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Needs Analysis to Develop Critical Thinking Skills Assessment Integrated with ESD in Phase F Physics Learning

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ABSTRACT

Critical thinking skills are an important competency in 21st-century physics learning. Ideally, assessments should not only measure students' conceptual understanding but also facilitate the development of critical thinking skills through contextual learning integrated with the principles of Education for Sustainable Development (ESD). However, preliminary findings indicate that students' critical thinking skills are still low, existing assessment practices are not aligned with critical thinking indicators, the characteristics of electronic assessments (e-assessments) have not been optimally implemented, and the integration of ESD in assessments is still limited. Based on these findings, this study aims to analyze the need for developing an integrated electronic assessment of ESD for critical thinking skills on the topic of Particle Motion Dynamics. A quantitative descriptive method was used involving 20 students of grade XI Phase F at SMA Muhammadiyah 3 Padang. Data were collected through critical thinking tests, questionnaires, document analysis, and interviews. The results showed low critical thinking skills (39.79%), inadequate implementation of ideal e-assessment characteristics, and low integration of ESD aspects in assessment practices. These findings indicate the need for the development of electronic assessments (e-assessments) integrated with Education for Sustainable Development (ESD), which are contextual, interactive, and capable of supporting the improvement of students' critical thinking skills in physics learning.

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INTRODUCTION

Twenty first century is known as the century of knowledge, information technology, globalization, and the Industrial Revolution 4.0. This demands that education produce human resources with 21st-century competencies to adapt and face global challenges. In the context

of 21st-century skills, there are four key competencies known as the 4Cs: Critical Thinking, Creativity, Collaboration, and Communication (Selman & Jaedun, 2020). Among these four components, critical thinking is a top priority in science learning, particularly physics, because it influences scientific reasoning, conceptual analysis, and problem-solving. This finding is supported by various recent studies showing that critical thinking skills are an important competency in 21st-century physics learning and contribute substantially to improving students' conceptual understanding and complex problem-solving abilities in increasingly complex real-world situations (Arni, 2025 ; Akbar et al., 2024).

Critical thinking is a high-level cognitive skill that involves conscious, reflective, and rational thought processes in understanding and evaluating information before making decisions or determining actions. According to Facione (2020), there are six indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation. These six indicators are interrelated and serve as an important foundation for developing students' ability to think logically, systematically, and responsibly when facing various problems. However, recent research shows that students' critical thinking skills have not developed optimally due to teacher-centered learning that provides little room for in-depth exploration and analysis (Dina et al., 2024 ; Tugirin et al., 2025).

Assessment serves as one of the key components in fostering critical thinking throughout the learning process. Assessment plays a crucial role in learning because it not only measures learning outcomes but also regularly stimulates and develops students' critical thinking skills. Assessment principles serve as a guide to ensure the assessment process truly reflects students' learning achievements in a comprehensive, fair, and meaningful manner. Assessment serves not only as an instrument for assessing learning outcomes but also as a reflective, remedial, and follow-up learning process that supports the continuous development of student competencies. According to Anggreaena (2025), the implementation of assessment must adhere to three main principles: fairness, objectivity, and educativeness.

Furthermore, the availability of quality assessments also needs to be supported by educational approaches relevant to global challenges, one of which is Education for Sustainable Development (ESD). ESD emphasizes that education should not merely focus on knowledge acquisition but should also cultivate the skills, values, and attitudes needed for learners to address sustainability challenges and support a more equitable and prosperous society (Kioupi & Voulvoulis, 2019). The development of quality assessments is closely linked to the achievement of such efforts support the achievement of SDG 4, which promotes equitable access to quality education and lifelong learning opportunities for all members of society. In the context of physics education, assessments that encourage higher-order thinking and authentic performance are considered an important strategy to support the implementation of SDG 4 (Emiliannur et al., 2026). Assessments designed in physics learning should ideally be able to integrate critical thinking skills with the ESD context. Research by Novita et al., (2025) shows that integrating ESD with physics learning can develop students' critical thinking, systems thinking, and anticipatory thinking skills in addressing sustainability issues. Integrating ESD into science learning can improve critical thinking skills as well as awareness of sustainability issues (Ekamilasari et al., 2022 ; Hoerunnisa et al., 2024).

