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Development of an Artificial Intelligence (AI) Based E-Module Using the ADDIE Model to Improve Critical Thinking and IPAS Learning Outcomes

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ABSTRACT

The learning process in elementary schools still shows limited development of critical thinking skills and suboptimal learning outcomes in the Science and Social Studies (IPAS) subject. Classroom observations and preliminary assessments revealed that students tended to be passive during instruction and had difficulty engaging in analytical and reflective activities. These issues were compounded by the limited use of interactive digital learning media and the absence of technology-supported learning resources. Responding to this condition, this study aimed to design and validate an AI-enhanced e-module intended to strengthen students' critical thinking abilities and improve their IPAS learning performance. This research followed a development-oriented approach based on the ADDIE framework, involving systematic stages of needs analysis, instructional design, product development, classroom implementation, and evaluation. Expert validation was carried out to ensure the quality of the e-module, while effectiveness was examined through a quasi-experimental pretest–posttest control group design. The evaluation results confirmed that the e-module met the criteria for valid (97%), practical (94%), and effective instructional media. Students who used the AI-based e-module demonstrated a significant improvement in both critical thinking skills and learning outcomes, with an N-Gain score of 0.62 and a p-value below 0.05. These findings indicate that AI-driven digital learning media can serve as a promising tool for supporting meaningful learning and fostering higher-order thinking skills among elementary students.

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1. INTRODUCTION

Rapid developments in digital technology and the widespread integration of artificial intelligence (AI) have reshaped educational practices across all levels of schooling. Learning environments are increasingly expected to adopt technology-based approaches that not only facilitate access to information but also promote efficiency, personalization, and higher-quality learning experiences (Muvid et al., 2024; OECD, 2019; Utami & Harjono, 2023). In Indonesia, national education policies, including curriculum reforms and digital transformation initiatives, emphasize the importance

of strengthening 21st-century competencies such as critical thinking, collaboration, and technological literacy (Kemendikbud, 2020; Zimmerman, 2007). As a result, schools are encouraged to implement digital learning innovations that align with these expectations.

However, the reality in many elementary classrooms remains far from ideal. Learning activities often rely on teacher-centered instruction, with minimal interaction and limited opportunities for students to analyze or evaluate information independently (Fu'adah & Ratnaningrum, 2024). Preliminary observations conducted in the research setting showed that students were mostly passive and struggled to engage in reasoning-based tasks. Assessment results also indicated low performance in critical thinking, reflected in an average score of 50.87, as well as low learning achievement, with only half of the students meeting the expected competency level (Ismail Rahman et al., 2024; Sudarmiani et al., 2017). These conditions illustrate a gap between policy demands and classroom practices, highlighting the need for more innovative instructional resources.

The integration of AI in learning media has the potential to address these challenges. AI-supported platforms offer adaptive features such as automated feedback, content recommendations, and personalized learning pathways, allowing students to learn at an appropriate pace while receiving targeted support. Research at the international level has reported that AI-assisted learning environments can foster engagement, enhance understanding, and strengthen critical thinking skills through interactive and adaptive instruction. Digital e-modules enriched with multimedia elements and AI capabilities therefore present a relevant alternative for supporting meaningful learning in elementary education (Holmes et al., 2019).

Critical thinking is a core component of 21st-century competencies, involving the ability to analyze information, make informed decisions, and evaluate arguments based on evidence (Lastri, 2023). In the context of IPAS learning, critical thinking enables students to connect scientific and social concepts with real-life situations (Rahman & I Nyoman, 2020). Interactive learning media supported by AI can provide structured guidance and reflective opportunities that help students develop these skills (Ulya et al., 2025). Previous studies have demonstrated that AI-based e-modules contribute to improvements in higher-order thinking and student achievement, suggesting that such media are promising tools for classroom implementation (Lee & Williamson, 2020).

Considering these conditions, this study was designed to develop and test an AI-enhanced e-module aimed at improving critical thinking skills and learning outcomes in IPAS among fifth-grade students (Amelia et al., 2023; Paremarta et al., 2025). The resulting product is expected to contribute both theoretically, by offering insights into the development of AI-supported instructional media, and practically, by providing teachers with a feasible and effective resource for classroom use within the framework of the Merdeka Curriculum.

