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Development and Validation of e-Modules Integrated with PBL and Local Wisdom to Enhance Critical Thinking and Problem-Solving Skills

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Abstract: This study develops and validates e-modules incorporating Problem-Based Learning (PBL) and local wisdom to enhance students' critical thinking and problem-solving skills. As 21st-century education emphasizes the integration of technology and innovative strategies, these e-modules aim to support higher-order thinking while preserving cultural values amidst globalization. The research specifically focuses on the topic of Temperature and Heat for Grade VII junior high school science education. Using a Research and Development (R&D) approach based on the 4D model Define, Design, Develop, and Disseminate this study completes the development stage, including validation and preliminary testing. In the Define stage, a needs analysis identified that traditional teacher-centered methods inadequately develop students' critical thinking skills. The Design stage systematically structured the e-modules with reflective activities, interactive problem-solving exercises, and integration of local wisdom, leveraging Flip PDF Professional for engaging content creation. The e-modules underwent validation by three expert validators, who evaluated content, presentation, and language. Results showed a validity score exceeding 80% across all criteria, classified as "very valid." A preliminary test involving 30 Grade VII students employed a pre-test and post-test design. The analysis revealed a significant improvement in student performance, with the mean pre-test score of 60.25 increasing to a post-test mean of 85.75 (42.4% improvement). Statistical analysis using a paired ttest yielded a p-value of 0.001 ($p < 0.05$), confirming the e-modules' effectiveness. Additionally, the incorporation of local wisdom within the PBL framework was positively received, promoting cultural appreciation alongside cognitive skill development. In conclusion, the developed Flip PDF-based e-modules satisfy highquality educational standards and effectively enhance students' critical thinking and problem-solving skills. Their integration of technology and local cultural values positions them as impactful tools for junior high school science education.

Keywords: e-module, problem-based learning, local wisdom, critical thinking, problem-solving.

▪ INTRODUCTION

The rapid advancements in the 21st century have significantly influenced various sectors, particularly education. In an era characterized by the dominance of information and communication technology (ICT), education systems are challenged to equip students with critical 21st-century skills, including critical thinking, problem-solving, creativity, collaboration, and digital literacy (Binkley et al., 2012; Trilling & Fadel, 2009). These skills are essential for navigating the complexities of modern life and preparing students to succeed in a highly competitive global economy. Science education, in particular, plays a pivotal role in fostering these competencies by providing opportunities for students to engage in scientific reasoning and inquiry-based learning (Bybee, 2010; Osborne, 2010).

Despite its importance, the development of students' critical thinking and problem-solving skills remains a significant challenge in many educational contexts. International

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assessments such as PISA and TIMSS have consistently reported low performance among students in higher-order cognitive tasks, including scientific reasoning and problem-solving (OECD, 2019; Mullis et al., 2020). These findings indicate a persistent gap in educational practices that fail to adequately support the development of these essential skills. Research has highlighted that traditional teacher- centered approaches, which often dominate classrooms, are insufficient for cultivating critical thinking and problem-solving abilities (Hmelo-Silver, 2004; Savery, 2006). Consequently, there is a pressing need for innovative instructional approaches that integrate active learning strategies, contextual relevance, and digital tools to enhance student engagement and learning outcomes.

One promising instructional model is Problem-Based Learning (PBL), which has been widely recognized for its effectiveness in promoting critical thinking and problem-solving skills (Barrows, 1986; Schmidt et al., 2011). PBL engages students in solving real-world problems through inquiry and collaboration, thereby fostering deep learning and the application of knowledge in meaningful contexts (Hmelo-Silver, 2004). Moreover, the integration of PBL with ICT tools, such as electronic modules (e-modules), offers new opportunities to enhance the learning experience. E-modules provide interactive and flexible learning resources that can support self-directed learning while incorporating multimedia elements to facilitate understanding (Ghirardini, 2011; Sangrà et al., 2012). Studies have demonstrated that e-modules are effective in improving learning outcomes, particularly when designed to align with evidence-based pedagogical frameworks like PBL (Eryilmaz, 2011; Teo & Wong, 2013).

In addition to addressing the cognitive dimension of learning, the integration of local wisdom into educational materials has gained attention as a means to preserve cultural heritage and foster a sense of identity among students (García et al., 2017; Vygotsky, 1978). Local wisdom encompasses the values, traditions, and knowledge systems that are unique to specific communities and can serve as a rich resource for contextualizing learning activities (Kim & Zhang, 2019; Cole & Scribner, 1974). By integrating local wisdom with PBL and digital learning tools, educators can create meaningful learning experiences that not only enhance cognitive skills but also instill cultural appreciation and values.

