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Electronic Assessment Design Integrated Critical Thinking Skills Education for Sustainable Development on Motion Kinematics Material

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ABSTRACT

Ideally, physics education in the 21st century should develop students' critical thinking skills to address global sustainability challenges. However, current physics assessment practices often do not effectively foster these skills and remain insufficiently integrated with the principles of Education for Sustainable Development (ESD). This study aimed to analyze the need for and develop an electronic assessment integrating critical thinking skills within ESD-based kinematics learning. The research employed a Research and Development (R&D) approach using the 4D model up to the development stage. The participants were 26 eleventh-grade students from SMAN 3 Pariaman. Data were collected through critical thinking tests based on Facione's indicators, questionnaires, and interviews. The results showed that students' critical thinking skills were relatively low, particularly in the evaluation aspect, which obtained the lowest score of 30.76%. In addition, ESD integration in assessment practices was still limited. Students' preference for visual and auditory learning styles indicates the potential effectiveness of digital assessments. Therefore, developing an electronic assessment integrating critical thinking and ESD principles is necessary to support meaningful and sustainability-oriented physics learning.

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INTRODUCTION

The rapid progress of science and technology in the 21st century has significantly influenced multiple areas of human life, particularly in the domain of education. Education should prepare students to be adaptive to change, competitive, and able to play an active role in facing global challenges. The learning process in this era is not only oriented towards mastering material but also must develop higher-order thinking skills that train students to analyze and solve problems creatively (Destiana et al., 2025;Ayu Uswah et al., 2024). Therefore, critical thinking is considered a key competency that must be fostered in 21st-century education, as it plays an essential role in developing logical, reflective, and problem-solving abilities (Afridiani & Faridah, 2021).

Critical thinking skills are important to develop in the learning process because they encourage students not only to receive information but also to understand and evaluate knowledge consciously and critically. Learning that promotes critical thinking can help students become more responsive to problems, capable of connecting knowledge with real-life situations, and confident in expressing opinions responsibly (Ramadani et al., 2025). In addition, strengthening critical thinking skills contributes to the development of students' character, including integrity, openness to differences, and awareness of social conditions in their surroundings (Sidqi et al., 2025.). Therefore, the development of critical thinking skills serves as an important foundation for fostering students' awareness of sustainability issues through the implementation of Education for Sustainable Development (ESD) in learning (Pangestika et al., 2022).

The integration of Education for Sustainable Development (ESD) in the educational process is essential for developing students who are not only intellectually competent but also aware of environmental, social, and economic sustainability. Through this approach, the learning process is directed toward fostering students' awareness of the importance of maintaining a balance between human needs and environmental sustainability, while also encouraging responsibility in every action taken (Rahmawati et al., 2021). ESD-oriented learning also encourages students to connect knowledge with real-life situations, think critically about the impact of every decision, and actively participate in creating sustainable solutions within their environment (Rohmah & Lestari, 2024). Therefore, the successful implementation of ESD values in learning requires an assessment system that is capable of measuring not only students' knowledge but also their attitudes and concrete actions toward sustainability issues (Salam & Hamdu, 2022).

Assessment plays a crucial role in determining the success of the learning process because it functions as a tool for teachers to evaluate the level of students' understanding of the material they have learned (Natasya, 2024). Through assessment, teachers can determine students' abilities to process information, draw conclusions, and apply knowledge to solve learning problems (Wijayanti et al., 2024). In addition, effective assessment results can assist teachers in improving learning strategies to make them more effective and aligned with students' needs. Therefore, the proper implementation of assessment becomes an important foundation for evaluating students' conceptual understanding and analytical skills, particularly in kinematics learning, which requires a deep understanding of motion phenomena. This also supports continuous monitoring of learning progress and encourages meaningful feedback for students' academic growth and development.

Kinematics plays an important role in physics learning because it provides the foundation for students to understand various motion phenomena that occur in their surroundings (Muzakki et al., 2022). Mastery of this material reflects the achievement of science learning objectives, particularly in developing students' reasoning abilities and their capacity to explain natural phenomena logically (Umami & Wulandari, 2025). (Umami & Wulandari, 2025). In addition, kinematics serves as a basis for understanding more complex physics concepts, making it fundamental in the structure of science learning in schools (Oktavia Nasution et al., 2025). Considering the importance of this topic, this research aims to develop an electronic assessment based on Education for Sustainable Development (ESD) to accurately measure and enhance students' critical thinking skills within the context of kinematics learning.