In physics learning, Particle Motion Dynamics constitutes an essential topic for understanding the principles governing motion. This study employs the topic of Particle Motion Dynamics as a learning context, supported by sustainability-oriented informational texts to facilitate students' conceptual understanding. The learning design aims to integrate physics concepts with the cultivation of critical thinking while fostering students' understanding of sustainability-related issues. Research by Rosyida & Prahani (2025) shows that physics learning about material dynamics (such as rotational dynamics) associated with contextual problem solving can be proven effective in improving students' critical thinking

skills. The evidence suggests that dynamics-related content provides meaningful opportunities for strengthening students' critical thinking capacities with great potential to be used as a context for developing critical thinking abilities by incorporating real-world sustainability contexts into the learning process.

Based on the results of the critical thinking ability test, it can be concluded that in general students' critical thinking abilities are still in the low category, especially in the explanation indicator. This situation indicates that students still have difficulty answering questions that require the ability to explain the relationship between physics principles and the context of sustainability. This indicates that students have not yet adapted to physics learning that explicitly integrates the context of sustainability. This situation reflects the gap between the demands of ESD-based assessments and students' readiness to construct logical and contextual scientific explanations. This is in line with the findings of Lubis's (2023) research, which stated that students are unable to provide explanations based on real-world concepts and contexts. Therefore, the integration of ESD in learning still needs to be strengthened.

To address these challenges, it is necessary to develop critical thinking assessments integrated with ESD and supported by digital technology. The integration of ESD into learning and assessment provides meaningful and contextual learning experiences that encourage students to critically analyze sustainability issues and make responsible decisions in real-life situations (Fadila, 2025). Furthermore, the development of electronic assessments can facilitate the measurement of students' critical thinking skills more effectively and interactively, while increasing student engagement in the learning process (Oktaviawati & Mufit, 2025). The implementation of innovative digital-based assessments is also considered capable of supporting transformative and holistic learning that prepares students to face global challenges (Ramadhani et al., 2025).

Digital platforms such as Google Forms offer several advantages, such as ease of access, automated response collection, efficient data management, flexible question formats, and rapid feedback, making them effective for evaluating online learning (Zaidaan et al., 2024 ; Rahayu et al., 2024). Furthermore, mobile-based and digital assessments have been shown to significantly improve students' critical and creative thinking skills through interactive and technology-enabled learning environments (Ridhoni et al., 2022). Furthermore, the integration of digital technology into assessment practices supports a more adaptive and student-centered learning environment, which is crucial for developing 21st-century competencies (Basilotta-Gómez-Pablos et al., 2022). Therefore, integrating Google Forms into ESD-based assessments can be an innovative alternative to improve students' critical thinking skills in the digital age.

Based on the previous discussion, this study aims to examine the need for developing an integrated ESD assessment of critical thinking skills in Phase F physics learning. The findings of this study are expected to provide a basis for designing effective assessment strategies that facilitate the achievement of learning objectives while supporting the achievement of the Sustainable Development Goals (SDGs). In addition, the development of this assessment is also expected to produce an assessment instrument that not only measures students' cognitive abilities but also encourages high critical thinking skills. Developing contextual, reflective, and relevant thinking skills to real-life problems, particularly those related to sustainability. Thus, the developed assessment can be an innovative approach to physics learning that is responsive to technological advances and aligned with the evolving demands of 21st-century education.

