports effective problem-solving in various contexts.

Critical thinking is commonly defined as a reflective and reasoned thinking process aimed at determining what to believe or what action to take (Ennis 2011). It involves purposeful, self-regulated judgment and the ability to evaluate information, arguments, and evidence before drawing conclusions. Because the capacity for critical thinking varies among individuals, it is considered a skill that must be deliberately nurtured through education (Asniar, Nurhayati, and Khaeruddin 2022).

In an educational setting, students' critical thinking skills can be systematically developed through intentional learning activities and well-designed assessments. One effective approach is to integrate *Assessment as Learning* (AaL) and *Assessment for Learning* (AfL) into the instructional process (Dasar and Yolanita 2024). *Assessment as Learning* emphasizes the active involvement of students in monitoring and evaluating their own learning progress, fostering metacognition and self-regulation. In contrast, *Assessment for Learning* focuses on providing timely and constructive feedback to guide students toward improvement, thus creating opportunities to refine their reasoning and decision-making abilities. Through these assessment practices, the cultivation of critical thinking becomes an integral and continuous part of the learning experience.

Assessment is a systematic, planned, and continuous process of gathering, analyzing, and interpreting information about students' learning progress in order to make informed decisions based on predetermined criteria and considerations (Lestari, B.K Gultom, and Saputri Zebua 2022). Learning assessment serves not only as a tool for measuring achievement but also as a strategic means to ensure that the expected learning objectives are met. Through well-designed assessments, educators can determine students' levels of understanding and skill mastery, enabling them to provide constructive feedback and tailored learning interventions. Moreover, effective assessment practices encourage students to engage in reasoning, analyze problems critically, and develop higher-order thinking skills. This is particularly important in Physics learning, where critical thinking is essential for connecting abstract concepts to real-world applications.

Physics, as a branch of science, is characterized by its dual nature as both a process and a product of inquiry. As a process, it involves systematic observation, experimentation, and reasoning; as a product, it yields scientific principles, theories, and technological innovations. One of the primary objectives of Physics education is to foster students' ability to think objectively, systematically, and creatively, while cultivating innovation in learning and application (Amalissholeh et al. 2023). The teaching of Physics holds strategic importance for several reasons. First, Physics education goes beyond the mere transmission of scientific facts—it functions as a medium for developing essential thinking skills that enable students to analyze and solve problems encountered in daily life. Second, Physics equips learners with the

competencies necessary for academic progression, particularly in meeting the knowledge, understanding, and entry requirements for higher education, as well as preparing them to contribute to advancements in science and technology (Bahasa et al. 2024).

In line with these purposes, the intended learning outcomes of Physics education extend beyond conceptual mastery to encompass the ability to respond to global challenges and participate actively in collaborative problem-solving. This vision aligns with the framework of the United Nations Sustainable Development Goals (SDGs), particularly through the lens of *Education for Sustainable Development* (ESD), as initiated by UNESCO (Ekamilasari, Permanasari, and Puspitasari 2021). ESD emphasizes the integration of sustainability principles—spanning environmental, economic, social, and cultural dimensions—into teaching and learning. In the context of Physics, this entails not only understanding scientific phenomena but also applying scientific reasoning to address pressing global issues such as climate change, energy sustainability, and technological innovation for a better future.

ESD is lifelong learning aimed at informing and engaging students to be active, creative, and capable of problem-solving, scientific, and social literacy, and committed to personal and group responsibility, which will ensure environmental well-being. ESD addresses issues based on four pillars: environment, social, cultural, and economic (Hamidah, Saputra, and Abadi 2023). In line with this, critical thinking competencies in the context of ESD explain that learners must be able to reflect on their own values, perceptions, and actions in taking positions related to sustainable discourse (Riduwan 2015). One of the key competencies in ESD is critical thinking, which plays an important role in helping individuals analyze, evaluate, and make informed decisions related to sustainability issues (Kioupi and Voulvoulis 2019).