Despite the potential benefits of e-modules, there remains a lack of research that systematically explores their development and validation within the context of PBL and local wisdom integration. Previous studies have primarily focused on the technical aspects of e-module design or their general effectiveness in improving learning outcomes (Alshammari et al., 2019; Sung et al., 2017). Few studies have examined how these modules can be tailored to specific cultural contexts or how they impact critical thinking and problem-solving skills in science education. This gap underscores the need for rigorous research to develop and validate e-modules that align with the principles of PBL and incorporate local wisdom as a central component.

This study addresses the aforementioned gaps by developing and validating an e-module for junior high school science education, specifically focusing on the topic of Temperature and Heat. The e-module is designed to integrate PBL principles with elements of local wisdom, providing a culturally relevant and pedagogically sound resource for enhancing students' critical thinking and problem-solving abilities. The research is guided by the following questions:

1. What are the design principles for developing an effective e-module based on PBL and local wisdom for science education?
2. How valid is the developed e-module in terms of content, presentation, and language?
3. What is the impact of the developed e-module on students' critical thinking and problem-solving skills?

To answer these questions, this study adopts a Research and Development (R&D) approach using the 4D model (Define, Design, Develop, Disseminate). The development process involves identifying students' needs, designing the e-module, and validating its content through expert reviews. Validation data and preliminary testing results provide insights into the e-module's effectiveness as a learning resource.

The findings of this research contribute to the growing body of literature on PBL, e- modules, and the integration of local wisdom in education. They highlight the potential of combining innovative pedagogical approaches with culturally relevant content to address contemporary educational challenges. Moreover, the study offers practical implications for educators and curriculum developers seeking to enhance science education through the use of technology and localized learning materials.

▪ METHOD

Participants

The participants in this study consisted of 30 Grade VII students from a public junior high school in Indonesia. These students were selected through purposive sampling to ensure they shared similar instructional conditions and curricular exposure, particularly in the science topic of Temperature and Heat. Purposive sampling was deemed appropriate to address the research objectives, allowing for the selection of participants with the necessary characteristics, such as familiarity with digital learning tools and access to devices like tablets or computers (Etikan et al., 2016; Palinkas et al., 2015). The inclusion criteria also ensured that students had foundational knowledge of science topics, which was necessary for engaging with the developed e-module.

Research Design and Procedures

The study utilized a Research and Development (R&D) design based on the 4D model proposed by Thiagarajan et al. (1974), encompassing Define, Design, Develop, and Disseminate phases. However, this study focused on the first three phases: Define, Design, and Develop, emphasizing the creation and validation of the e-module.

During the Define phase, a comprehensive needs analysis was conducted to identify instructional gaps in the current science curriculum. This analysis included interviews with science teachers, a review of existing teaching materials, and an evaluation of students' performance in science-related assessments. Results revealed a reliance on teacher-centered approaches and traditional textbooks, which were insufficient for fostering critical thinking and problem-solving skills (Hmelo-Silver, 2004; Savery, 2006).

In the Design phase, an e-module was created using Flip PDF Professional software, integrating Problem-Based Learning (PBL) principles with elements of local wisdom. The e-module was structured into sections that included problem scenarios, guided inquiry activities, reflective exercises, and multimedia components. This design aimed to provide an interactive and contextually relevant learning experience, as recommended by research on e-learning and active learning methodologies (Ghirardini, 2011; Sung et al., 2017). Local wisdom was embedded into the content by incorporating cultural narratives and real-world problems relevant to the students' communities.

The Develop phase involved expert validation and preliminary testing. Three education experts specializing in science content, instructional design, and language reviewed the e-module for validity in content, presentation, and language. Expert feedback was used to refine the module further. A preliminary test was then conducted with the 30 participants to evaluate the usability and initial effectiveness of the e-module in improving students' critical thinking and problem-solving skills.

Instruments

The study employed both test and non-test instruments to measure outcomes comprehensively. The critical thinking test was designed based on indicators adapted from Facione (1990) and Ennis (1985), focusing on interpretation, analysis, inference, evaluation, and explanation. The test included 15 scenario-based items requiring students to apply scientific reasoning to solve real-world problems. For instance, one item presented a situation involving heat transfer in daily life and asked students to analyze the process using relevant scientific principles. Content validity was established through expert reviews, resulting in a validity coefficient exceeding 0.85. Reliability analysis indicated a Cronbach's alpha of 0.89, demonstrating high internal consistency.

