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Needs Analysis for Developing a Deep Learning-Based E-Module Integrating Local Wisdom to Enhance Students' Critical Thinking Skills on Climate Change

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ABSTRACT

Critical thinking is one of the essential competencies in 21st-century physics education. However, preliminary observations revealed that students' critical thinking skills remain low, while existing learning materials have not optimally supported deep learning or incorporated local wisdom into physics instruction. This study aimed to analyze the need for developing a deep learning-based e-module on climate change that integrates local wisdom and utilizes Canva AI to facilitate students' critical thinking skills. The novelty of this study lies in combining deep learning principles, local wisdom, and Canva AI within a digital e-module framework to promote more contextual, engaging, and meaningful physics learning. This study employed a quantitative descriptive method involving 31 Grade XI students at SMAN 9 Sijunjung. Data were collected through critical thinking tests, questionnaires, interviews, and document analysis. The results showed that students' critical thinking skills were still low, with an average score of 37.5%. Furthermore, existing learning materials did not adequately promote critical thinking, contextual learning, or the integration of local wisdom, while students expressed a strong need for interactive digital learning materials. Integrating local wisdom enables students to connect climate change concepts with their surrounding environment, whereas Canva AI supports the development of visually engaging and interactive learning materials that enhance students' learning experiences. These findings confirm the need to develop a deep learning-based e-module integrated with local wisdom and assisted by Canva AI. The proposed e-module is expected to serve as a practical reference for teachers in designing innovative physics learning materials that foster students' critical thinking skills while promoting contextual and meaningful learning experiences.

Keywords :e-module, deep learning, local wisdom, climate change, critical thinking skills.

I. INTRODUCTION

The rapid advancement of science, technology, and digital transformation in the twenty-first century has transformed educational paradigms worldwide, including in Indonesia through the implementation of the Merdeka Curriculum across various levels of education [1], [2]. In response to these changes, education is expected to equip students with competencies that enable them to adapt to increasingly complex scientific and technological developments. Among the essential competencies for twenty-first-century learning, critical thinking is regarded as one of the most important skills because it enables students to analyze information, evaluate evidence, solve problems, and make reasoned decisions in various contexts [3], [4]. In physics education, the development of critical thinking is particularly important because students are expected not only to understand scientific concepts but also to apply scientific reasoning to investigate natural phenomena and solve authentic problems. Therefore, learning activities should consistently facilitate the development of higher-order thinking skills to prepare students for the challenges of the twenty-first century [4], [5].

Critical thinking is a higher-order cognitive skill that enables students to interpret information, analyze evidence, evaluate arguments, draw logical conclusions, explain their reasoning, and regulate their thinking when solving problems [6], [7]. These competencies are particularly important in climate change education because students are required to understand complex environmental phenomena, evaluate scientific information, and make responsible decisions based on scientific evidence [8], [9]. Nevertheless, previous studies have

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consistently reported that students' critical thinking skills in science learning remain relatively low, particularly when they are required to analyze contextual environmental issues and apply scientific concepts to real-life situations [10], [11]. A preliminary needs analysis conducted in the present study also indicates that students still encounter difficulties in demonstrating critical thinking during climate change learning. This finding highlights the need for innovative learning resources that not only facilitate conceptual understanding but also actively promote the development of critical thinking through meaningful and contextual learning experiences.

Climate change has become one of the most significant global challenges of the twenty-first century, making climate change education an essential component of science learning [12], [13]. In physics education, climate change topics require students to understand the relationships among various scientific concepts, interpret environmental data, evaluate scientific evidence, and analyze the impacts of human activities on natural systems [14]. Consequently, learning about climate change demands not only conceptual understanding but also strong critical thinking skills to enable students to make informed and responsible decisions regarding environmental issues. However, in classroom practice, climate change learning is often delivered through teacher-centered instruction and textbook-oriented approaches that emphasize conceptual knowledge rather than students' active engagement in analyzing authentic environmental problems [15]. As a result, students tend to acquire knowledge at a surface level without fully understanding the complexity of climate change or its relevance to their daily lives, indicating the need for more meaningful and contextual learning experiences.

One learning approach that has the potential to address these challenges is Deep Learning, which emphasizes meaningful knowledge construction through active student engagement rather than rote memorization [16], [17]. In the context of the Merdeka Curriculum, Deep Learning encourages students to develop conceptual understanding, critical thinking, and problem-solving skills through the integration of mindful learning, meaningful learning, and joyful learning experiences [18]. By actively engaging students in exploring scientific phenomena, reflecting on evidence, and connecting learning with authentic contexts, this approach enables students to construct knowledge more deeply and apply scientific concepts in everyday situations. Therefore, Deep Learning is considered a promising pedagogical approach for facilitating students' critical thinking in climate change learning. However, implementing this approach effectively requires appropriate learning resources that are capable of supporting active, contextual, and student-centered learning experiences.