Through ESD-based learning, it is hoped that learners can think critically in addressing existing problems, especially in physics lessons. ESD equips students with the knowledge, skills, values, and attitudes needed to contribute to sustainable development. Education that instills awareness of environmental, social, and economic issues helps achieve the 17 SDGs, especially Goal 13, Climate Action. This goal focuses on urgent action to combat climate change, which is closely related to the topic of global warming.

One of the topics studied in physics is Global Warming. In this study, the Global Warming topic was used to help students better understand the concept through various sustainability-focused informational texts. The main objective is to connect physics concepts with critical thinking skills and develop students' awareness of sustainable development. Thus, students not only learn the theoretical aspects of Global Warming but also integrate information from written texts, analyze climate change data, apply critical thinking skills in a broader context, and develop sustainable solutions to environmental problems.

Based on research conducted by (Agusti et al. 2019) using a one-group pretest-posttest design, the results showed that students tended to be unable to identify the relationship between human activities and climate change, unable to explain the impact of global warming on socio-economic aspects of society, and unable to propose sustainable solutions to overcome global warming problems. Furthermore, according to (Kusumawati, Supahar, and Pebriana 2024), although students have a basic understanding of global warming, they still experience difficulties in analyzing the interrelationship between environmental, social, and economic aspects in the context of sustainable development, and are not yet able to develop critical thinking about how to apply the principles of sustainability in everyday life.

Based on interviews with physics teachers, it was found that schools have used multiple-choice and essay-based assessments in the learning assessment process. However, in its

implementation, the assessments carried out have not fully assessed students' critical thinking skills, especially in relating physics concepts to predetermined learning outcomes and learning objectives. Furthermore, students experienced difficulties when asked to relate environmental issues to the information obtained or to understand the relationship between local actions and global impacts.

To address these challenges, it is necessary to create an ESD-integrated critical thinking assessment utilizing technology, such as the wizer.me application. Wizer.me transforms static worksheets into interactive digital resources (Durango-Urrego et al. 2023). Wizer.me is a digital platform that provides various types of questions that can be used for learning evaluation (Syarqiy, Yuliati, and Taufiq 2023).

Based on the above description, the purpose of this study is to determine the needs in developing an ESD-integrated critical thinking assessment to achieve Phase E learning outcomes aimed at achieving sustainable development goals (SDGs). This study also aims to identify problem-solving methods through interviews with physics teachers who have relevant knowledge and experience. The data from these interviews are expected to serve as a basis or reference for the creation of an effective ESD-integrated critical thinking assessment to support physics learning.

METHODS

This study is a quantitative descriptive study that aims to analyze the learning needs of physics and the critical thinking skills of students. This test was conducted on February 11, 2025, and the population in this study consists of 69 students in grade X Phase E for the 2024/2025 academic year. The sample for this study was selected using random sampling, with 33 students as the research subjects. The needs analysis was conducted to determine the needs in physics learning at Padang. This study included a questionnaire to determine students' understanding of electronic assessment and ESD, a test covering critical thinking ability indicators to determine the level of students' critical thinking ability, and interviews with physics teachers to determine the assessment used in the learning process. Additionally, this study aims to identify whether the current physics learning methods are in line with the needs and expectations of students. By utilizing data from the student needs questionnaire and critical thinking ability tests, this study is expected to provide insights into the steps needed to improve the quality of physics learning, particularly in facilitating students to develop better critical thinking skills.

The instruments employed in this study consisted of two main components: a student needs questionnaire and a Physics critical thinking skills test, where this questionnaire is referenced based on Creating a 21st Century Skills Survey Instrument for High School Students developed by (R. Kelley et al. 2019). The student needs questionnaire was designed to gather comprehensive information regarding learners' perceptions, challenges, and expectations in relation to Physics learning, thereby providing valuable input for the development of targeted instructional strategies. Meanwhile, the critical thinking skills test was developed based on the five core indicators of critical thinking proposed by Ennis, which serve as a well-established framework for assessing higher-order thinking abilities. These indicators include: (1) providing simple explanations, which assesses the ability to clarify concepts, define terms, and interpret statements accurately; (2) building basic skills, which measures the capability to identify assumptions, evaluate the credibility of sources, and observe relevant data; (3) drawing conclusions, which evaluates logical reasoning in making