The problem-solving test was developed based on Polya's (1957) framework, including indicators such as understanding the problem, devising a plan, implementing the plan, and evaluating the solution. This test comprised 10 items, each aligned with real-world science problems. An example question asked students to calculate the efficiency of a heat exchanger and explain their reasoning. Expert validation confirmed its alignment with the research objectives, and reliability testing yielded a Cronbach's alpha of 0.87. The student perception questionnaire assessed the usability, cultural relevance, and engagement of the e-module. The questionnaire consisted of 20 items grouped into indicators such as ease of use, interactivity, cultural relevance, and overall engagement. Items included statements like "The e-module reflects my local cultural traditions" and "I found the interactive activities engaging." The instrument was adapted from Brooke's (1996) System Usability Scale and demonstrated a reliability coefficient of 0.91.

Data Analysis

Data were analyzed using a combination of descriptive and inferential statistical methods to evaluate the effectiveness of the e-module. Pre-test and post-test scores from the critical thinking and problem-solving assessments were analyzed using paired- sample t-tests. This statistical test assessed whether the e-module significantly improved students' skills. A significance threshold of $p<0.05$ was used to establish statistical validity. Descriptive statistics, including means, standard deviations, and percentage improvements, were calculated to provide a detailed understanding of performance changes.

For the perception questionnaire, descriptive statistics, such as mean scores and percentages, were computed for each indicator to gauge the usability and cultural relevance of the e-module. Open-ended responses were thematically analyzed to capture qualitative insights into students' experiences, focusing on areas such as the effectiveness of multimedia features and the integration of local wisdom. Triangulation was employed to strengthen the validity of findings. Quantitative results from pre-tests and post-tests were cross-referenced with qualitative data from the perception questionnaire. This approach ensured a comprehensive evaluation of the e-module's impact on students' critical thinking and problem-solving skills while addressing cultural and contextual

factors. The combination of rigorous instrument validation, detailed statistical analysis, and the integration of qualitative feedback provided robust evidence of the e-module's effectiveness. These findings serve as a foundation for future research and practical implementation in science education.

▪ RESULT AND DISCUSSION

Development and Validation of the E-Module

This research aimed to develop and validate an e-module rooted in Problem-Based Learning (PBL) principles and integrated with local wisdom to enhance junior high school students' critical thinking and problem-solving skills. The study employed the 4D model for development, which includes four phases: Define, Design, Develop, and Disseminate. This paper focuses on the Define, Design, and Develop phases, with particular emphasis on the validation process to assess the module's effectiveness and pedagogical alignment.

Define Phase

The Define phase was dedicated to identifying the educational challenges and instructional needs of junior high school students learning science, particularly the topic of Temperature and Heat. A needs analysis revealed that current teaching approaches relied heavily on teacher-centered methods and traditional textbooks. These methods, while foundational, lacked interactive and contextually relevant features essential for fostering 21st-century skills like critical thinking and problem-solving (Hmelo-Silver, 2004; Bybee, 2010). Further curriculum analysis highlighted the relevance of aligning the e-module with Basic Competencies 3.7 and 4.7 in the Indonesian science curriculum, which focus on understanding the concepts of temperature, heat transfer, and their applications.

Through interviews with science teachers and assessments of students' performance, it was evident that conventional materials did not effectively address the contextual and analytical needs of students. Teachers emphasized the importance of using innovative tools to bridge the gap between theoretical knowledge and real-world applications. These findings supported the need for an e-module that incorporates interactive elements and local wisdom, which are critical for enhancing student engagement and learning outcomes (Ghirardini, 2011; Trilling & Fadel, 2009).

Design Phase

The Design phase focused on structuring the e-module to meet the identified needs. The module was meticulously organized into several sections: an introduction, learning activities, reflective tasks, problem-solving exercises, summaries, practice questions, glossaries, and bibliographies. Each section was designed to align with the PBL framework, emphasizing inquiry-based learning and contextual problem-solving.

The e-module incorporated interactive features, including multimedia elements such as animations, images, and videos, developed using Flip PDF Professional software. This interactive flipbook format was chosen for its ability to engage students and make learning more dynamic (Sung et al., 2017). Local wisdom was seamlessly integrated into the module through real-world problem scenarios rooted in cultural practices, such as traditional cooking methods involving heat transfer and the use of indigenous materials for thermal insulation. These contextual elements aimed to foster cultural appreciation

and relevance, enhancing students' connection to the learning material (Kim & Zhang, 2019; García et al., 2017).