METHODS

This study employed a Research and Development (R&D) approach aimed at developing an electronic assessment to measure students' critical thinking skills integrated

with the principles of Education for Sustainable Development (ESD) in kinematics learning. The research was conducted during the 2025 academic year at SMAN 3 Pariaman. The participants consisted of eleventh-grade students (Phase F) selected through purposive sampling based on the requirements of the development process. This study adopted the 4D development model introduced by Thiagarajan et al (1974), which consists of four stages: Define, Design, Develop, and Disseminate (Thiagarajan et al., 1974).

At the define stage, several analyses were carried out, including initial analysis, learner characteristics, task analysis, concept analysis, and the formulation of learning objectives. The design stage involved constructing assessment instruments, selecting appropriate digital platforms such as Google Sites, Wizer.me, and Quizizz, determining an essay-based format, and developing the initial prototype. The develop stage focused on refining the product and conducting expert validation to evaluate its feasibility. Finally, the dissemination stage was implemented on a limited scale by introducing the product to physics teachers to gather preliminary feedback.

The instruments used in this study included a needs analysis questionnaire, interview and observation guidelines, a critical thinking test, an expert validation sheet, and a practicality questionnaire. The needs analysis questionnaire, interviews, and observations were conducted to identify problems and learning needs in physics education. The critical thinking test was developed based on Facione's critical thinking framework, encompassing six core skills: interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, 2011). The expert validation sheet was used to assess the validity of the product, while the practicality questionnaire evaluated its usability in the learning process. Data were collected through interviews, observations, tests, and questionnaires and analyzed using qualitative and quantitative methods. Qualitative data were analyzed descriptively to identify students' conditions and learning needs, whereas quantitative data were analyzed using descriptive statistics and percentage-based criteria to determine the validity, practicality, and students' critical thinking skill levels (Kasliyanto et al., 2025).

The evaluation of critical thinking skills in this study was conducted using a percentage approach to provide an accurate picture of the subjects' achievements. The obtained data were then interpreted based on assessment criteria adapted from to objectively determine the classification of students' abilities. The use of percentage intervals aims to convert quantitative data into more in-depth qualitative information regarding the respondents' critical thinking abilities. These skill levels were classified into five main categories based on predetermined score ranges. The score calculation process was carried out using the formula below, while the details of the category division are systematically summarized in Table 1:

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

Table 1. Categories of Student's Critical Thinking Skills

Index (%)	category
0 – 20	Very low
21 – 40	Low
41 – 60	Enough
61 – 80	Tall
81 – 100	Very High

Source: (Riduwan, 2015)

RESULTS AND DISCUSSION

Results

Results of Students' Critical Thinking Skills

This study analyzed students' critical thinking skills through a test consisting of six stimulus-based essay questions developed based on Facione's (2020) critical thinking framework. The test was administered to 26 Grade XI Phase F students at SMAN 3 Pariaman on October 12, 2025. The instrument measured six critical thinking indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The results of each indicator are presented in Figure 1 and indicate that students' critical thinking skills have not yet reached the expected level across all assessed indicators.