inferences and determining the validity of arguments; (4) providing further explanations, which examines the capacity to relate concepts to broader contexts, offer justifications, and integrate supporting evidence; and (5) organizing strategies and tactics, which assesses planning, problem-solving approaches, and the selection of effective methods for addressing complex tasks. Together, these instruments provided a comprehensive picture of students' learning needs and their current level of critical thinking in Physics, enabling a deeper analysis of both cognitive skills and instructional gaps.This study analyzed data using descriptive statistical techniques, which aim to process, summarize, and present data in a structured manner so that it is easy to understand. The results of the needs analysis were analyzed using a scoring formula obtained by dividing the score by the maximum score and then multiplying it by 100.

The percentage can be calculated using the following formula:

$$Score = \frac{Achieved\ Score}{Maximum\ Score} \times 100\% \quad (1)$$

Analyze the data to evaluate the need for each indicator through the use of the provisions in Table 1.

Table 1. Categories of needs analysis

No.	Category	Percentage
1.	Very good	80 < N ≤ 100
2.	Good	60 < N ≤ 80
3.	Simply	40 < N ≤ 60
4.	Less	20 < N ≤ 40
5.	Very less	≤ 20

Source : (Riduwan 2015)

RESULTS AND DISCUSSION

Results

The results of this study can be seen from the critical thinking ability test of the students, which was conducted at SMAN 12 Padang. The test was conducted on February 11, 2025, and was participated in by 33 tenth-grade students. The test used was an essay-type question consisting of 5 stimuli, and 69 tenth-grade students in Phase E completed the questionnaire. The data can be viewed in more detail in Appendix 1. In this test, the instrument used was developed by Fadhila (2023). The results of the critical thinking ability analysis per indicator can be seen in the following figure.

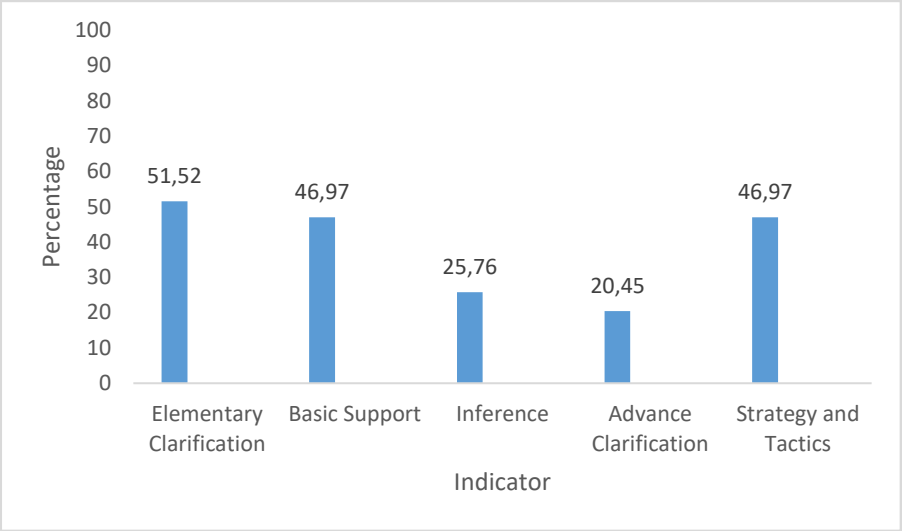

Figure 1. Results of Critical Thinking Ability Tests for Students

Figure 1. Results of Critical Thinking Ability Test Based on Figure 1, the highest average score was found in indicator 1, namely elementary clarification (providing simple explanations) with a moderate category. Meanwhile, the lowest average score was found in indicator 4, namely advanced clarification (providing further explanations) with a low category. In the question, students were asked to analyze and provide further explanation regarding the advantages of using PLTS, which are unlimited resources, environmentally friendly, no greenhouse gas emissions, and relatively low operational costs. The test results of one student on the advanced clarification indicator can be seen in Figure 2.

masalah sampah di berbagai kota besar di Indonesia. Prinsip sederhana dari PLTSa atau Waste to Energy ini adalah:

1. Membakar sampah yang kemudian menghasilkan panas
2. Panas yang timbul digunakan untuk memanaskan air
3. Uap Air yang muncul digunakan untuk menggerakkan turbin
4. Turbin menghasilkan listrik. Manfaat utama PLTSa ini sebenarnya adalah dapat mengurangi "volume" sampah yang menggunung. Listrik yang dihasilkan dapat digunakan untuk membantu operasional pengelolaan sampah. Sebenarnya Teknologi pengolahan sampah untuk pembangkit listrik tidak terlalu sulit diterapkan diIndonesia.