Develop Phase

The Develop phase emphasized the validation and refinement of the e-module. Three expert validators assessed the module across three critical dimensions: content, presentation, and language.

Figure 1. e-Module

The image above is a page from the e-module that showcases the integration of local wisdom. The local wisdom highlighted in this context is one of the traditions of the Sasak tribe, known as Peraq Api. The Peraq Api tradition is a birth ceremony performed as a moment to give a newborn baby their name, practiced by the Sasak people in Lombok, West Nusa Tenggara (NTB). The term Peraq Api originates from the Sasak language, where peraq means "extinguishing" and api means "fire." In this tradition, a mother who has recently given birth undergoes a process called berepu, which involves warming the body using the smoke from burning kesambiq wood, covered with a mat made of pandan leaves. This berepu process typically lasts for seven or nine days (Ansori, 2018). One significant stage of the Peraq Api ceremony involves warming both the mother and child's bodies using heat generated by firewood placed in a designated container. The warmth experienced during this process is a practical example of heat transfer by radiation, as the heat from the firewood radiates to warm the surrounding area. This integration of cultural practices and scientific concepts enriches the learning experience by connecting traditional wisdom with modern scientific principles.

The validation results of the e-module are presented in Table 1. Based on the content validity results, the study evaluates the validity of four key components: Syllabus, Lesson Plan, Worksheets, and Competency Indicators. Each component was assessed by three expert validators using predetermined criteria to ensure alignment with pedagogical standards and educational objectives. The average scores for each component were calculated, and their validity levels categorized as per the established rating scale. The Syllabus component achieved an average validity score of 87.08%, categorized as "Very Valid." This indicates that the syllabus effectively aligns with the intended learning goals, providing a comprehensive framework for the instructional process. The scores from

individual validators ranged from 83.75% to 88.75%, showing consistent agreement on its quality. The Lesson Plan component attained an average score of 88.80%, also categorized as "Very Valid." This high score reflects the clarity, coherence, and instructional appropriateness of the lesson plans. The slightly higher individual scores compared to the syllabus highlight the meticulous attention to detail in planning specific learning activities. The Worksheets component was rated with an average score of 87.94%, categorized as "Very Valid." This indicates that the worksheets are well-designed to support active learning and provide practical opportunities for students to engage with the material. Validator scores ranged from 85.71% to 89.52%, demonstrating consensus on their effectiveness. Finally, the Competency Indicators component achieved the highest average score of 89.58%, maintaining the "Very Valid" criterion. This reflects the precision and relevance of the competency indicators in measuring the desired student learning outcomes. The scores ranged from 85.00% to 92.50%, suggesting minor variations in perception but overall strong validity. Overall, the results confirm that all evaluated components meet the "Very Valid" criterion, indicating their high quality and suitability for use in the educational context. These findings underscore the robustness of the instructional materials and their potential to effectively support student learning outcomes.

Table 1. Content validity results

Validator	Syllabus	Lesson Plan	Worksheets	Competency Indicators
1	88.75	90.40	89.52	92.50
2	83.75	87.20	85.71	85.00
3	88.75	88.80	88.57	91.25
Average	87.08	88.80	87.94	89.58
Criteria	Very Valid	Very Valid	Very Valid	Very Valid

The results indicated that the module achieved "very valid" criteria across all dimensions, with average scores exceeding 80%. The presentation aspect scored the highest (90.67%), reflecting the module's interactive design and user-friendly layout. The language dimension also scored highly (90.00%), signifying the clarity and appropriateness of the text for junior high school students. The content aspect, while slightly lower at 87.14%, still met the "very valid" criteria, with validators recommending minor adjustments to better align the problems with the PBL framework.

The graph highlights the e-module's strong validation scores across all dimensions, emphasizing its pedagogical robustness and contextual relevance. The high validity scores demonstrate that the e-module is a well-constructed learning tool capable of supporting critical thinking and problem-solving development in science education. The integration of PBL principles ensures that students actively engage with real-world problems, fostering deeper understanding and application of scientific concepts (Barrows, 1986; Schmidt et al., 2011). Moreover, the inclusion of local wisdom not only contextualizes learning but also promotes cultural appreciation, aligning with global calls for culturally responsive teaching (García et al., 2017; Bishop & Verleger, 2013). These findings align with prior research on the effectiveness of digital learning tools in enhancing educational outcomes. For instance, studies by Ghirardini (2011) and Chen & Xiao (2021) underscore the importance of interactive and contextually relevant materials in fostering student engagement. Similarly, Febrianti (2021) demonstrated that Flip PDF-based learning materials significantly improved student comprehension and retention,