2. METHODS

This research was conducted as a development study aimed at producing an AI-enhanced e-module that could be used effectively in elementary IPAS instruction. The development process followed the ADDIE framework, which provided a structured pathway beginning with a needs analysis and continuing through stages of design, product creation, classroom implementation, and final evaluation. The approach allowed the researchers to systematically refine the product based on expert input and empirical data collected in the field.

The study took place in a public elementary school located in Kartoharjo District, Madiun City, during the 2024/2025 academic year. Participants included a fifth-grade IPAS teacher and students selected based on the school's readiness to integrate digital learning media, particularly the availability of devices such as laptops and Chromebooks supplied by the local government. This context ensured that the product was tested under realistic instructional conditions.

Several techniques were used to gather data relevant to the development and evaluation of the e-module. Interviews with teachers and students provided information about learning needs and existing challenges in classroom instruction. Observations were used to examine student engagement

and classroom dynamics prior to implementation(Martini et al., 2025; Sudirman, 2024). Expert validation sheets were completed by specialists in content, language, and media design to assess the feasibility of the product. In addition, pretests and posttests were administered to measure students' critical thinking skills and learning outcomes before and after using the e-module. Student and teacher response questionnaires were used to evaluate practicality and user experience.

Multiple instruments supported data collection, including validation sheets, critical thinking assessments based on indicators proposed by Facione, learning achievement tests aligned with Merdeka Curriculum competencies, and user response questionnaires (Facione, 1994). These instruments enabled the researchers to evaluate the e-module from the perspectives of quality, usability, and impact.

Both qualitative and quantitative procedures were applied in data analysis. Qualitative data obtained from interviews, observations, and expert feedback were synthesized through reduction, categorization, and interpretation to identify key improvements throughout the development process (Sudirman, 2024). Quantitative data from pretests and posttests were analyzed using statistical procedures, including paired sample t-tests to determine whether significant improvements occurred after the e-module was implemented. Learning gains were calculated using the N-Gain formula and categorized based on established criteria. Instrument validity was examined through Pearson Product-Moment correlation, and reliability was determined using Cronbach's Alpha, with α values above 0.7 interpreted as acceptable (Kazanskaia, 2025).

The use of multiple data sources and analytical approaches allowed for a comprehensive evaluation of the e-module, ensuring that the final product was not only technically sound but also effective in supporting learning.

3. FINDINGS AND DISCUSSION

3.1 Findings

This study aimed to develop an AI-enhanced e-module based on the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) to improve fifth-grade students' critical thinking skills and learning outcomes in IPAS. The findings of each development stage are presented below(Molenda, 2015).

1) Analysis Stage

   The initial needs assessment involved interviews with teachers and questionnaires distributed to fifth-grade students at SDN Oro-Oro Ombo. The results indicated that 75% of students remained passive during learning activities, and 70% of teachers had not utilized interactive digital media in instruction. Students' average critical thinking score of 50.87, categorized as moderate, highlighted the need for instructional innovation capable of stimulating higher-order thinking.

   These results validated the urgency of integrating technology-based learning media that support active and adaptive engagement. An AI-based e-module was selected due to its potential to provide automated feedback and personalized pacing tailored to individual learning needs (Riyanto & Kawuryan, 2025).

2) Design and Validation Stage

   The design phase focused on structuring the e-module, developing the user interface, and integrating AI functionalities (Wang et al., 2024). The module was created using Google Sites and equipped with an AI tutor, interactive instructional videos, and voice-based explanations. Lesson planning aligned with the Merdeka Curriculum, emphasizing critical thinking as a key learning outcome (Riyanto & Kawuryan, 2025).

   The design process included structuring instructional content, developing the user interface, and integrating AI tutoring features. Validation was conducted by experts in content, language, and media. The results are presented in Table 1.

Table 1. Expert Validation Results of the AI-Based E-Module

Validator	Assessed Aspect	Score (%)	Category
Content Expert	Content relevance and basic competencies	96	Very Valid
Language Expert	Language accuracy and readability	97	Very Valid
Media Expert	Interface design and interactivity	98	Very Valid
Average		**97%**	**Highly Feasible**

The 97% overall score confirms that the developed e-module meets feasibility requirements for technology-supported instruction.

3) Development and Limited Trial

The validated module was tested with 15 students and one IPAS teacher to assess practicality, usability, and attractiveness. The module received an overall practicality score of 94%, with the following details: Teacher practicality: 95%, Student engagement and attractiveness: 94% and Ease of use: 93%

Minor revisions were made based on user feedback, including improving color contrast, enhancing AI-generated audio explanations, and adjusting text size on evaluation pages (Fu'adah & Ratnaningrum, 2024). The revised module was then prepared for broader implementation.

