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Research Article

Improving critical thinking ability in elementary schools with interactive e-modules

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ABSTRACT

This research project focuses on developing an interactive e-module specifically designed to improve critical thinking skills in elementary school students. To achieve this goal, we used a research and development approach based on the 4D model, involving 36 fourth-grade students at Pasirhuni State Elementary School, Indonesia as the research sample, data collection using validation sheets and tests, data analysis using expert validation questionnaires, classical

completeness tests, and N-gain tests. The validation results showed high scores on the media and material aspects, with an average score of 89.40%, which indicated that this e-module was very valid, in the effectiveness test conducted on a wide scale, the pre- and post-test scores showed a percentage of classical completeness of 89% with complete criteria. The implementation of the interactive e-module resulted in a significant increase in students' critical thinking skills. This recommendation can contribute to further research on the role of visual and interactive features in digital modules to support the development of student's cognitive skills.

Keywords: interactive e-modules, critical thinking, elementary schools, students

INTRODUCTION

In the 21st century, education in Indonesia faces new demands that emphasize the importance of developing critical thinking skills in students (An Le & Hockey, 2022; El Soufi & See, 2019). Education in this era is expected to not only teach academic knowledge but also prepare students with strong analytical skills to face increasingly complex global challenges (Benjakul, 2023). Critical thinking skills enable students to make thoughtful, independent decisions, as well as contribute to society in a responsible and innovative way (Erna et al., 2021; Norouzi et al., 2012; Syahfitri & Muntahanah, 2024). These critical thinking skills can be enhanced through the right learning approach (Altun & Yildirim, 2023; Yi-Ming Kao et al., 2025). Various studies have shown that innovative learning models, strategies and teaching materials play an important role in promoting the development of critical thinking skills in students (Akihary et al., 2024; Antón-Sancho et al., 2023; Krasodomska & Godawska, 2021; Marín-Vinuesa & Rojas-García, 2024).

However, in reality, many elementary schools in Indonesia still rely on conventional teaching materials that focus on memorization and factual knowledge, so they tend not to provide sufficient space to develop students' critical thinking skills. Research by Chen et al. (2016) found that teaching approaches that rely solely on memorization tend not to encourage students to conduct in-depth analyses or explore their understanding of learning materials. Furthermore, a study by Yandra and Sari (2020) showed that students who learn with rote-oriented teaching materials have difficulty developing critical thinking skills, such as analysis and evaluation of information. Another study by Logan et al. (2021) also highlighted that students who only receive passive teaching through conventional teaching materials have limitations in solving problems independently and tend to be less able to apply concepts in real contexts. The result of this kind of teaching approach is that students only have a surface understanding, and do not have sufficient opportunities to exercise their critical thinking skills (Kistofer et al., 2019).

This gap emphasizes the importance of developing more effective and interactive teaching materials, which not only present information but also motivate students to think critically and question the information presented. Research by Aris et al. (2025), Irwansyah et al. (2017), Rincón Leal et al. (2019), and Setiyani et al. (2022) show that interactive digital teaching materials, such as e-modules, can create an immersive and engaging learning experience, which is more effective in improving students' critical thinking skills. According to Kistofer et al. (2019), Laaziz et al. (2023), Radović et al. (2020), and Seruni et al. (2020), technology-based e-modules can increase student engagement in active and reflective learning, while Logan et al. (2021), Song and Cai (2024), and Yandra and Sari (2020) emphasized the importance of modules that can adjust to individual learning pace to effectively support the development of critical thinking skills. With a more suitable approach, teaching materials can help foster students' critical thinking skills early on, equipping them with a strong foundation to face challenges in a complex global era (Kowitlawakul et al., 2017; S & D, 2024).

Research on the development of interactive e-modules shows that this digital learning media has great potential to improve student's critical thinking skills. According to Niyazova et al. (2023) and Yafie et al. (2020), interactive modules encourage students to think analytically through features that facilitate independent exploration and reflection on the material. Another study by Drigas and Karyotaki (2014) and Sari Dewi and Kuswanto (2023) confirmed that e-modules can help students hone critical thinking skills by providing access to problem-solving exercises and interactive scenarios that invite students to think deeply. In addition, Zhang and Jenkinson (2024) found that e-modules that provide instant feedback allow students to evaluate their understanding and identify areas that need improvement. However, there is still a gap in research related to the development of interactive e-modules specifically designed to suit the critical thinking skills of students at the elementary school level. So further development is needed to understand how e-modules can be effective

in building critical thinking skills in students at the elementary level with an approach that is appropriate for their age and ability.