The successful implementation of Deep Learning is closely related to the availability of learning resources that actively engage students in meaningful learning experiences. Among various digital learning resources, e-modules offer considerable potential because they provide structured learning materials that can integrate text, visual representations, multimedia, and interactive learning activities within a single platform [19], [20]. Compared with conventional printed teaching materials, e-modules encourage students to learn independently, explore scientific concepts more actively, and construct knowledge through inquiry-based and contextual learning processes [21]. Nevertheless, many existing e-modules primarily focus on delivering conceptual content and have not been specifically designed to support the principles of Deep Learning while simultaneously fostering students' critical thinking skills. Therefore, the development of innovative e-modules that align with Deep Learning principles is necessary to provide more meaningful, student-centered, and contextually relevant learning experiences.

Although previous studies have reported the positive contributions of Deep Learning, digital e-modules, local wisdom integration, and artificial intelligence in science education, these approaches have generally been implemented separately. Limited studies have integrated Deep Learning principles with local wisdom in climate change learning while simultaneously utilizing artificial intelligence to support the systematic design of digital learning resources. In this study, Canva AI is positioned not merely as a design application but as an AI-assisted instructional design tool that facilitates the development of visually meaningful, well-organized, and pedagogically appropriate learning materials capable of supporting students' conceptual understanding and critical thinking. Therefore, this study proposes a Deep Learning-based e-module integrating local wisdom and developed with the support of Canva AI as an innovative learning resource for climate change education. The present article aims to describe the results of the preliminary needs analysis that serve as the foundation for developing the proposed e-module framework to enhance students' critical thinking skills.

II. METHOD

This study employed a quantitative descriptive research design to systematically describe students' critical thinking skills in understanding climate change concepts. This research design was selected because it enables researchers to obtain objective information through numerical data analysis without manipulating the research variables. The quantitative descriptive approach provides measurable descriptions of students' abilities based on specific indicators of critical thinking skills, allowing researchers to identify students' strengths and weaknesses in each aspect of critical thinking. In this study, students' critical thinking skills were analyzed based on Facione's framework, which consists of six indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. This approach serves as an important foundation for identifying students' actual critical thinking profiles and providing empirical information regarding the challenges faced by students in understanding climate change phenomena integrated with local environmental contexts.

The research process consisted of several interconnected activities, including field observation, curriculum analysis, theoretical literature review, and analysis of student characteristics. The researcher conducted direct observations at SMAN 9 Sijunjung to identify the conditions of physics learning, the learning resources utilized by teachers and students, and the challenges encountered during the implementation of climate change learning. Furthermore, an in-depth analysis of the Merdeka Curriculum documents was conducted, particularly the Learning Outcomes (Capaian Pembelajaran) and Learning Objectives (Tujuan Pembelajaran) related to environmental and climate change topics, to ensure the relevance between the research focus and curriculum demands. A literature review was also conducted to strengthen the theoretical foundation regarding climate change education, local wisdom integration, and critical thinking skills as essential competencies in 21st-century learning. All information obtained during this stage was used as a reference for determining the research instruments and designing appropriate data collection procedures according to the characteristics of the research context.

The research participants consisted of 31 eleventh-grade students from class XI F3 at SMAN 9 Sijunjung during the 2025/2026 academic year. The research location was selected because the school represents the learning context where students experience challenges in understanding environmental issues, particularly climate change concepts. The selection of participants was conducted using purposive sampling based on the consideration that the selected class had relevant characteristics with the research objectives and had participated in physics learning activities related to environmental phenomena. The instruments used for data collection included a critical thinking skills test based on Facione's indicators, a student response questionnaire, and a semi-structured interview guide for physics teachers. Prior to field implementation, the instruments were reviewed and validated by experts to ensure the relevance, clarity, and suitability of each item with the research objectives.

The collected data were analyzed quantitatively using percentage analysis to determine the level of students' critical thinking skills for each indicator. The students' responses on the critical thinking test were assessed using a scoring rubric developed based on Facione's indicators, where each response was categorized according to the level of students' reasoning and explanation. The percentage scores were then interpreted using predetermined criteria to classify students' critical thinking levels. In addition, ethical considerations were applied throughout the research process by obtaining permission from the school and ensuring that participants were informed about the research objectives and procedures. The collected data were kept confidential and were used solely for academic research purposes.