4) Implementation and Effectiveness Testing

The effectiveness of the developed e-module was examined using a quasi-experimental pretest-posttest control group design. Two classes were involved: the experimental class, which utilized the AI-based e-module, and the control class, which received conventional instruction.

Table 2. Mean Pretest and Posttest Scores and N-Gain

Group	Pretest Mean	Posttest Mean	N-Gain	Category
Experimental	62.4	83.5	0.62	Moderate–High
Control	61.7	71.2	0.28	Low

The findings reveal that students in the experimental group demonstrated a more substantial improvement than those in the control group, especially in terms of their critical thinking proficiency.

Table 3. Paired Sample t-Test Results

Variable	Group	t-value	p-value	Description
Critical Thinking	Experimental	5.784	0.000	Significant
IPAS Learning Outcomes	Experimental	4.932	0.001	Significant

Statistical analysis using the paired-sample *t*-test produced a significance value below 0.05, confirming the presence of a meaningful difference between pretest and posttest results. The computed N-Gain score of 0.62, which falls within the moderate-to-high category, signifies a notable enhancement in learners' critical thinking capabilities. Collectively, these outcomes confirm that the AI-supported e-module contributed effectively to improving both learning achievement and higher-order thinking competencies among students.

Table 4. Effect Size Calculation (Cohen's d)

Variable	Group	Mean Pre-test	Mean Post-test	N-Gain	t-value	p-value	Effect Size
Critical Thinking	Experiment	62.4	83.5	0.62	5.784	<0.001	1.25 (large)
Learning Outcomes	Experiment	61.7	83.5	0.62	4.932	0.001	1.10 (large)

The effect size calculation (Cohen's d = 1.25) indicates a very strong influence on student improvement. Taken together, these results provide robust evidence that the implementation of the AI

based e-module was highly effective in improving critical thinking skills and IPAS learning outcomes (Cohen, 1992).

5) Evaluation Stage

The comprehensive evaluation results indicate that the AI-based e-module meets the three essential criteria of high-quality instructional media: validity, practicality, and effectiveness. The product was categorized as highly feasible (97%), practical to implement (94%), and effective in improving learning outcomes ($p < 0.05$).

These findings align with Facione (1994) theoretical perspective, which asserts that critical thinking can be strengthened through exploratory and reflective learning supported by interactive media. The auto feedback features and adaptive AI embedded within the e-module allow students to analyze, evaluate, and solve problems independently.

The current findings align with the observations of Aji (2024) Paremarta et al. (2025)and Diantama (2023) Aslik et al. (2022), who identified that integrating AI within digital modules can stimulate students' higher-order thinking skills (HOTS). Furthermore, Kurniawan et al. (2022) and Salim et al. (2023) emphasized that AI-driven digital learning media can enhance learning motivation and concept retention through adaptive interaction.

Overall, the results of this study demonstrate that the application of the ADDIE model is effective in producing instructional media that are systematic, empirically validated, and aligned with the learning needs of 21st-century students (Janah & Haryono, 2025). The sequential validation and effectiveness testing procedures ensured that the product is not only technically feasible but also has a significant impact on improving learning outcomes and critical thinking skills.

3.2 Discussion

3.2.1 Development of the AI-Based E-Module

The design phase produced an interactive digital module incorporating AI-assisted tutoring components, automatic feedback systems, multimedia instructional materials, and audio explanations for enhanced comprehension. This outcome aligns with the instructional design principles proposed by Sugiyono (2022) and Molenda (2015), which emphasize that the ADDIE model yields systematic, validated, and sustainable media products.

Unlike prior studies such as Najuah et al. (2020), Rahman & I Nyoman (2020), and Lastri (2023), which focused primarily on conventional multimedia, the present study integrates adaptive AI-driven feedback mechanisms capable of tailoring instruction to learner characteristics. This positions the module as an example of AI implementation in Indonesian elementary education contexts.

3.2.2 Improvement in Critical Thinking Skills

The evaluation results demonstrated a statistically significant enhancement in students' critical reasoning performance, reflected by an N-Gain of 0.62, which signifies a moderate-to-high level of progress. This suggests that the AI-based module successfully encouraged analytical reasoning, evaluation, and reflection within IPAS learning.