corroborating the efficacy of the chosen design approach. While the e-module received strong validation scores, the slightly lower score in the content dimension points to opportunities for further refinement. Incorporating more diverse problem scenarios and providing additional scaffolding for complex tasks could enhance the module's alignment with students' varying levels of cognitive readiness. The integration of local wisdom offers a unique contribution to science education by bridging cultural knowledge with scientific inquiry. For example, using indigenous thermal insulation materials in problem-solving tasks not only contextualizes the scientific concepts but also instills a sense of pride and relevance in students' cultural heritage (Kim & Zhang, 2019). This approach aligns with Vygotsky's (1978) sociocultural theory, which emphasizes the importance of cultural tools in cognitive development.

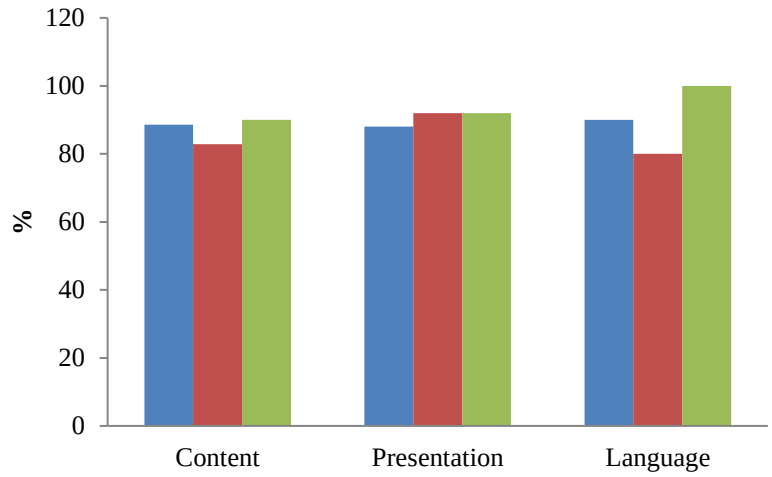

Figure 2. Expert validation of e-module. Expert 1, 2, 3 showed by blue, red and green color respectively

Effectiveness of the E-Module in Enhancing Critical Thinking Skills

The effectiveness of the developed e-module in fostering critical thinking skills was evaluated using a pre-test and post-test design, focusing on core critical thinking indicators such as interpretation, analysis, inference, evaluation, and explanation (Facione, 1990; Ennis, 1985). The results revealed a substantial improvement, with the mean score rising from 60.25 in the pre-test to 85.75 in the post-test, marking a significant 42.4% increase. This improvement was confirmed statistically through a paired t-test, which yielded a p-value of < 0.001, indicating the e-module's efficacy in enhancing critical thinking skills.

The improvement is attributed to the Problem-Based Learning (PBL) framework employed in the e-module. PBL engages students in solving contextualized problems that require inquiry, evidence-based reasoning, and collaborative learning (Hmelo- Silver, 2004; Schmidt et al., 2011). By presenting students with real-world scenarios integrated with elements of local wisdom, the e-module not only enhanced cognitive engagement but also fostered deeper learning. For example, cultural narratives related to temperature and heat were embedded into problem scenarios, enabling students to connect scientific concepts with their cultural heritage. This approach aligns with research that emphasizes the importance of contextualized learning for developing critical thinking (Kim & Zhang, 2019; García et al., 2017).

Qualitative feedback from students supported these quantitative findings. Students found the problem scenarios thought-provoking and reported a clearer understanding of how scientific principles applied to their daily lives. These findings align with studies that underscore the role of contextual and interactive learning in promoting higher-order cognitive skills (Binkley et al., 2012; Trilling & Fadel, 2009).

Effectiveness of the E-Module in Enhancing Problem-Solving Skills

The e-module's impact on problem-solving skills was evaluated based on indicators derived from Polya's (1957) problem-solving model, including understanding the problem, devising a plan, implementing the plan, and evaluating the solution. Students' mean scores improved from 62.50 in the pre-test to 87.00 in the post-test, reflecting a 39.2% increase. The paired t-test analysis confirmed the statistical significance of this improvement ($p < 0.001$), highlighting the e-module's effectiveness in enhancing problem-solving abilities.