The purpose of this research is to develop an interactive e-module specifically designed to improve the critical thinking skills of elementary school students. The module will integrate elements such as text, images, audio, and video presented interactively, to motivate students to be actively involved in learning. In this way, e-modules are expected to overcome the limitations of printed teaching materials and create learning experiences that are relevant to the needs of education in the digital era. So this study aims to find out *how effective interactive e-modules are in improving the critical thinking skills of elementary school students.* This study aims to make a valuable contribution to the advancement of interactive e-modules that are more aligned with the needs of elementary schools.

LITERATURE REVIEW

Interactive E-Modules

Interactive e-modules offer a flexible and accessible learning experience that surpasses the limitations of traditional teaching methods (Lewin et al., 2024; Olvet & Sadigh, 2023). As technology advances, so do the ways we create and deliver learning materials. Electronic modules, which can be accessed on computers, are becoming increasingly sophisticated. These modules are often developed using specialized software (Yandra & Sari, 2020).

E-modules, or electronic learning modules, are interactive learning tools that package educational materials, methods, assessments, and any limitations clearly and engagingly (Aliyah & Widiyatmoko, 2023; Alyusfitri et al., 2024). Designed electronically, they target specific learning goals based on difficulty level and ensure learners achieve the expected competencies (Irwansyah et al., 2017). This module aims to deliver curriculum-aligned learning materials that cater to students' individual needs and social backgrounds. It strives to achieve educational goals efficiently and effectively by offering self-paced learning opportunities and fostering a growth mindset where students can continuously learn and understand new concepts (Detroyer et al., 2016; Naser-ud-Din, 2015). The module's design is based on the principle of mastery learning, ensuring students achieve a deep understanding of the presented material (Charlina et al., 2022) .

E-modules represent a significant leap forward from traditional learning materials (Booth et al., 2021; Detroyer et al., 2016). They offer a new way to present independent learning content, systematically organized into bite-sized pieces to help students achieve specific learning objectives (Sitorus et al., 2019). E-modules offer a more engaging and interactive learning experience compared to traditional materials (Bradshaw, 2016). They go beyond text-based content and incorporate multimedia elements like images and videos to deliver information more communicatively (Seruni et al., 2020).

The interactive format of e-modules draws students in and encourages them to explore the teacher's material (Irwansyah et al., 2017). E-modules offer students the flexibility to revisit unclear topics and provide them with the tools for independent learning (Logan et al., 2021). E-modules empower students to learn at their own pace, offering them easy access to materials and fostering a deeper understanding of the subject matter (Gaikwad & Tankhiwale, 2014).

E-modules are a perfect fit for today's learners who are comfortable with digital tools (have good digital literacy), self-motivated (have an ardent desire to be independent), and appreciate practical applications (applicable) (Kistofer et al., 2019). The use of e-modules has seen a surge in recent years, with many educational institutions around the world integrating them into their curriculum (Kowitlawakul et al., 2017). E-modules promote a more sustainable learning environment by minimizing paper usage compared to traditional printed textbooks (Sendari et al., 2019). Creating an effective e-module requires teachers to be creative (Moylan et al., 2025). They must ensure the materials align with the curriculum, cater to students' specific needs and learning styles, utilize available resources effectively, and ultimately help students achieve the desired learning outcomes (Seruni et al., 2020). E-modules, well-suited for today's digitally literate, self-motivated learners, are increasingly integrated into curricula worldwide, promoting sustainability by reducing paper usage and requiring teachers to creatively align materials with curriculum and students' needs (Fadillah et al., 2024; Hay, 2024; Lee & Suh, 2024).

Critical Thinking

Critical thinking, as a cognitive process, is distinguished by objectivity, persistence, and engagement when individuals encounter challenges, opposing viewpoints, or disagreements (Serrano Cardona & Muñoz Mata, 2018; Shieh & Nasongkhla, 2024). Well-crafted interactive learning environments foster favorable conditions for reflection and critical thinking, encouraging their development through enhanced student involvement, promoting the popularity of online learning, and contributing to successful learning outcomes (Yafie et al., 2020). By engaging with information technologies, people gain a richer mental experience and develop the ability to reflect critically, which is essential for effective thinking (Song & Cai, 2024).