METHOD

This research is a quantitative descriptive study that aims to analyze students' Physics learning needs and critical thinking skills. Data collection was conducted on September 20,

2025, with a study population of 20 grade XI Phase F students of the 2025/2026 academic year. A needs analysis was conducted to identify Physics learning needs relevant to students' characteristics. Data in this study were collected using questionnaires, tests, and interviews. Questionnaires were administered to determine students' learning styles, which serve as a basis for developing a more adaptive learning approach. Tests were used to measure critical thinking skills, while interviews with physics teachers were conducted. Conducted to collect relevant information regarding assessment practices applied during the learning process.

This research instrument consists of two main parts: a questionnaire is required for students, along with a critical thinking skills assessment. The questionnaire is designed to obtain information about students' learning styles, thus serving as a reference for developing assessments aligned with their needs. Meanwhile, the critical thinking assessment instrument is designed based on six indicators introduced by Facione (2020): interpretation, analysis, evaluation, inference, explanation, and self-regulation, which reflect higher-order cognitive skills. The use of these two instruments provides a comprehensive overview of students' learning needs and levels of critical thinking skills in the context of physics learning. The data obtained were analyzed using descriptive statistics, an analytical technique aimed at processing, summarizing, and presenting data in an orderly manner for easy understanding (Sugiyono, 2022). Thus, the analysis results can provide accurate information as a basis for developing more effective learning assessments.

The results of the needs analysis are calculated using a percentage formula, which involves comparing the obtained score to the maximum score and then multiplying it by 100%. This calculation is used to determine the level of achievement of each aspect measured in the study. These percentages are then used as a basis for interpreting student need categories and levels of critical thinking skills.

$$Score\ percentage = \frac{Total\ score\ obtained}{Maximum\ possible\ score} \times\ 100\% \quad (1)$$

Data analysis to evaluate the need for each indicator through the use of the provisions in Table 1.

Table 1. Needs Analysis Categories

No	Percentage(%)	Criteria
1.	0-20	Very low
2.	21-40	Low
3.	41-60	Enough
4.	61-80	High
5.	81-100	Very high

Source: (Riduwan, 2019)

The categorization framework for evaluating the instructional needs analysis is structured systematically into five distinct criteria as detailed in Table 1. This classification serves as a methodological benchmark to interpret the empirical percentage scores obtained from the critical thinking skills assessment. Score intervals falling below 40% are strictly designated within the 'very low' and 'low' boundaries, indicating a severe deficit in the measured indicators. Conversely, percentage achievements ranging from 41% to 80% represent the 'moderate' (enough) and 'high' transitional echelons of student readiness. Ultimately, any calculated percentage exceeding the 80% threshold up to 100% is definitively categorized as 'very high', reflecting an optimum level of indicator fulfillment.

RESULTS AND DISCUSSION

Results

The data in this study were obtained through a critical thinking skills test conducted at SMA Muhammadiyah 3 Padang on September 20, 2025, with 20 eleventh-grade students participating. The instrument used was an essay-based assessment comprising six stimulus-driven questions, constructed with reference to the critical thinking skill indicators developed by Facione (2020). Detailed data from the critical thinking skills analysis for each indicator are presented in Table 2.

Table 2. Results of Students' Critical Thinking Ability Test

Critical Thinking Skills Indicators	Percentage (%)	Category
Interpretation	41.3	Enough
Analysis	40.0	Low
Evaluation	41.3	Enough
Conclusion	38.8	Low
Explanation	37.5	Low
Self-Regulation	40.0	Low
Average	39.8	Low