(sumber: sumber.belajar.kemdikbud.go.id)

Berdasarkan **Stimulus 4**, rumusan permasalahan yang ada dan pertanyaan kunci untuk menyelesaikan permasalahan adalah… (Boleh memilih lebih dari satu jawaban)

- ✓ Sudahkah kamu memilah-milah sampah?
- o Bagaimana pengelolaan sampah di lingkungan sekitarmu?
- o Bagaimana cara pengolahan sampah menjadi energi listrik?
- o Bagaimana efektivitas pembangkit listrik tenaga sampah?

Figure 2. Critical thinking test answers on the advance clarification indicator

Based on Figure 2, the test results show that students had difficulty providing further explanations. The low percentage on this indicator shows that most students had difficulty connecting the physics concepts they had learned with real phenomena and were unable to develop logical arguments based on the data obtained. Many students fail to build strong arguments because they struggle to connect physics concepts with real-world contexts and use convincing argument structures (Guisasola et al. 2023). Learning based on real-world

phenomena and involving argument structures is crucial for improving conceptual understanding and the ability to explain physics (Sundari and Sarkity 2021). Many students have fragmented physics concepts. This makes it difficult for them to transfer knowledge to real-world situations or construct cohesive and conceptual explanations (R. Kelley et al. 2019). This is also evident from research findings indicating that students' low critical thinking skills are evident in the categories of drawing conclusions and providing follow-up explanations (Harmawati et al. 2024). The low critical thinking skills of students pose a challenge for teachers in implementing physics education. Especially in applying appropriate teaching methods to develop students' critical thinking skills.

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This relates to the ability to draw conclusions and provide further explanations for a problem, which is also supported by a questionnaire given to students, based on Creating a 21st Century Skills Survey Instrument for High School Students developed by (Simanjuntak et al. 2025). This needs survey has four components: Critical Thinking Skills, Sustainability Awareness, and Technology Skills. Based on the needs survey used, the results for each component can be analyzed for the four components of the student needs survey. The Critical Thinking Skills component can be seen in Figure 3.