The study investigated how mobile learning tools can be used to develop critical thinking skills (Astuti et al., 2018). Studies have shown that integrating gadgets in education leads to a double benefit: improved critical thinking skills and academic performance (Chimakonam & Ogbonnaya, 2024; Tangkish et al., 2024). Developing critical thinking is often seen as the cornerstone of formal education, as this ability empowers students to succeed beyond the classroom (Norouzi et al., 2012).

Mobile learning software is emerging as a powerful tool for fostering critical thinking skills (Eliza et al., 2023; Miller & Olthouse, 2013). Students using mobile platforms can quickly adjust to new learning environments, actively engage in the learning process, and tackle intriguing theoretical and practical problems that encourage critical thinking (Rincón Leal et al., 2019). A closer look at how teaching methods impact learning reveals that many factors contribute to developing strong critical thinking skills. These factors can be broken down into three main categories: student-related factors like learning style and motivation, teaching method factors including techniques, class duration, and feedback, and finally, environmental factors such as classroom atmosphere and reward systems (Lorencová et al., 2019).

The ability to think critically, which involves analyzing problems with raw data and exploring different solutions, is surprisingly easy to develop through the right kind of mental exercises (Lestari et al., 2019). To develop the best approach for critical thinking education within a specific institution, several steps are crucial. First, analyze the existing teaching methods and environment. Second, define clear learning objectives focused on developing critical thinking skills. Third, actively promote critical thinking throughout university education. Fourth, create a supportive learning environment. Finally, implement and adapt a critical thinking development program, which can leverage interactive platforms for enhanced learning (X. Song, 2016). Implementing a successful critical thinking education program involves analyzing current teaching methods, setting clear objectives, promoting critical thinking throughout the curriculum, creating a supportive environment, and leveraging interactive platforms for better learning (Eliza et al., 2024; Fadli et al., 2024; Hakiki et al., 2024).

The Objective of the Research

This research aims to achieve the following objectives:

1. The first aim of this research is to measure the validity of the developed product which was given to several media and material experts
2. The second objective of this research is to measure product limitation tests developed from limited-scale testing
3. The third aim of this research is to measure students' critical thinking abilities using interactive e-modules

Importance of This Study

The importance of this research is determined by the following aspects:

1. **Development of critical thinking skills:** In today's information era, critical thinking is an essential skill that students need to develop. This research focuses on enhancing this ability from an early age, at the elementary school level, which can help students analyze, evaluate, and make better decisions in the future.
2. **Application of technology in education:** The use of interactive e-modules demonstrates how technology can be effectively applied in the learning process. This is crucial in the context of

globalization and technological advancements, where integrating technology into education becomes increasingly relevant.

3. **Measurement of effectiveness:** The research also serves to measure the effectiveness of interactive e-modules in enhancing students' critical thinking abilities. The findings can provide valuable insights for educators and policymakers in designing and implementing more effective learning strategies.

METHOD

This study uses a research and development approach by applying the 4D development model (*define, design, develop, disseminate)*. This model consists of four interrelated and structured phases, namely problem definition, module design, module development, and product dissemination. The 4D model was chosen because it provides a systematic and comprehensive framework for producing effective learning products. (Lederman & Maloney, 2004). The advantages of this model are that the stages are relatively short and flexible and allow for revision and consultation with experts before the module is trialed. Thus, this model can ensure that the final product achieves optimal functionality in improving students' critical thinking skills. The steps can be seen in **Figure 1**.