The test results show that students' critical thinking skills are generally still in the low category, with an average score of 39.8%. The explanation indicator has the lowest percentage, at 37.5%. Low achievement in this indicator indicates that students still have difficulty expressing reasons, explaining their thoughts, and constructing arguments logically and systematically based on evidence or concepts they have learned. This condition indicates that students are not yet accustomed to physics learning that explicitly integrates ESD principles and real-world sustainability issues into the learning process. As a result, students tend to focus on memorizing concepts rather than developing a deeper understanding that enables them to explain phenomena critically and contextually. This situation reflects the gap between the demands of ESD-based assessments and students' readiness to construct logical and contextual scientific explanations. In the context of physics education, the ability to provide explanations is essential because it allows students to connect scientific concepts with everyday situations, analyze environmental and social problems, and propose evidence-based solutions. This finding is in line with research by Lubis (2023), which states that low achievement in the explanation indicator is caused by students' lack of ability to construct explanations based on real-life concepts and contexts. Therefore, learning and assessment strategies are needed that can train students to develop scientific arguments, logical reasoning, communication skills, and the ability to explain physical phenomena contextually while considering sustainability perspectives promoted through ESD.

Students' low critical thinking skills are closely related to the assessment practices implemented in schools. Based on teacher interviews, the assessments used focus more on measuring students' mastery of concepts and mathematical calculation skills as the basis for assigning grades, while aspects of thinking processes, explanation skills, and scientific argumentation have not been a primary focus. Therefore, an analysis of the assessments used by physics teachers was conducted to determine the suitability between the assessments implemented in schools and the characteristics of ideal electronic assessments (e-assessments). The results of this analysis are presented in Table 3.

Table 3. Analysis of Particle Motion Dynamics Assessment

Characteristics of Ideal E-Assessments	Percentage (%)	Category
Multimedia & Interactivity	20	Very low
Feedback	40	Low
Automated data analysis	20	Very low
Adaptivity	20	Low
Digital integrity & security	40	Low
Flexibility of access	40	Enough

Based on the analysis results, the least fulfilled characteristics of e-assessment were multimedia and interactivity, automated data analysis, and adaptivity, each obtaining a percentage of 20% (very low). Meanwhile, the aspects of feedback, digital integrity and security, and flexibility of access obtained a percentage of 40% (low). These findings indicate that the assessments currently used by teachers are still dominated by conventional assessment practices and have not optimally utilized the key features of e-assessment. Therefore, there is a need to develop an e-assessment that can provide interactivity, effective feedback, automated analysis, flexible access, and support academic integrity as well as students' learning needs.

The low level of multimedia and interactivity suggests that assessment activities are still largely limited to text-based questions and have not incorporated dynamic learning stimuli such as videos, animations, simulations, or contextual visualizations. As a result, students have limited opportunities to engage with authentic problems that require analysis, interpretation, and evaluation. Similarly, the absence of automated data analysis and adaptive features indicates that the assessment system is not yet capable of identifying individual learning difficulties, monitoring achievement indicators efficiently, or providing differentiated assessment experiences based on students' abilities. This condition may reduce the effectiveness of assessment in supporting meaningful learning and the development of higher-order thinking skills.

Furthermore, although feedback, digital integrity and security, and flexibility of access achieved relatively higher percentages, these aspects remain far from the characteristics of an ideal e-assessment. Feedback is generally limited to providing scores without diagnostic information or conceptual explanations, while digital security features have not fully supported the prevention of academic dishonesty. In addition, flexibility of access has primarily focused on device availability rather than personalized and inclusive assessment experiences. Therefore, the development of an integrated e-assessment is urgently needed not only to measure learning outcomes more comprehensively but also to foster students' critical thinking skills through interactive, adaptive, and technology-enhanced assessment environments. In addition, the need for the development of e-assessments that are capable of measuring critical thinking skills comprehensively needs to be accompanied by the integration of learning approaches that are relevant to the challenges of the 21st century and global sustainability issues in diverse and authentic contexts.

The development of assessment instruments also needs to be adapted to the demands of 21st-century learning, which emphasizes students' ability to understand, analyze, and solve real-world problems sustainably. One approach that can be implemented is through the integration of ESD concepts into learning assessments. Integrating ESD into assessments is expected to encourage students to not only understand physics concepts theoretically, but also to have the ability to analyze contextual problems, make decisions based on scientific evidence, and raise awareness of sustainability issues in the surrounding environment and society. Furthermore, ESD-based assessments can facilitate the development of higher-order thinking skills, responsible decision-making, and problem-solving abilities relevant to

everyday life. Thus, the developed assessments can support the achievement of critical thinking skills while shaping student competencies that are in line with the demands of 21st-century learning and sustainable development goals.