III. RESULTS AND DISCUSSION

1) Analysis of Students' Critical Thinking Skills

The results of the critical thinking skills test conducted during the preliminary research phase at SMAN 9 Sijunjung indicate that students' abilities in understanding climate change concepts are categorized as low and require further improvement. Based on the obtained data, the average percentage score of students' critical thinking skills reached only 37.5% of the expected competency level. This finding indicates that students still experience difficulties in applying critical thinking processes when analyzing environmental phenomena related to climate change. The low achievement reflects that students' reasoning abilities in interpreting information, evaluating evidence, constructing arguments, and reflecting on solutions to climate change issues have not yet developed optimally. This condition may occur because learning activities are still frequently oriented toward conceptual understanding and information acquisition rather than encouraging students to analyze authentic environmental problems and develop evidence-based reasoning. This situation becomes an important concern because critical thinking skills represent one of the essential competencies in 21st-century learning, particularly in addressing complex issues such as climate change that require students to evaluate information, make rational decisions, and propose appropriate solutions.

A more detailed analysis of each critical thinking indicator based on Facione's framework reveals that students obtained the highest percentage in the interpretation indicator, with a score of 50%, while the lowest achievement was found in the self-regulation indicator, with only 16%. The relatively higher achievement in interpretation indicates that some students were able to identify and understand basic information related to climate change phenomena presented in learning materials. However, the very low achievement in self-regulation demonstrates that students still face difficulties in monitoring, evaluating, and reflecting on their own thinking processes when solving climate change-related problems. This finding suggests that students have not been sufficiently trained to evaluate the accuracy of their reasoning, reconsider the information obtained, and improve their decision-making processes based on scientific evidence. The weakness in self-regulation may also influence other higher-order thinking processes, such as evaluation and inference, which require students to critically assess arguments and formulate logical conclusions. Therefore, these findings provide an important empirical foundation for designing learning activities that facilitate deeper cognitive engagement through meaningful, reflective, and contextual learning experiences. The percentage results for each critical thinking indicator are presented in Table 1.

Table 1. Percentage of students' critical thinking skills

Critical Thinking Skills Indicators	Percentage (%)	Category
Interpretation	50	Enough
Analysis	45	Enough
Evaluation	34	Low
Conclusion	40	Low
Explanation	40	Low
Self-Regulation	16	Very low
Average	37.5	Low

2) Analysis of Instructional Materials Needs and Field Challenges

The results of in-depth interviews with physics teachers revealed that the learning process of climate change topics still faces several challenges, particularly in providing learning experiences that are contextual, interactive, and capable of encouraging students' critical thinking skills. Teachers explained that learning resources currently used in the classroom are still predominantly conventional textbooks and teacher-provided materials, which mainly emphasize the explanation of concepts and definitions without providing sufficient opportunities for students to analyze real environmental problems. Although digital technology facilities are available at school, their utilization as interactive learning resources remains limited. Teachers also stated that climate change is a complex topic to teach because it involves abstract processes and long-term environmental phenomena that are difficult for students to understand only through verbal explanations or static illustrations. The existing instructional materials have not fully integrated local environmental contexts, such as traditional conservation practices in Sijunjung, which could help students connect scientific concepts with phenomena occurring in their surroundings. Consequently, students tend to memorize climate change concepts without deeply understanding the causes, impacts, and possible solutions based on scientific evidence. Therefore, learning materials that integrate digital technology, deep learning principles, and local wisdom contexts are needed to facilitate more meaningful learning experiences and strengthen students' critical thinking skills in understanding climate change issues.

The analysis of students' learning preferences indicates that most students require learning materials supported by attractive visual representations, interactive multimedia, and contextual examples to improve their understanding of climate change concepts. Based on the questionnaire results, 87% of students preferred learning materials that incorporated visual elements such as videos, illustrations, infographics, and animations, while 85% showed a preference for learning activities involving direct observation and contextual experiences. Students stated that the use of multimedia-based learning resources could help them understand climate change phenomena that are difficult to visualize through conventional textbook explanations. The availability of digital devices owned by students and internet access at school represents an important potential resource that has not been fully optimized to support interactive and independent learning activities. Students also considered conventional learning materials less engaging because they often present climate change concepts in a theoretical manner without sufficient connection to environmental phenomena in their local surroundings. Therefore, the development of a deep learning-based e-module enriched with multimedia components, contextual activities, and local wisdom integration is considered an appropriate approach to accommodate students' learning preferences. The utilization of digital learning resources supported by adequate technological facilities can facilitate self-directed learning and strengthen students' scientific literacy and critical thinking skills in facing complex environmental challenges in the 21st century.