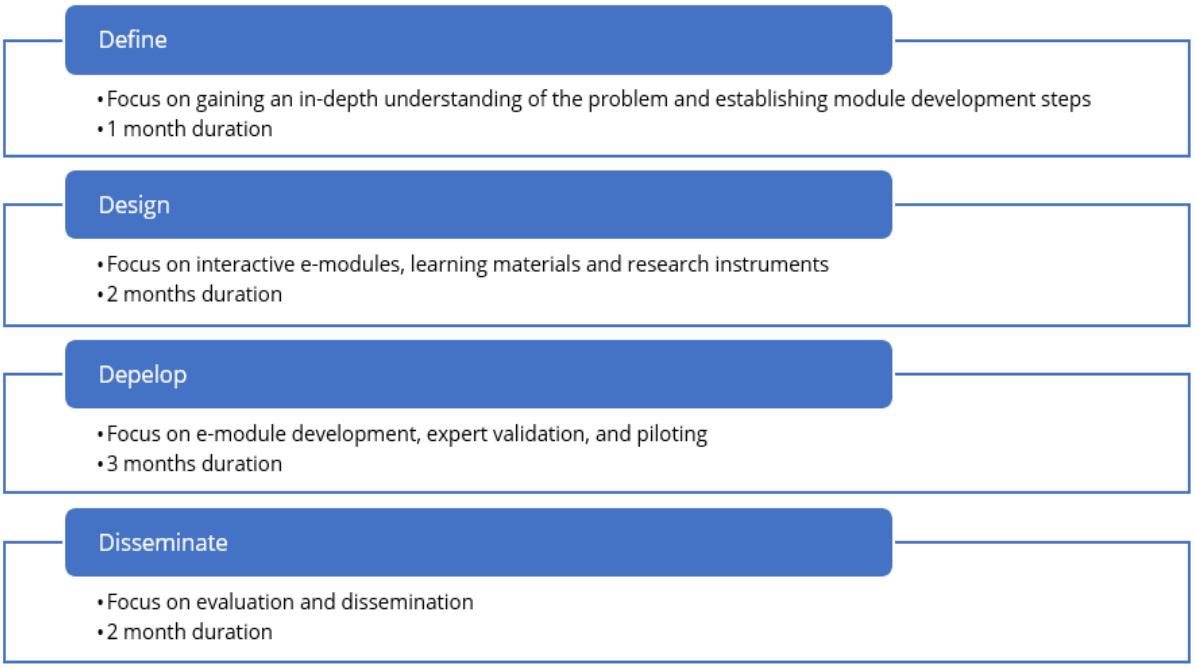

Figure 1. Research procedure (the authors' own work)

Based on **Figure 1** of the define phase, the first step is to define the problem to be addressed based on the issues identified in the research background. Then, a field situation analysis is conducted to understand important aspects of module development, such as the selection of research samples, evaluation of student characteristics, deepening of learning concepts, observation of required tasks, and formulation of learning objectives that are by the context and needs of students. This phase aims to gain an in-depth understanding of the problems encountered and establish steps in module development. This phase is expected to last for 1 month.

The design phase of developing the interactive e-learning module will focus on three main aspects: user interface design, learning material design, and research instrument preparation. The development team will design the module interface to be easily accessible and understandable by elementary school students, considering aesthetics and ease of navigation. The materials are arranged according to the student's level of understanding and the learning objectives that have been set. Research instruments such as questionnaires and other evaluation tools will also be prepared in this phase. All these elements will be combined in an initial

prototype of the module that will be trialed in the development phase. This phase is estimated to last for 2 months.

The development phase of the interactive e-module begins to be developed by adapting the material content to the applicable elementary school curriculum. The development team will add interactive features that support independent learning, ensure the module is easy to use, and interact with students effectively. In addition, discussions and validation with learning media and learning material experts will be conducted to ensure the quality of the developed module. Furthermore, testing will be conducted to see the effectiveness of the developed e-module. This phase is expected to last for 3 months.

The main purpose of the dissemination phase is to extend the reach of the learning module to a wider audience, such as students, teachers, or educational institutions. This phase includes steps to ensure the learning module or materials can be accessed and utilized by those who need it. Dissemination steps may include providing access to the e-module, presentation to other study groups, or dissemination of learning outcomes through online platforms. This phase is estimated to last for 2 months, including final evaluation and validation.

Respondents

This interactive e-module uses several validators to see the validity of the experts' perceptions. Validators in this study consisted of two experts from Yogyakarta State University, namely media experts and material experts. Furthermore, the interactive e-module has been validated and revised, then tested on 36 fourth-grade students of Pasirhuni Public School, Indonesia. Respondent selection using a purposive sampling technique (Barratt et al., 2015; Campbell et al., 2020).

Collecting Data

Data collection instruments are an important element in research because they determine the quality of data obtained by researchers. To obtain the desired data, data collection instruments are used. In **Table 1**, there are details of the aspects assessed, the instruments used, the data observed, and the respondents involved.