To determine the extent to which ESD aspects are implemented in the assessment process at school, an analysis of the ESD indicators integrated into the assessments used by teachers was conducted. This analysis aimed to identify the alignment between existing assessment practices and ESD principles. The indicators examined encompassed sustainability-related knowledge, attitudes, and skills. Such analysis is essential for evaluating the degree to which assessment practices support the objectives of Education for Sustainable Development and promote the development of sustainability competencies among students. Moreover, the findings provide a foundation for improving assessment design to better incorporate ESD dimensions within physics learning. The results of this analysis are presented in Figure 1.

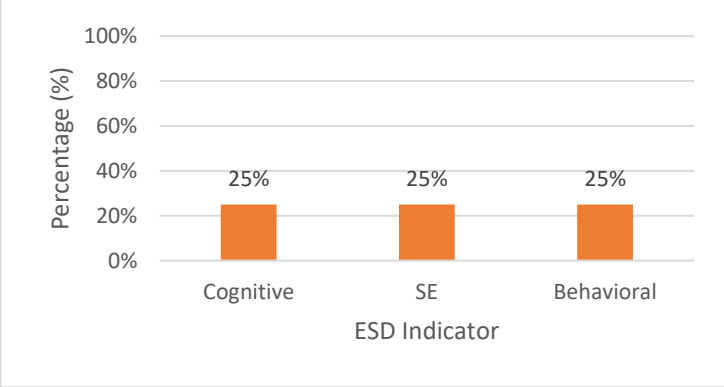

Figure 1. ESD Analysis of Particle Motion Dynamics Assessment

Based on the analysis of Figure 1, it can be concluded that the integration of ESD in the assessment of particle motion dynamics is still in the low category. All indicators in the cognitive, socio-emotional, and behavioural aspects show a low category. The assessment used still focuses on calculations and theoretical understanding of physics concepts, without connecting them to sustainability issues, contextual problem analysis, or evidence-based decision-making. This condition indicates that existing assessments are not yet able to accommodate the demands of 21st-century learning, which emphasizes the relationship between scientific concepts and real-world problems in the environment. The integration of ESD in assessment is crucial to direct students not only towards conceptual mastery, but also towards critical thinking skills, environmental awareness, and responsible decision-making related to sustainability issues.

In line with these needs, assessment development also requires consideration of student characteristics as a crucial factor influencing the learning process. Understanding student learning styles provides the basis for designing more effective assessments that align with students' perceptions and information processing. The results of student learning style analysis can be used as a reference in developing assessments that are more adaptive, contextual, and able to optimally facilitate competency achievement. The empirical data reveals that the student population is predominantly characterized by visual and auditory learning preferences, necessitating a highly interactive testing interface. Consequently, incorporating multimodal elements like dynamic diagrams and audio-visual contexts into the electronic assessment becomes vital to accommodate these diverse cognitive traits. The results of the learning style analysis can be seen in Figure 2.