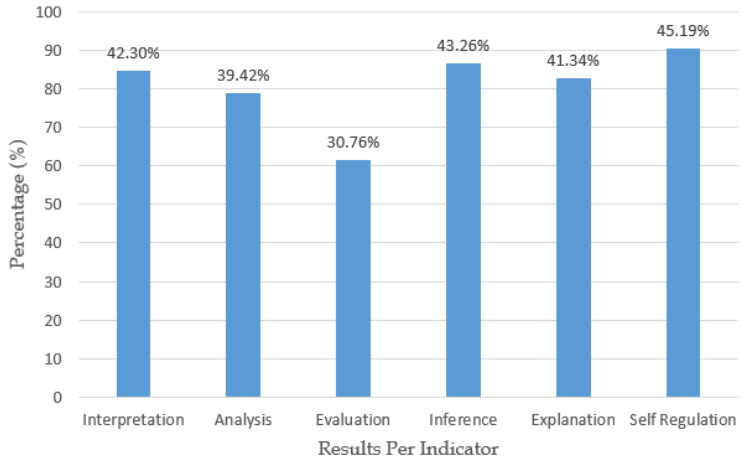

Figure 1. Students' Critical Thinking Skills Test Results

As shown in Figure 1, self-regulation obtained the highest percentage (45.19%), followed by inference (43.26%), interpretation (42.30%), explanation (41.34%), and analysis (39.42%), while evaluation achieved the lowest score (30.76%). Although self-regulation ranked highest, all percentages remained below 50%, indicating that students' critical thinking proficiency is still relatively low. The 14.43 percentage-point gap between self-regulation and evaluation suggests that students are more capable of monitoring their own understanding than critically assessing evidence and arguments. Consequently, the development of evaluative thinking skills should become an important focus of learning and assessment activities.

The low achievement in the evaluation indicator indicates that students experience difficulties in judging the credibility of information, examining supporting evidence, and making logical decisions. Analysis of students' responses showed that many answers contained brief conclusions without adequate explanations or evidence-based reasoning. Students often provided final answers directly without clearly describing the reasoning process used to reach those conclusions. In addition, the relatively low score in the analysis indicator suggests that students still face challenges in identifying relationships among concepts and determining the relevance of information within contextual physics problems.

These findings may be related to existing classroom learning and assessment practices. Based on teacher interview results, assessment activities mainly emphasize conceptual understanding and procedural problem solving, while opportunities to evaluate arguments, critique evidence, and justify conclusions remain limited. As a result, students become more accustomed to obtaining correct answers than developing evidence-based reasoning and defending their viewpoints. Therefore, learning and assessment activities should incorporate more contextual, inquiry-based, and argumentation-oriented tasks to promote the

development of critical thinking skills, particularly in evaluation and analysis.

Results of Assessment Analysis at School

Current assessment practices in physics learning have not explicitly measured students' critical thinking skills based on Facione's framework. Interviews with teachers revealed that although several assessment items were developed at the C3 (Apply) and C4 (Analyze) cognitive levels, they were not specifically designed to assess critical thinking skills. Most assessment tasks primarily emphasize mathematical calculations and procedural problem-solving activities, requiring students to apply formulas and obtain numerical solutions. As a result, students become more accustomed to solving routine physics problems than engaging in higher-order thinking processes, such as evaluating evidence, constructing logical arguments, and reflecting on their own reasoning. This finding suggests that current assessment practices remain focused on measuring procedural achievement rather than fostering the comprehensive development of critical thinking skills. To further examine this issue, all assessment items were analyzed using Facione's six critical thinking indicators, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation. The results of this analysis are presented in Table 2.

Table 2. Analysis of Existing School Assessment Items Based on Facione's Critical Thinking Indicators

Assesment Type	Item	Interpretation	Analysis	Inference	Evaluation	Explanation	Self-Regulation
Assessment of Learning	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
	4	X	X	X	X	X	X
	5	X	X	X	X	X	X
Assessment for Learning	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
	4	X	X	X	X	X	X
	5	X	X	X	X	X	X

Note: X = the critical thinking indicator is not explicitly measured in the assessment item according to Facione's critical thinking framework.

As shown in Table 2, all analyzed assessment items were marked with a cross (X) across Facione's six critical thinking indicators, indicating that interpretation, analysis, inference, evaluation, explanation, and self-regulation were not explicitly assessed. Although several questions were designed at the C3 (Apply) and C4 (Analyze) levels, they primarily required students to apply formulas and follow predetermined procedures to obtain correct numerical answers. Students were not required to evaluate evidence, justify arguments, formulate explanations, draw conclusions, or reflect on their reasoning. Therefore, the assessment process mainly emphasized procedural accuracy rather than critical thinking development.

In addition, most assessment tasks were presented as structured physics problems with predetermined solution methods and minimal connection to real-world or sustainability-related issues. Consequently, students had limited opportunities to apply physics concepts in authentic contexts that require critical analysis and responsible decision-making. This condition indicates a gap between existing assessment practices and the critical thinking competencies expected in twenty-first-century learning. Therefore, the development of an

ESD-integrated electronic assessment is needed to provide contextual, interactive, and reflective assessment activities that support the measurement of students' critical thinking skills.