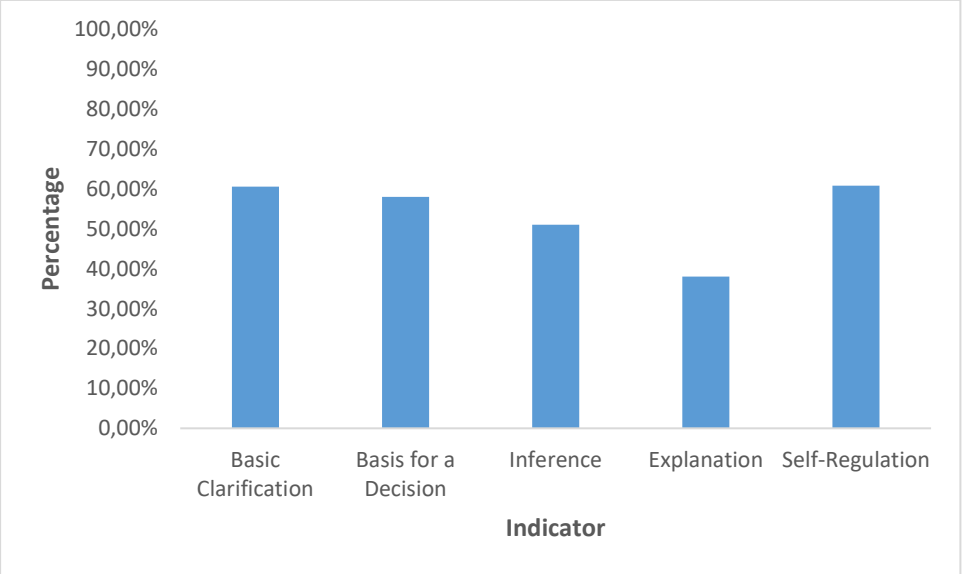

Figure 3. Results of Critical Thinking Ability Component Analysis

The average score for critical thinking skills is 53.37% in the Simply (adequate) category. This means that students demonstrate a basic understanding, but have not yet reached a proficient level overall. The questionnaire results on Critical Thinking Skills were consistent with the test results, where in the category of providing further explanations, students were in the low category at 38%. Next is the component of Sustainable Awareness, which can be seen in Figure 4.

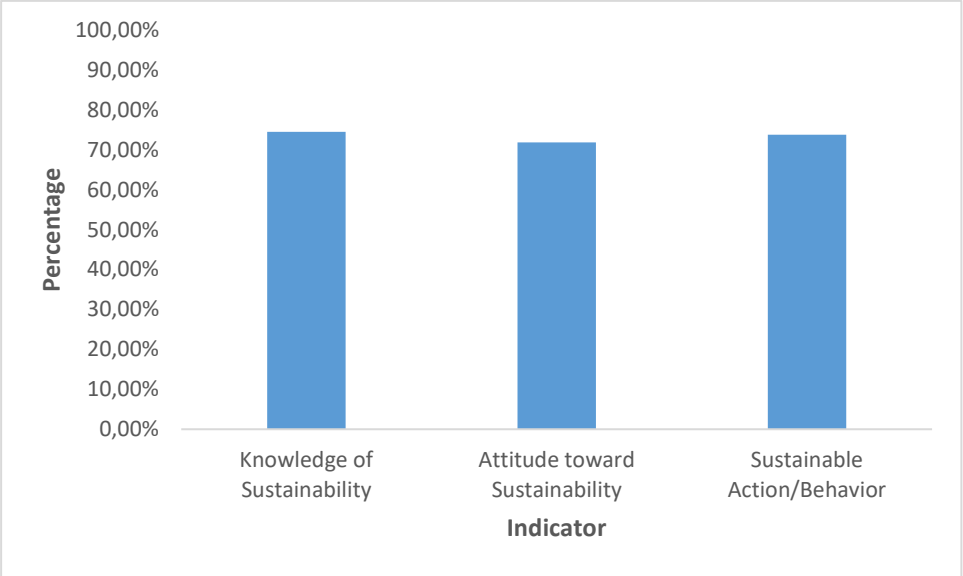

Figure 4. Results of Sustainability Awareness Analysis

Based on the figure above, it can be explained that the value of each component of Sustainable Awareness in the results of the student needs questionnaire is in the good category because it has an average value of 73.36%. The final component in the student needs questionnaire is the Technology Skills component. The results of the analysis for this component can be seen in Figure 5.