Table 1. Observed data and respondents

Data	Instrument	Observed data	Respondents
E-module needs	Questionnaires & interviews	Teachers and students need interactive e-modules	Teachers & students
Product validity	Validation sheet	Material and media validity	E-module expert
Effectiveness	Test	Assessing the impact of instruction on students' critical thinking ability.	Students

Research Instrument

Validity instrument

The validity instruments used in this study were developed through a systematic process to ensure their suitability for the research objectives and the scope of the assessment indicators. The validity instruments for media experts were designed based on relevant theoretical frameworks and best practices in learning media evaluation. The development process involved literature review and consultation with instructional design and multimedia learning experts. The indicators used include presentation techniques to assess the conciseness of concepts, systematic consistency, and balance between subchapters; presentation support to evaluate the appropriateness and accuracy of illustrations, and the use of up-to-date references in text, images, and appendices; and learning presentation to assess learner engagement, student-centered learning approach, development of concept understanding, creation of appropriate interactive communication, and suitability to subject characteristics. The validity instruments for material experts were designed with a focus on content quality, including the suitability of the material to the learning outcomes (CPs), the accuracy of concepts and facts, the relevance of the material to the development of science and technology, and its ability to encourage learners' curiosity. All of these instruments were pilot-tested by involving experts consisting of

educational practitioners and academics. Input from the pilot test results was used to improve and ensure that the instruments had clarity and relevance to the research objectives.

Effective instrument

The effectiveness instrument in this study was designed to measure the improvement of students' critical thinking skills, which is the main objective of the study. The development process begins with a review of the critical thinking framework, such as determining indicators that can be measured by the module objectives. The indicators used include the ability to analyze arguments, answer explanations critically, generalize and consider consequences, provide precise definitions, and classify information based on certain features. This instrument was tested through a pilot test stage involving a small group of students using the e-module. Tests were conducted before and after the use of the module to measure changes in critical thinking skills. The results of this pilot test were used to refine the test items to make them clearer and by the research objectives.

Data Analysis Procedure

Validity analysis

The validation instrument used in this study was an expert validation questionnaire designed to assess the quality of materials and media in the interactive e-module. The questionnaire items were developed based on the research objective, which was to ensure that the e-module effectively supports the development of student's critical thinking skills. Items included aspects such as "appropriateness of content to learning objectives," "visual layout and design," and "readability and clarity of information."

To ensure content validity, the instrument was reviewed by material and media experts through a pilot testing phase. The feedback obtained was used to refine the questionnaire, ensuring clarity, consistency, and alignment with the research objectives. Descriptive statistics were used to analyze the validation data, and the percentage score of each item was calculated using the following formula:

$$N = \frac{score}{maximum\ score} \times 100\%.$$

The results of the analysis obtained from the respondent's data can be seen in **Table 2** regarding the criteria for concluding and interpreting the results of this validity.

Table 2. Criteria for validity

Percentage	Category	Description
75.01%–100%	Very valid	Very valid (can be used without revision)
50.01%–75.00%	Valid	Valid (can be used with minor revisions)
25.01%–50.00%	Moderately valid	Moderately valid (can be used with improvements)
00.00%–25.00%	Not valid	Very invalid (cannot be used)

The validity criteria, as presented in **Table 2**, show categories ranging from 'not valid' to 'very valid.' An e-module is considered valid if it gets a rating of 'valid' or 'very valid' according to the standards set (Fendler, 2016).

The use of descriptive statistics for validity analysis was chosen to summarize the expert ratings in a clear and interpretable manner, facilitating categorization based on established validity thresholds. This approach ensures transparency in evaluating the module's quality and suitability for its intended purpose. Additionally, the descriptive analysis provides a straightforward method to identify areas requiring improvement while maintaining alignment with the study's objective of developing an effective tool to enhance critical thinking skills.

Effectiveness analysis

The data analysis in this study employed two primary methods, the classical completeness test and the N-gain test. These methods were chosen to comprehensively evaluate the effectiveness of the interactive e-module in enhancing students' critical thinking skills, aligning with the research objectives.

Classical completeness test: The classical completeness test was used to calculate the percentage of students who successfully achieved the expected competencies through the use of the interactive e-module. The formula applied was:

$$Percentage = \frac{number\ of\ students\ who\ are\ complete}{Total\ number\ of\ learners} \times 100\%.$$

Learning with the interactive e-module was considered successful if the classical completeness rate exceeded 75% (Kharisudin & Cahyati, 2020). This test was selected because it provides a clear and straightforward representation of student success in meeting the minimum competency standards.

N-gain test: The N-gain test was used to measure the improvement in students' critical thinking skills by comparing pre- and post-test scores using the formula:

$$< g > = \frac{<posttest\ score> - <pretest\ score>}{<maximum\ score> - <pretest\ score>}.$$

Interpretation is an interpretation of the results of the N-gain data analysis. As a guideline for interpretation, the criteria in **Table 3** are set out below.