Results of the Analysis of ESD-Integrated Teaching Materials

The findings revealed that the integration of Education for Sustainable Development (ESD) principles into physics assessment practices has not yet been implemented optimally. Interviews with teachers indicated that most teachers still have limited experience in designing assessment tasks that connect physics concepts with sustainability issues. Consequently, ESD elements are rarely incorporated into classroom assessments, resulting in limited opportunities for students to engage with sustainability-oriented learning contexts. This condition affects students' exposure to learning activities that promote sustainability awareness and responsible decision-making. Therefore, strengthening teachers' understanding of ESD integration is essential to support more meaningful and contextual assessment practices.

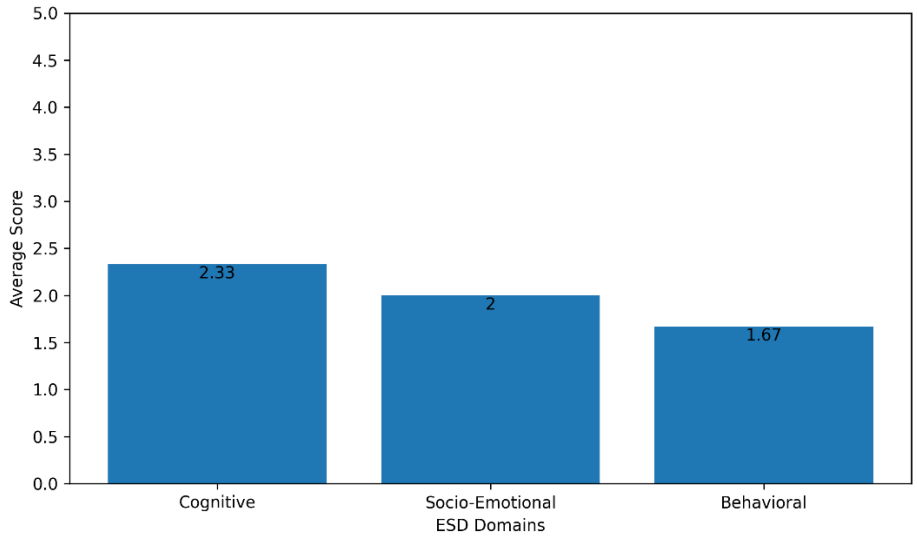

Figure 2. Results of ESD Integration in Physics Assessment Practices.

Based on Figure 2, students' ESD competencies were relatively low across all assessed domains. The cognitive domain obtained the highest average score (2.33), followed by the socio-emotional domain (2.00) and the behavioral domain (1.67). These findings indicate that students have begun to understand basic sustainability-related concepts in physics, but their awareness and application of sustainability principles remain limited. The lower scores in the socio-emotional and behavioral domains suggest that sustainability values have not yet been fully internalized and translated into actions. Therefore, greater integration of ESD-oriented assessment activities is needed to strengthen students' sustainability awareness, critical thinking skills, and responsible behavior.

Results of Student Learning Style Analysis

In addition, the analysis of the student learning style questionnaire revealed that the auditory style was the most dominant, accounting for 85.19%, followed by the visual style at 76.15% and the kinesthetic style at 65.77%. These findings indicate that most students tend to process information more effectively through listening activities and visual representations. The dominance of auditory and visual preferences suggests that students may benefit from learning resources that combine verbal explanations with visual elements. Understanding these learning characteristics is important because it provides a basis for designing learning

and assessment activities that align with students' needs. The overview of these results is presented in Table 3.

Table 3. Students' Learning Style Analysis

Learning Style	Total Score	Dominance Percentage	Ranking
Visual (A)	396	76,15%	2
Auditory (B)	443	85,19%	1
Kinesthetic (C)	342	65,77%	3

As shown in Table 3, auditory and visual learning styles were more dominant than kinesthetic learning styles among students. These findings have important implications for the design of electronic assessments because students tend to understand information more effectively through audio explanations and visual representations. Therefore, multimedia features such as videos, images, animations, and audio instructions should be integrated into assessment activities to accommodate these learning characteristics. The use of various media formats can help students access information more easily and engage more actively in assessment tasks. Consequently, assessment design should consider students' dominant learning preferences to create a more effective evaluation process.