3) Design Characteristics of the Proposed Deep Learning-Based E-Module

The proposed e-module design developed for climate change learning integrates the principles of deep learning, including mindful learning, meaningful learning, and joyful learning, combined with local wisdom contexts to create a contextual and student-centered learning environment. The e-module was designed as a digital learning resource that can be accessed flexibly through various devices, allowing students to engage with learning materials independently without being limited by classroom conditions. The structure of the e-module is arranged systematically according to the learning stages of understanding, applying, and reflecting, enabling students to construct knowledge through exploration, contextual problem-solving, and self-reflection activities.

The learning content is enriched with interactive multimedia elements, including videos, illustrations, infographics, and contextual examples related to climate change phenomena in students' surrounding environments. The integration of local wisdom, such as hutan adat (Rimbo Larangan), lubuk larangan, and Batobo Kongsi in Sijunjung, provides authentic learning experiences that allow students to connect scientific concepts with real environmental practices within their communities. The main focus of this design is to develop an interactive self-directed learning environment that encourages students' active cognitive engagement in understanding climate change issues, analyzing environmental problems, and formulating sustainable solutions based on scientific knowledge and local values. The integration of deep learning principles and local wisdom is expected to facilitate meaningful learning experiences while gradually strengthening students' critical thinking skills in responding to real-world environmental challenges. The integration of deep learning stages and local wisdom contexts within the e-module structure is presented in Table 2.

Tabel 2. Integration of Deep Learning Stages and Local Wisdom Context in the E-Module Structure

Deep Learning Stage	Learning Activity	Local Wisdom Context	Critical Thinking Indicator
Mindful Learning	Observing climate change phenomena through videos and questions	Hutan Adat Rimbo Larangan	Interpretation
Meaningful Learning	Analyzing environmental problems	Lubuk Larangan & Tambang Emas	Analysis, Evaluation
Joyful Learning	Collaborative activities and reflection	Batobo Kongsi	Explanation, Self-Regulation

The deep learning approach integrated into the e-module consists of three interconnected pillars: mindful learning, meaningful learning, and joyful learning, which support students' higher-order thinking processes in understanding climate change issues. The mindful learning pillar is implemented through reflective questions, observation activities, and problem identification tasks that encourage students to build awareness of climate change phenomena and understand the purpose of each learning activity. Through this approach, students are encouraged to actively engage in the learning process by connecting scientific concepts with environmental conditions occurring around them. The meaningful learning pillar is applied by linking climate change concepts with real-life environmental issues and local wisdom practices in Sijunjung, such as the conservation values reflected in hutan adat (Rimbo Larangan), lubuk larangan, and Batobo Kongsi. These contextual connections enable students to understand the relationship between scientific concepts, human activities, and environmental sustainability based on their own experiences and local conditions. Meanwhile, the joyful learning pillar is realized through an attractive digital interface, interactive multimedia components, contextual activities, and collaborative learning tasks that create an enjoyable learning atmosphere and encourage students' active participation.

The integration of these three pillars within the e-module design plays an important role in facilitating meaningful cognitive processes and improving students' critical thinking skills in analyzing climate change phenomena. The strength of this deep learning-based e-module lies in its ability to provide flexible and student-centered learning experiences through various digital resources, including videos, visual representations, environmental cases, and reflective activities. Students who require additional support can revisit learning materials and multimedia content according to their individual learning pace, while students who have achieved conceptual understanding can further explore complex environmental problems and propose sustainable solutions. Therefore, the implementation of deep learning principles in the e-module is expected to strengthen students' scientific literacy, environmental awareness, and critical thinking competencies required to address future global challenges.

The indicators of critical thinking skills, including interpretation, analysis, evaluation, inference, explanation, and self-regulation, are facilitated through various learning activities embedded within the e-module structure. The interpretation and analysis indicators are primarily developed during the understanding stage, where students are encouraged to identify climate change phenomena, analyze environmental information, and construct relationships between scientific concepts and real-world conditions. Furthermore, the evaluation and inference indicators are strengthened through contextual problem-solving activities in the application stage, where students examine environmental issues, evaluate possible causes and impacts, and formulate logical conclusions based on scientific evidence. Meanwhile, the explanation and self-regulation indicators are developed through reflection activities that encourage students to communicate their reasoning, evaluate their learning processes, and consider appropriate actions toward climate change mitigation and adaptation.