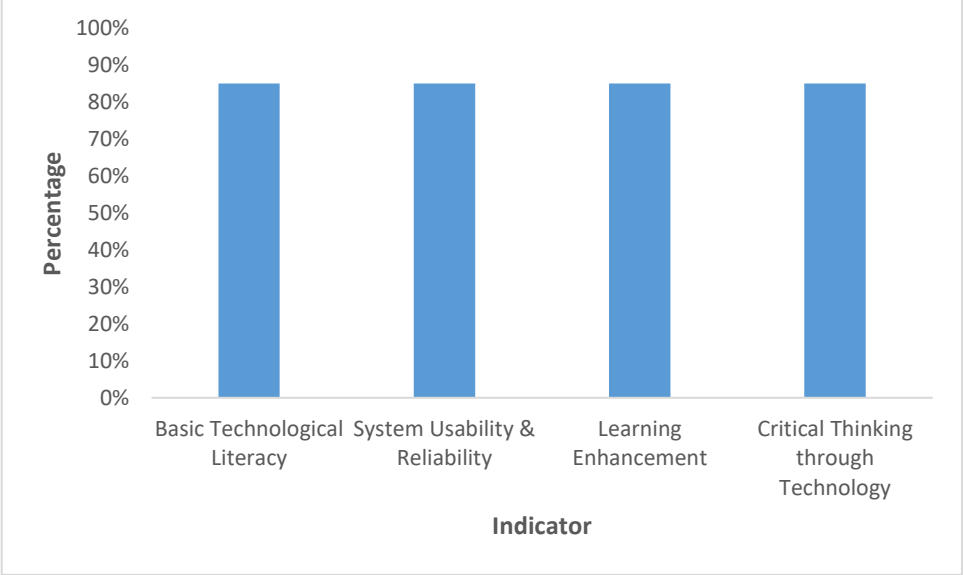

Figure 5. Results of Technology Capability Component Analysis

Based on the figure above, it can be explained that the value of each component of technological capability in the results of the student needs questionnaire is in the very good category because it has an average value of 80.57%. Based on the three components in the student needs questionnaire, the results of the analysis of the average value of the student needs questionnaire can be seen in Figure 6.

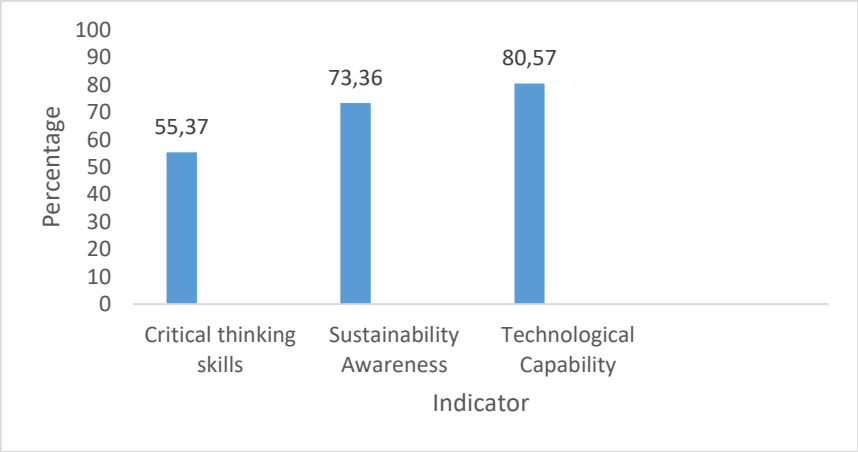

Figure 6. Results of the student needs survey

Based on the results of the data analysis in Figure 6, it can be concluded that the technological capabilities of students are at a very good level, with high and even scores (80.57%) across all indicators. This shows that students have strong digital literacy, are comfortable using digital assessment platforms, and feel the real benefits of technology in the learning process. On the other hand, students' awareness of sustainability was also quite good and stable, with scores ranging from 71.9% to 75.17%, reflecting a strong understanding of environmental issues and involvement in environmentally friendly behavior. However, 55.37% of students still experienced difficulties in aspects of higher-order critical thinking.

Discussion

Based on the results of data analysis, it can be concluded that students' technological abilities are at a very good level, with high and consistent scores across all indicators. This shows that students have strong digital literacy, are comfortable using digital assessment platforms, and feel the real benefits of technology in the learning process. On the other hand, students' awareness of sustainability is also quite good and stable, with scores ranging from 71.9% to 75.17%, reflecting a strong understanding of environmental issues and involvement in environmentally friendly behavior. Interestingly, students not only understand the theory but also begin to apply it in their daily lives. For example, some of them have tried to save water and electricity at home. However, for activities that require more effort, such as sorting waste or sharing knowledge with others, many students have not yet implemented this.

This data is highly relevant to Sustainable Development Goal (SDG) 13 on climate action, as it shows that students are beginning to realize the importance of taking action against climate change. When the majority of students understand the impact of climate change, it means that the foundation for taking climate action has been established. Based on data from a digital literacy survey of junior high school students in Madiun City (385 respondents), students' abilities in operating digital media, learning platforms, ethical use, and digital security are at a "very good" level (Nurhasanah et al. 2021). In line with these findings, a survey of university students across various regions in Indonesia (2,921 respondents) noted that digital literacy levels, including technological, critical, communication, and security skills, are sufficiently strong and representative at the national level (Ubaidillah et al. 2023). This supports the notion that students' high and consistent scores above 80% reflect a solid foundation in digital literacy, comfort in using digital assessment platforms, and effective utilization of technology in learning.