Compared with conventional text-based assessments, multimedia-based electronic assessments provide multiple ways for students to access and process information. The integration of visual and auditory elements enables students to understand assessment content through modalities that match their learning preferences. Previous studies have reported that multimedia environments can improve student engagement and comprehension by combining visual and auditory stimuli (Fallace, 2025; Sayed et al., 2025). This advantage is particularly relevant because most students in this study demonstrated auditory and visual learning tendencies. Therefore, multimedia-based electronic assessments are considered suitable for supporting students' learning characteristics and facilitating meaningful assessment experiences.

Design of E-Assessment

The E-Assessment was developed using Google Sites as a web-based platform that provides an organized, accessible, and interactive assessment environment. The platform was designed based on the results of the needs analysis, which indicated that current assessment practices in schools have not yet fully utilized digital technology, multimedia resources, and critical-thinking-oriented assessment tasks. Therefore, the E-Assessment was developed to address these limitations by providing a structured digital environment that supports learning and assessment activities in an integrated manner.

The platform consists of several main menus, including Introduction, E-Assessment User Guide, E-Assessment Description, Learning Outcomes, Learning Objectives, and Assessment Indicators. These features provide students with clear information regarding the assessment procedures, learning targets, and indicators to be achieved. The use of navigation buttons, visual icons, images, videos, hyperlinks, and interactive forms enhances user accessibility and engagement during the assessment process. Such features are intended to create a more interactive and meaningful assessment experience compared with conventional paper-based assessments.

The development of this platform was also supported by the findings presented in Table 4. The results indicate that current school assessment practices still show weaknesses in several aspects of ideal E-Assessment characteristics. Interactive interface design obtained a value of 2 (Weak), multimedia integration obtained a value of 1 (Very Weak), digital platform utilization obtained a value of 2 (Weak), and critical thinking development obtained a value

of 2 (Weak). Meanwhile, the availability of clear instructions and learning objectives received a value of 3 (Moderate). These findings highlight the need for an assessment platform that integrates digital technology, multimedia resources, and critical-thinking-oriented tasks more effectively.

Table 4. Characteristics of Ideal E-Assessment and School Assessment Conditions

Ideal E-Assessment Characteristics	Assessment Conditions at School	Value	Category
E-Assessment has an interactive interface design	The assessment interface is still monotonous and less attractive	40	Weak
Integrates audio, video, images, and hyperlinks	The use of multimedia is still very limited	20	Very Weak
Uses an interactive and easily accessible digital platform	Assessment is still predominantly paper-based and has not been optimally integrated into digital platforms	40	Weak
Develops students' critical thinking skills	Assessment items still focus on concept memorization and calculations	40	Weak
Provides clear instructions and learning objectives	Learning information is available but not yet complete	60	Moderate

The E-Assessment was specifically designed to assess students' critical thinking skills while integrating Education for Sustainable Development (ESD) principles. Assessment tasks are presented through contextual physics problems related to environmental, social, and economic sustainability issues. Students are required to interpret information, analyze evidence, evaluate alternative solutions, and provide reasoned explanations for their answers. Through this approach, the platform serves not only as an assessment tool but also as a learning medium that promotes critical thinking, sustainability awareness, and digital literacy.

Figure 3. The Design of Interactive E-Assessment Interface

The interface shown in Figure 3 presents the homepage of the E-Assessment platform for Grade 11 Phase F students. The page features a navigation panel on the left side that provides access to the main sections, including Introduction, E-Assessment User Guide, E-Assessment Description, Learning Outcomes, Learning Objectives, and Assessment Indicators. A prominent "Main Menu" banner is displayed at the center of the page, accompanied by a background collage of student activities that enhances visual

attractiveness. Each menu is represented by a distinctive icon to facilitate navigation and improve user accessibility. Overall, the interface reflects the characteristics of an interactive digital assessment platform by providing organized navigation, clear information, and multimedia-supported features that address the limitations identified in current school assessment practices.