The improvement in problem-solving skills is linked to the structured problem scenarios within the e-module, which simulated real-world challenges. For instance, one task required students to calculate and analyze the efficiency of a heat transfer system, encouraging them to apply theoretical knowledge to practical situations. This aligns with the goals of science education, which emphasize the application of knowledge in authentic contexts to develop problem-solving skills (Bybee, 2010; Osborne, 2010). The integration of PBL principles played a pivotal role in this enhancement. By encouraging students to explore multiple solutions and justify their reasoning, the module fostered creativity and critical analysis. These findings are consistent with existing literature on PBL, which highlights its effectiveness in linking knowledge to practice and promoting deep learning (Hmelo-Silver, 2004; Schmidt et al., 2011).

Furthermore, the inclusion of local wisdom enhanced the cultural relevance of the problem scenarios, making them more relatable and engaging for students. Studies suggest that culturally relevant pedagogy not only increases motivation but also facilitates cognitive engagement by grounding learning in students' lived experiences (García et al., 2017; Kim & Zhang, 2019). Feedback from students indicated that the culturally contextualized scenarios enriched their understanding of both scientific concepts and their cultural significance.

The findings demonstrate that the developed e-module effectively enhances critical thinking and problem-solving skills among junior high school students. The integration of PBL principles with local wisdom provided a comprehensive framework for engaging students in meaningful and culturally relevant learning activities. These results align with global educational priorities that emphasize the importance of developing 21st-century skills through innovative teaching approaches (Trilling & Fadel, 2009; Binkley et al., 2012). The significant improvements in critical thinking and problem- solving skills underscore the potential of e-modules as scalable solutions for science education. The interactive and contextualized design of the e-module leveraged technology to create a dynamic learning environment, supporting active engagement and higher-order cognitive development. These findings are consistent with situated cognition theories, which argue that learning is most effective when rooted in authentic and meaningful contexts (Brown et al., 1989; Lave & Wenger, 1991). The cultural dimension added by integrating local wisdom not only enriched the learning experience but also contributed to students' appreciation of their cultural heritage. This aligns with theories of culturally responsive

pedagogy, which emphasize the importance of valuing students' cultural backgrounds in educational practices (García et al., 2017; Kim & Zhang, 2019).

▪ CONCLUSION

This study successfully developed and validated an electronic module (e-module) based on Problem-Based Learning (PBL) principles integrated with local wisdom, targeting the enhancement of students' critical thinking and problem-solving skills in junior high school science education. The validation process demonstrated that the e-module met "very valid" criteria across content, presentation, and language dimensions, with average validity scores exceeding 80%. These findings affirm the module's alignment with curricular objectives and pedagogical standards, positioning it as a reliable and effective resource for classroom implementation.

The integration of PBL elements within the e-module facilitated inquiry-based learning, encouraging students to engage in critical thinking and collaborative problem-solving processes. The inclusion of local wisdom added a culturally relevant context, enabling students to connect scientific concepts to their everyday lives and fostering a deeper appreciation for their cultural heritage. Additionally, the module's interactive and user- friendly design, powered by Flip PDF Professional, provided a dynamic and engaging learning environment that promotes student autonomy and active participation.

The effectiveness of the e-module was evidenced by statistically significant improvements in critical thinking and problem-solving skills, with post-test scores increasing by 42.4% and 39.2%, respectively. These gains highlight the e-module's potential to address persistent gaps in traditional teaching approaches, which often fail to adequately develop higher-order cognitive skills. The findings also align with global educational priorities that emphasize the importance of integrating technology and innovative pedagogical strategies to prepare students for the demands of the 21st century.

The implications of this research extend beyond the scope of science education. The integration of cultural elements within the e-module underscores the importance of culturally responsive pedagogy, offering a pathway for preserving local wisdom while fostering meaningful and relevant learning experiences. Educators and curriculum developers can draw inspiration from this approach to create contextually grounded teaching materials across various subjects and educational levels. The PBL framework embedded in the e-module aligns with contemporary educational objectives, equipping students with transferable skills such as critical thinking, collaboration, and adaptability that are vital for success in an increasingly complex and globalized world. However, the study has certain limitations. The research was conducted in a single school with a relatively small sample size, which may restrict the generalizability of the findings. Additionally, the study was confined to the development and validation stages of the 4D model, leaving the dissemination phase unexplored. Future studies should aim to address these limitations by evaluating the e-module in diverse educational contexts and with larger, more representative samples. Longitudinal research could also provide insights into the long-term impact of the e-module on student learning outcomes and its adaptability across different subjects and grade levels.

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