Through structured learning activities supported by multimedia content, contextual problems, and local wisdom integration, students are gradually trained to engage in higher-order thinking processes independently. The integration of environmental contexts, such as hutan adat (Rimbo Larangan), lubuk larangan, and Batobo Kongsi, provides authentic experiences that enable students to connect climate change concepts with real-life sustainability practices. The effectiveness of this digital learning resource depends on its ability to provide meaningful, accessible, and engaging learning experiences that support teachers and students in achieving learning objectives. Through a systematic design based on deep learning principles, the e-module is expected to improve students' critical reasoning abilities compared with conventional learning approaches that often emphasize conceptual memorization without sufficient exploration of environmental meanings. Students' active involvement in analyzing real-world climate change issues and reflecting on their learning experiences can strengthen their conceptual understanding, environmental awareness, and long-term development of critical thinking competencies needed to face future global challenges.

4) An In-Depth Discussion of Students' Critical Thinking Skills

The results of the study indicate that students' critical thinking skills in understanding climate change concepts are categorized as low, with an average achievement of 37.5%. This finding demonstrates that students have not yet fully developed higher-order thinking processes required to analyze complex environmental issues systematically. The low achievement does not only indicate limitations in students' cognitive abilities but also reflects that existing learning experiences have not optimally facilitated the development of critical thinking skills. Climate change is a complex topic that requires students to interpret information, evaluate scientific evidence, analyze human impacts, and formulate appropriate solutions based on environmental conditions. However, students often encounter difficulties when learning activities emphasize conceptual understanding and information recall rather than engaging them in authentic problem-solving processes. Therefore, learning strategies that provide meaningful experiences and encourage active cognitive involvement are needed to support students in developing critical thinking competencies.

A more detailed analysis based on Facione's indicators reveals that the self-regulation indicator obtained the lowest percentage score, reaching only 16%. This finding indicates that students still experience difficulties in monitoring, evaluating, and reflecting on their own thinking processes when analyzing climate change problems. Self-regulation is an essential component of critical thinking because it enables students to review their reasoning, identify weaknesses in their arguments, and improve decision-making based on available evidence. The low achievement in this indicator suggests that students have limited opportunities to engage in reflective learning activities that encourage awareness of their own learning processes. In contrast, the interpretation indicator showed the highest achievement, with a percentage score of 50%, indicating that students had relatively better abilities in identifying and understanding basic information related to climate change phenomena. However, this ability has not yet been followed by adequate skills in evaluating evidence and constructing deeper conclusions regarding environmental issues.

Furthermore, the relatively low achievement in evaluation (34%), inference (40%), and explanation (40%) indicates that students are still unfamiliar with analyzing environmental problems, assessing the validity of information, and constructing scientific arguments. This condition may be caused by learning practices that are still dominated by teacher explanations and textbook-based activities, which provide limited opportunities for students to investigate real environmental phenomena and develop evidence-based reasoning. In climate change learning, students need to be encouraged to examine relationships between human activities, environmental changes, and possible mitigation strategies through contextual learning experiences. Without sufficient opportunities to analyze authentic problems, students tend to memorize climate change concepts without deeply understanding their implications in real life.

These findings are consistent with previous theoretical studies stating that learning approaches emphasizing memorization and passive information reception are less effective in developing students' critical thinking skills. Students require learning environments that encourage inquiry, reflection, argumentation, and knowledge construction through meaningful experiences. Therefore, the integration of deep learning principles combined with local wisdom contexts can become an alternative approach to facilitate students' cognitive engagement. Through mindful learning activities that encourage awareness, meaningful learning activities connected with real environmental issues, and joyful learning activities that increase motivation, students can gradually develop stronger critical thinking skills to analyze and respond to climate change challenges.

IV. CONCLUSION

Based on the findings of this preliminary study, it can be concluded that students' critical thinking skills in understanding climate change concepts remain in the low category, with an average achievement score of 37.5%. This finding indicates that students still require learning experiences that encourage deeper analysis, evaluation, and reflection when addressing environmental issues. The practical implication of this study is the need for innovative learning resources that integrate digital technology, deep learning principles, and contextual environmental issues to support the development of students' critical thinking skills. Therefore, a deep learning-based e-module integrated with local wisdom contexts is proposed as a potential learning solution for climate change education. Future research will focus on developing the complete e-module prototype and conducting validity, practicality, and effectiveness evaluations through broader implementation to determine its contribution to improving students' critical thinking skills and scientific literacy.

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