Based on interviews with Physics teachers in Grade X Phase E, it was found that the school has been using multiple-choice and essay-based assessments in the learning assessment

process. These assessments are conducted digitally using Google Forms, aiming to enhance efficiency in measuring students' understanding. However, in its implementation, the assessments conducted have not fully evaluated students' critical thinking skills, particularly in relating physics concepts to learning outcomes and established learning objectives. Research has shown that various types of instruments, including Two Tier, Four Tier, open-ended essays, and multiple-choice questions, have been developed based on Ennis and Facione's theory and are considered valid and reliable. These findings indicate that conventional multiple-choice assessments (such as Google Forms) are still inadequate for measuring complex critical thinking aspects (Walsh et al. 2019).

Critical thinking skills are an essential aspect of physics learning, as they enable students to analyze, evaluate, and solve problems based on a deep understanding of concepts (Velempini 2025). The lack of critical thinking assessment can make it hard for students to connect theory with practical application in everyday life. As a result, most students still struggle to achieve optimal learning outcomes, so remedial measures are often needed to help them meet the expected competency standards.

Furthermore, in the context of ESD, students demonstrate a good understanding of basic concepts such as the importance of preserving the environment and the impact of climate change. However, when asked to connect environmental issues with the information obtained or to understand the relationship between local actions and global impacts, students' responses tend to be more moderate (R. Kelley et al. 2019). This condition indicates a gap between conceptual understanding and the ability to apply knowledge in a broader context, which is in line with the low achievement on the Advance Clarification indicator in the critical thinking ability test (Ramadhani and Wasis 2024). This is in line with the results of research which shows that conventional assessments, including multiple choice and simple essay-based assessments, tend to be less effective in measuring students' critical thinking skills comprehensively, especially in terms of in-depth analysis and the relevance of concepts to real-world contexts (Redecker and Johannessen 2013). Research through the development of the Physics Lab Inventory of Critical Thinking (PLIC) also confirms that measuring critical thinking in physics learning requires instruments that can evaluate reasoning processes and concept application, not just final answers (Linda and Lestari 2019). Furthermore, in the context of Education for Sustainable Development (ESD) emphasizes that learning that integrates environmental issues with science subjects, accompanied by appropriate assessments, can strengthen students' ability to connect local knowledge with global impacts. Thus, the results of interviews and analysis conducted at hugh school Padang indicate the need for innovative digital assessments that not only measure conceptual understanding but also stimulate critical thinking skills and the application of physics concepts to sustainability issues.

Based on observations conducted at SMAN 12 Padang, there are issues that need to be addressed. A solution that can be implemented is to create an integrated ESD-based electronic critical thinking assessment that helps improve students' critical thinking skills. The assessment can also help teachers measure students' critical thinking skills in line with learning objectives, with questions designed to evaluate students' understanding of content or topics, diverse contexts, and various levels of cognitive processes. This aims to test students' ability to identify, analyze, and apply information in diverse situations, ranging from basic understanding to higher-level critical thinking skills.

The development of this assessment aims to provide a tool that can effectively evaluate students' critical thinking skills, as well as offer a more interactive and engaging learning experience. Using wizer.me, this instrument can be accessed online, allowing students to This aims to test students' ability to identify, analyze, and apply information in various situations, ranging from basic understanding to higher-level critical thinking skills.

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CONCLUSION

Based on the results of the analysis of the research conducted, this study found that the assessments carried out by teachers did not fully assess students' critical thinking skills, especially in connecting physics concepts with predetermined learning outcomes and learning objectives, while students had difficulty connecting the physics concepts they had learned with real phenomena and were unable to develop logical arguments based on the data obtained. Given this gap, there is a need for electronic assessments specifically designed to improve critical thinking skills in the context of ESD, especially on the subject of global warming. This integration is particularly relevant given that global warming is directly related to environmental sustainability issues.

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