Table 3. N-gain criteria

N-gain value	Criteria
g > 0.7	High
0.3 ≤ g ≤ 0.7	Medium
g < 0.3	Low

The interactive e-module was deemed effective in enhancing critical thinking skills if the N-gain results fell within the *medium* or *high* category (Akihary et al., 2024). This test was chosen because it effectively measures the magnitude of improvement in students' critical thinking skills.

Justification for Statistical Analysis

The statistical methods used, including the classical completeness test and the N-gain test, were chosen to align with the study's objective of comprehensively evaluating the effectiveness of the interactive learning approach. The classical completeness test provides a straightforward metric for overall student success, while the N-gain test offers a detailed understanding of the extent of improvement in critical thinking skills. The combination of these methods ensures a robust and reliable assessment of the learning outcomes.

Statistical Power Analysis

A power analysis was conducted to ensure that the sample size was adequate for detecting meaningful differences in learning outcomes. The analysis confirmed that the sample size achieved a statistical power greater than 80%, meeting the standard threshold to minimize the risk of type II errors. This ensures the study's ability to reliably detect significant effects of the e-module on students' critical thinking skills.

Handling Missing Data and Outliers

Missing data were addressed using the pairwise deletion method, allowing analyses to utilize available data without introducing bias. Outliers were identified using standardized z-scores and visually inspected through boxplots. Outliers deemed valid were retained, while data entry errors were corrected. This approach ensured the reliability and integrity of the analysis while maintaining robust findings.

RESULT

The development of interactive e-modules aims to improve students' critical thinking skills in the context of learning in elementary schools. The design created is in **Figure 2**.

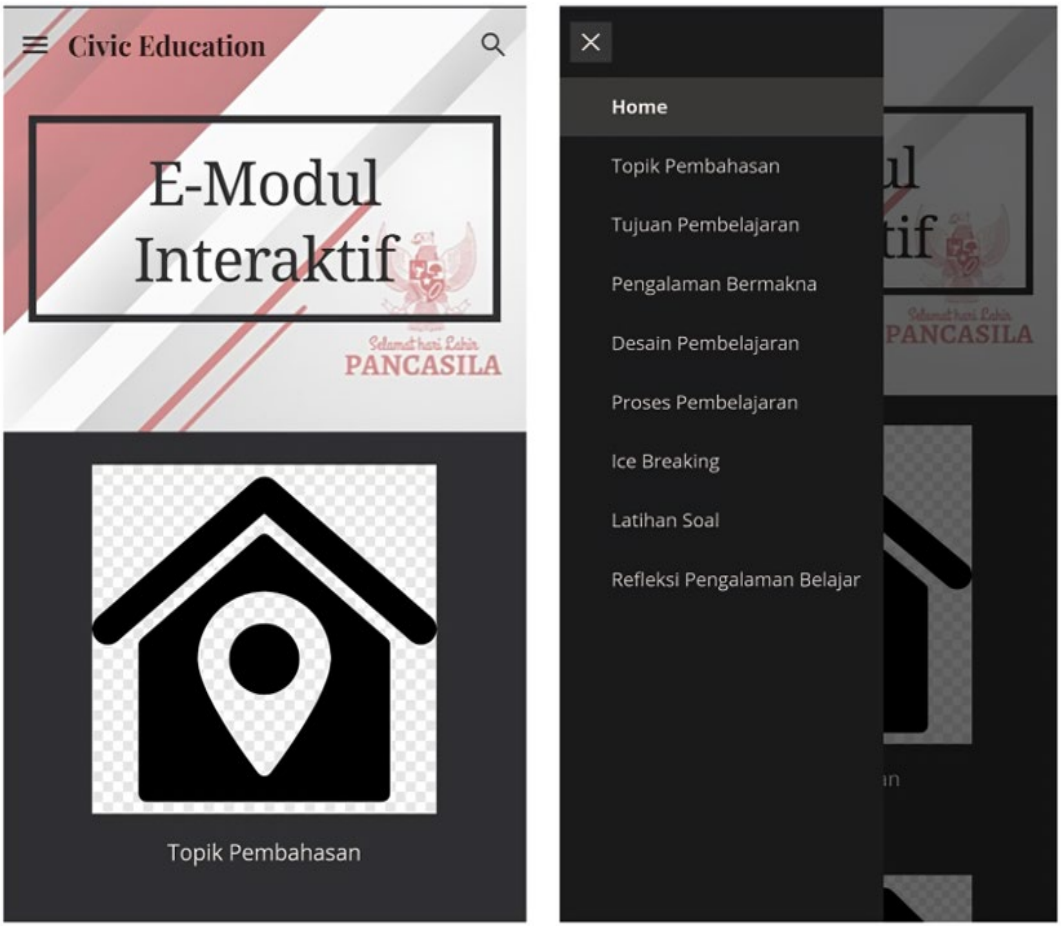

Figure 2. Interactive e-module display (Source: https://rb.gy/kxvseu)