Discussion

The findings indicate that students' critical thinking skills at SMAN 3 Pariaman are still relatively low, particularly in the evaluation and analysis indicators. The evaluation indicator obtained the lowest percentage score (30.76%), showing that students experienced difficulties in assessing evidence, judging the credibility of information, and making logical decisions based on scientific reasoning. In addition, the low achievement in the analysis indicator suggests that students still struggle to identify relationships among concepts and interpret information in contextual physics problems. These results are consistent with previous studies stating that students' critical thinking skills are often underdeveloped because classroom assessments tend to emphasize conceptual understanding and procedural problem solving rather than reflective and evidence-based reasoning (Demircioglu et al., 2023; Matthee & Turpin, 2019).

The findings from Table 2 further strengthen this result. Although several assessment items were categorized at the C3 (Apply) and C4 (Analyze) cognitive levels, none of the questions explicitly measured Facione's critical thinking indicators, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation. Most assessment tasks only required students to apply formulas and obtain numerical answers using predetermined procedures. As a result, students became more accustomed to solving routine physics problems than evaluating arguments, explaining reasoning, or reflecting on the validity of their answers. This finding supports previous research showing that higher cognitive levels in Bloom's Taxonomy do not automatically measure critical thinking skills if the tasks do not involve reflective judgment and evidence-based reasoning (Nurazizah et al., 2024; Yuliani & Mufit, 2025).

Another important finding is related to the limited integration of Education for Sustainable Development (ESD) in physics assessment practices. Based on Table 3, students were generally able to understand the concept of uniform linear motion (GLB), but they still had difficulty connecting physics concepts with sustainability issues. Most students explained only the characteristics of motion without discussing environmental impacts such as emission reduction, energy efficiency, or sustainable transportation. In the socio-emotional and behavioral domains, students also showed limited awareness, responsibility, and problem-solving abilities related to sustainability issues. These findings indicate that students' contextual analysis and application skills remain underdeveloped because learning activities still focus mainly on theoretical understanding and mathematical calculations. Similar findings were reported by (Christodoulou & Papanikolaou, 2023), who explained that ESD-based learning is important for encouraging reflective thinking, responsible decision-making, and sustainability awareness through contextual learning experiences.

The findings also revealed that students tend to have dominant auditory and visual learning styles. This condition suggests that students may learn more effectively through multimedia-based learning environments that combine visual representations, audio explanations, videos, and interactive content. Therefore, the development of electronic assessments becomes relevant for supporting students' learning characteristics while simultaneously improving critical thinking skills. Multimedia-based digital assessments can provide contextual scenarios, immediate feedback, and interactive activities that are difficult

to implement in conventional paper-based assessments. Previous studies have shown that multimedia learning environments can improve student engagement, comprehension, and cognitive participation because information is delivered through multiple modalities (Fallace, 2025; Sayed et al., 2025).

Based on these findings, this study proposes the development of an ESD-integrated electronic assessment using Google Sites as an interactive platform. The developed E-Assessment combines critical thinking indicators, sustainability contexts, and multimedia features within a single assessment environment. Students are encouraged not only to solve physics problems but also to interpret information, analyze evidence, evaluate solutions, justify conclusions, and reflect on sustainability-related issues. Consequently, the developed assessment is expected to support the improvement of higher-order thinking skills, sustainability literacy, digital competence, and meaningful learning experiences in physics education.

CONCLUSION

The findings of this study indicate five important results. First, students' critical thinking skills were relatively low across all Facione indicators, particularly in evaluation and analysis skills. Second, the analysis of existing school assessments showed that current assessment items primarily focus on procedural problem solving and do not explicitly measure critical thinking skills. Third, the integration of Education for Sustainable Development (ESD) in physics assessment practices was still limited, resulting in low achievement in students' cognitive, socio-emotional, and behavioral sustainability competencies. Fourth, the learning style analysis revealed that auditory and visual learning styles were the most dominant among students, indicating the need for multimedia-supported assessment environments. Fifth, based on these findings, an ESD-integrated electronic assessment was developed using Google Sites to provide interactive, contextual, and critical-thinking-oriented assessment activities that support students' critical thinking skills, sustainability awareness, and digital literacy.

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