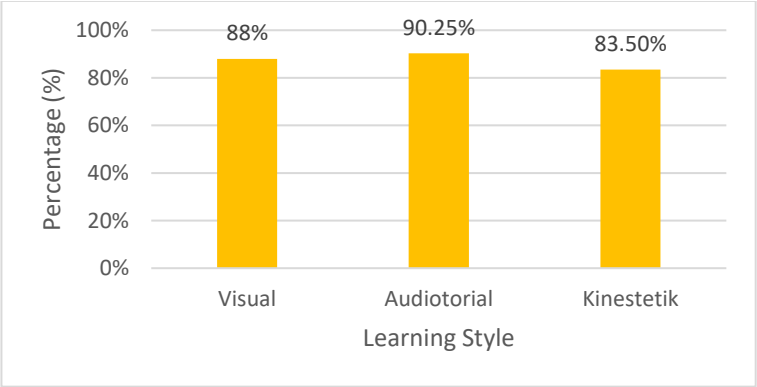

Figure 2. Results of Student Learning Style Analysis

Based on the data analysis, it can be concluded that auditory and visual learning styles have the highest percentages compared to other learning styles. This finding indicates that most students find it easier to understand material through oral explanations, discussions, listening activities, and the use of visual media such as images, graphs, and learning videos. The dominance of these two learning styles indicates that the learning and assessment process needs to be designed by integrating audio and visual elements in a balanced manner. Therefore, the results of this learning style analysis can be used as a basis for developing assessments that are more suited to the characteristics and learning needs of students, thereby supporting their engagement and understanding during the learning process.

Discussion

The results of the study indicate that overall, students' critical thinking skills are still relatively low, as reflected in the average score of 39.79%. This indicates that efforts to foster higher-order thinking skills in physics learning have not been fully effective. When analyzed based on each indicator, only the interpretation and evaluation indicators are in the adequate category, while the analysis, inference, explanation, and self-regulation indicators are still relatively low. Specifically, the explanation indicator obtained the lowest percentage score (37.5%), indicating that students still have difficulty explaining scientific reasoning, constructing arguments based on physics concepts, and connecting concepts to contextual phenomena. Based on the analysis of student answer sheets, many students were only able to state formulas or concepts without providing logical explanations supported by scientific reasoning. This finding indicates that students are still not qualified to solve contextual and reflective problems that require a deeper reasoning process. This finding is in line with various recent studies that show that critical thinking skills in physics learning remain a global challenge, mainly due to the dominance of conventional learning that does not fully encourage active student involvement in higher-order thinking processes (Arni, 2025). Furthermore, a literature review shows that critical thinking skills are one of the main focuses in 21st-century education, but their implementation in the classroom is still uneven and tends to be less effective (Akbar et al., 2024) .

The explanation indicator was the aspect with the lowest achievement in this study. This indicates that students still experience difficulties in presenting logical reasoning, constructing conceptually based arguments, and explaining the relationship between physics concepts and real-world phenomena. Students also tend to provide short and direct answers without elaborating on the reasoning process behind their answers. Conceptually, explanation skills represent the integration of several higher-order thinking processes, such as analysis, evaluation, and inference. Therefore, low achievement in this indicator indicates fundamental weaknesses in students' cognitive processes. This finding is supported by recent

research stating that scientific explanation skills are often low because students are less accustomed to context-based learning and inquiry (Pfefferová & Plesch, 2025). Therefore, limitations in explanation skills affect not only conceptual understanding but also the ability to solve problems comprehensively. This finding also reinforces previous research by showing that students' difficulties become more apparent when physics problems are presented in sustainability-related and contextual situations.

Furthermore, low student critical thinking scores are closely related to assessment practices implemented in learning. Although teachers have used a combination of multiple-choice and essay questions, these instruments have not been specifically designed to measure critical thinking skills. Based on interviews and document analysis, teacher assessments are still dominated by questions focused on conceptual understanding and direct mathematical calculations. Students are rarely given the opportunity to analyze phenomena, evaluate information, or explain reasoning processes reflectively. This mismatch between learning objectives and assessment practices is a major obstacle to improving students' higher-order thinking skills. Recent research suggests that effective assessments must be designed in the form of open-ended, problem-based, and contextual tasks to stimulate students' reasoning and argumentation processes (Jatmiko et al., 2025). Furthermore, this study found that although the learning objectives prepared by teachers reflected Higher-Order Thinking Skills (HOTS), the assessment instruments were not fully aligned with these objectives. This indicates that the principle of constructive alignment between learning objectives and assessment has not been optimally implemented.