This interactive e-module has various features to support the learning process as a whole. On the main page or Home, users can return to the main menu and access other features. Topic discussion contains the main material that will be discussed in the module, helping users understand the theme or subject matter that is the focus. Learning objectives explain the expected outcomes after completing the module so that users can know the competencies that must be mastered. Through meaningful experience, users are introduced to relevant and applicable activities, linking the material to real situations to provide a deeper understanding.

The learning design displays the flow or steps to be taken in the module, guiding users to follow the learning structure that has been developed. The learning process outlines the learning stages in detail, allowing users to follow the flow systematically. To create a comfortable learning atmosphere, the ice-breaking feature presents ice-breaking activities before starting the core material, making users feel more ready to learn. The module is also equipped with practice questions, which contain evaluation questions to test the user's understanding of the material that has been learnt. Finally, learning experience reflection provides a space for users to reflect on their learning process, helping to internalize the material and give meaning to their learning experience. All of these features are designed to make learning interactive, allowing users to not only read but also actively engage in the learning process.

In addition, the Learning Process feature in this e-module is designed to improve students' critical thinking skills. This feature not only contains learning steps but is also equipped with interesting images that stimulate students' interest and thinking power. With interesting visuals, users are expected to analyze and explore the material more deeply, to understand the concepts critically. The presence of these images helps users think more creatively and critically in understanding the learning context. The display of the learning process menu is in **Figure 3**.

Figure 3. Learning process view (Source: https://rb.gy/kxvseu)

The learning process display depicts a class leader election process that involves deliberation and collective decision-making, where each student votes openly for a candidate. After the voting results are announced, Kadir is elected as the class leader with the most votes, and his peers express willingness to cooperate in every class activity.

The learning process feature of this e-module, which is equipped with interesting visuals such as this picture, plays an important role in improving critical thinking skills. Through detailed images, students are invited to analyze each stage in decision-making and learn about democratic values, such as deliberation and cooperation. With this picture, users can more easily understand the concept deeply and critically, while linking learning with real experiences in everyday life.

Validation Results

The validation results show that the developed interactive e-module meets the criteria of highly valid, which indicates that the module is suitable for use in teaching in elementary schools. A summary of validation scores from material experts and media experts is shown in **Table 4**.

Table 4. Recapitulation of expert validation results

Assessment	Percentage	Criteria
Material expert	87.14%	Very valid
Media expert	91.67%	Very valid

Based on **Table 4**, the percentage of interactive e-module assessments by material experts reached 87.14% with 'very valid' criteria, and the percentage of assessment by media experts reached 91.67%, also with 'very valid' criteria. Overall, the interactive e-module received an average validity score of 89.40%, indicating a high level of feasibility for use in the classroom. This validity testing also resulted in positive feedback from the validators who recommended immediate implementation for further evaluation.

Pre- and Post-Test Results: Improvement of Critical Thinking Skills

After conducting a wide-scale test by comparing pre- and post-test scores. The initial pre-test was given to measure students' critical thinking skills before using the interactive e-module, while the post-test was used to measure the improvement, with the results shown in **Figure 4**.

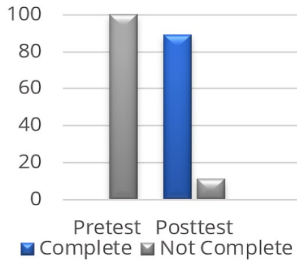

Figure 4. Student pre- and post-test results (the authors' own work)

Based on **Figure 4**, none of the students in the product test class reached the minimum completion criteria (MCC) with the pre-test score. However, in the post-test, 32 out of 36 students (89%) successfully achieved the MCC score, indicating that the interactive e-module had a significant impact on students' critical thinking skills. These results fulfil the class success criteria, where a minimum of 75% of students must achieve classic completeness. Details of this classical completeness are shown in **Table 5**.