These findings are consistent with Lai (2018) and Sundari et al. (2018), who noted that critical thinking skills develop through reflective and exploratory tasks supported by meaningful feedback. The AI tutor and automated feedback features provide immediate, individualized responses that facilitate iterative reasoning.

Critical thinking, defined as reflective reasoning used to evaluate claims and identify supporting evidence (Nuryanti et al., 2006; Widiastuti et al., 2022; Wuryani et al., 2021), and social skills such as collaboration (Janah, 2025; Sudarmiani et al., 2019) are foundational for technological literacy and lifelong learning. The module's interactive structure promotes both competencies by encouraging inquiry-based exploration and peer discussion. These findings reinforce prior research by Paremarta et al. (2025) and Diantama (2023) Aslik et al. (2022), which demonstrated that AI-based e-modules enhance

higher-order thinking skills through adaptive learning pathways. The integration of generative AI and voice-based assistance strengthens Indonesia's position in global literature on AI-supported critical thinking development (Liu et al., 2024).

3.2.3 Improvement in IPAS Learning Outcomes

IPAS learning requires contextual and analytical understanding. Significant improvements in learning outcomes ($p < 0.05$) with a higher post-test average in the experimental group illustrate the module's effectiveness in supporting conceptual mastery.

According to Maier & Klotz (2022), learning effectiveness increases when instructional stimuli, feedback, and system adaptation align with learner characteristics. The results of this study affirm that appropriately designed AI-supported media can enhance student engagement and conceptual understanding.

The findings are also consistent with Kurniawan et al. (2022) and Salim et al. (2023), who reported that interactive digital learning media improve motivation and retention. This study extends these conclusions to elementary-level AI applications with lightweight yet effective technological integration.

3.2.4 Effectiveness of the ADDIE AI Hybrid Model

Implementation of the ADDIE framework was shown to be highly effective, yielding a learning product characterized by strong validity (97%), high practicality (94%), and significant pedagogical impact. This supports Branch (2009), who noted that the evaluative structure of ADDIE ensures alignment between instructional design and learner needs.

This study introduces a conceptual extension referred to as the ADDIE–AI Hybrid Model, in which AI components are embedded during development and implementation to enhance personalization and interactivity. Such an approach reflects a growing trend in instructional design research, particularly within adaptive and technology-mediated learning contexts.

3.2.5 Theoretical Synthesis and Implications

The findings align with digital social constructivism, as described by Liu et al. (2024), which argues that adaptive interaction between learners and AI systems functions as a form of digital scaffolding that strengthens meaningful learning. Practically, AI-based e-modules can support student autonomy, critical thinking development, and effective implementation of the Merdeka Curriculum. Thus, the study not only addresses its research objectives but also contributes to instructional design theory and digital learning practice in Indonesian elementary education.

4. CONCLUSION

Drawing on the development, validation, implementation, and evaluation phases, this study concludes that the AI-integrated e-module demonstrates strong methodological rigor, high usability, and significant pedagogical effectiveness. Expert validation scores ranging from 96% to 98% (mean = 97%) confirm that the module meets established standards for content quality, language clarity, and interface design, while practicality ratings of 94–95% indicate that it is both feasible and user-friendly in authentic classroom contexts, with positive responses from teachers and students toward its AI-supported features. Empirically, the module contributes to meaningful improvements in students' critical reasoning, as evidenced by an N-Gain of 0.62 and statistically significant results ($t = 5.784$; $p < 0.001$), suggesting that its adaptive feedback and AI tutoring functions operate effectively as digital scaffolding tools. In addition, the module exerts a substantial impact on IPAS learning outcomes, with the experimental group outperforming the control group (83.5 vs. 71.2) and a large effect size (Cohen's $d = 1.25$), indicating enhanced engagement and conceptual mastery through AI-driven personalization. Nevertheless, the findings are constrained by the single-site implementation, the primary focus on cognitive outcomes, and the use of only semi-adaptive AI features, limiting generalizability and the scope of insight into broader learning dimensions. Future research should therefore extend

implementation across diverse contexts and educational levels, integrate more advanced AI capabilities such as real-time learning analytics and fully adaptive feedback systems, and support teacher capacity building alongside institutional and policy alignment to sustain adoption. Overall, the study affirms that AI-supported e-modules developed through the ADDIE AI Hybrid Model constitute effective, engaging, and adaptive instructional media for improving critical thinking skills and learning outcomes in elementary IPAS education.

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