On the other hand, limitations in the integration of ESD (Education for Sustainable Development) in physics learning also contribute to students' low critical thinking skills. Research shows that students experience difficulties when faced with problems that connect physics concepts to sustainability issues. This indicates that the learning process has not optimally connected the material to real-life contexts. Analysis of student responses also revealed that many students struggled to explain physics phenomena related to environmental and sustainability issues, indicating limited exposure to contextual learning experiences. Recent research has shown that the integration of ESD in science learning can improve critical thinking skills, systems thinking, and awareness of global issues (Novita et al., 2025). Therefore, the lack of exposure to sustainability contexts makes it difficult for students to develop reflective and contextual thinking skills.

Furthermore, learning style questionnaire data indicates that students tend to have visual and auditory learning style preferences. This suggests that students more easily understand material through visual representations and verbal explanations, such as images, videos, discussions, and teacher explanations. This finding aligns with recent research suggesting that multimodal and interactive learning environments can enhance student engagement and critical thinking skills (Ahzari & Akmam, 2025). In this context, the use of digital technologies such as interactive multimedia is highly relevant to support the learning process. Technology-based media can present more engaging, contextualized stimuli tailored to students' learning characteristics, thereby encouraging deeper cognitive engagement. In light of these findings, the development of electronic assessments integrated with interactive visual and contextual elements can better support students' critical thinking processes and enhance meaningful learning experiences.

Conceptually, the integration of ESD-based assessment into physics learning, particularly particle dynamics, has significant potential to develop critical thinking skills. Dynamics is closely related to everyday phenomena, such as energy efficiency, transportation, and environmental issues. By connecting physics concepts to real-world sustainability-based problems, students can be trained to think systematically, analytically, and reflectively. Recent studies have also shown that contextual learning approaches that

integrate sustainability issues can enhance students' knowledge transfer, critical thinking, and complex problem-solving skills (Bramastia et al., 2025). Furthermore, ESD-based assessment can provide meaningful learning experiences because students are encouraged not only to understand concepts theoretically but also to evaluate the impact of scientific and technological applications on environmental and social sustainability.

Overall, the empirical findings demonstrate that students' low critical thinking skills are predominantly driven by four core factors. These include: (1) assessments that have not been designed to measure and train critical thinking skills specifically, (2) assessments that do not include the characteristics of ideal electronic assessments, (3) suboptimal integration of ESD in physics learning, and (4) the lack of use of learning media that are appropriate to the characteristics of students' learning styles. These findings are in line with the results of a recent meta-analysis which stated that technology-based, contextual, and student-centered learning is the most effective approach in developing critical thinking skills (Ahzari et al., 2023). Thereby necessitating to develop ESD-based electronic assessments that are designed systematically, contextually, and aligned with indicators of critical thinking skills. This assessment is expected to function not only as an evaluation tool, but also as a means to build meaningful learning experiences that are relevant to the global challenges of the 21st century.

CONCLUSION

Based on the results and discussions that have been carried out, four conclusions can be drawn from this research, namely: (1) students' critical thinking skills in the Dynamics of Particle Motion material still need to be improved because students still experience difficulties in analyzing problems, building scientific arguments, and explaining physical phenomena logically; (2) the characteristics of the assessments used in schools have not fully met the ideal e-assessment criteria so that they have not been able to measure and develop students' critical thinking skills optimally; (3) the integration of Education for Sustainable Development (ESD) in the assessment is still limited so that the assessment has not been able to adequately connect physics concepts with sustainability issues and contextual problems; and (4) students tend to have auditory and visual learning styles so that assessment development needs to integrate interactive audio and visual elements. These findings indicate the need to develop an integrated ESD critical thinking skills e-assessment that aligns with learning objectives and student learning characteristics to support more contextual, interactive, reflective, and sustainability-oriented physics learning.

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