Table 5. Calculation results of classical completeness values

Number of students who completed	Total number of students	Completion percentage	Criteria
32	36	89	Complete

The completion percentage of 89% in the post-test showed a significant increase in students' critical thinking skills. This indicates that the interactive e-module is effective in understanding and successfully improving students' critical thinking skills.

N-Gain Analysis

The improvement of students' critical thinking skills was further analyzed using the N-gain test. **Table 6** presents the N-gain values calculated based on the difference in pre- and post-test scores.

Table 6. N-gain scores for critical thinking ability

Ability	Pre-test average	Post-test average	N-gain value	Criteria
Critical thinking	43.47	83.05	0.70	High

The analysis in **Table 6** shows a significant increase with an N-gain value of 0.70, which meets the criteria of 'high'. These results confirm that the interactive e-module is able to significantly improve students' critical thinking skills.

DISCUSSION

The developed interactive e-module can improve students' critical thinking skills. The interactive e-module developed has met the criteria of very high. This shows that the use of this e-module can train students to think more critically. In addition, the developed e-module has also met very high standards, in terms of quality, effectiveness, and features in the module. In other words, this e-module not only functions well but is also recognized as having very adequate criteria. This interactive e-module is designed through various features and approaches that encourage active engagement and deep understanding. By presenting structured material and attractive visual displays, the module helps users critically analyze, evaluate and connect information.

The advantage of this interactive e-module lies in the display of features that have an impact on critical thinking skills, namely in the learning process feature, where the feature is equipped with interesting images that stimulate student interest and thinking. In line with his research (Aristin et al., 2023; Dahal et al., 2023), digital modules designed with attractive visual elements can improve students' critical thinking skills. Interactive modules are designed with bright colors and attractive illustrations, which according to Erna et al. (2021) and Evans and Joshi (2020) can motivate students to be more creative and critical in the learning process. This result is also in line with the findings of Fitzpatrick et al. (2021) and Johansson (2020), who stated that digital modules that are attractive and easy to understand can strengthen students' critical thinking skills, especially in the context of visual learning.

Critically, the success of this e-module in improving students' critical thinking skills can be explained through a learning approach that focuses not only on the presentation of material but also on deeper cognitive processing. The module is designed for students to analyze, evaluate and connect information, which is in line with the theory of constructivism, where learning occurs through a process of active interaction between students and learning materials (Fitzpatrick et al., 2021; Osman & Lee, 2014). With engaging and structured features, the module creates an environment that supports deep cognitive engagement, an aspect

also emphasized by activity-based learning theory (Aliyu et al., 2023; Antón-Sancho et al., 2023; Norouzi et al., 2012).

This study shows consistency with previous research regarding the important role of visual and interactive features in digital modules to develop students' critical thinking skills. Support from Huang et al. (2024) revealed that a combination of visual and interactive features can help students connect complex concepts independently through a design that motivates active participation, aligning with the findings of this study which emphasized the importance of student engagement. In addition, Sahraie et al. (2024) found that interactive elements such as adaptive quizzes and dynamic simulations significantly improved students' critical thinking ability, which is consistent with this study's focus on developing analytical skills through interactive features. A meta-analysis review by Kavadella et al. (2013) also supports these findings, showing that the combination of engaging visuals and interactive content increases student engagement and comprehension. However, there are inconsistencies with the study by Sujanem and Putu Suwindra (2023), although highlighting the importance of visual features to improve students' critical thinking, it is not the main factor in improving students' critical thinking skills, as the main factor is the aspect of students' direct participation in the learning content. As such, this research adds a new perspective on the role of active engagement through interactive features in building students' critical skills, while expanding the understanding of the synergy between visual and interactive elements.

This research makes an important contribution to critical learning theory and educational technology by showing that a well-designed e-module can improve critical thinking skills that can be applied in a learning context. Furthermore, the findings challenge the assumption that the use of technology in learning serves only as a visual aid. Instead, e-modules with a structured approach can play an active role in promoting deep learning and can enhance critical thinking skills. In other words, this e-module shows that technology is not just a passive tool but also a medium that facilitates students' critical thinking process (Lemarié et al., 2017; Muda & Rashid, 2022; Xianxiao, 2024).

This research provides significant benefits in education, particularly in improving students' critical thinking skills through learning technology. A well-designed interactive e-module is proven and effective in actively improving students' cognitive skills. The implications of this research include the potential integration of interactive e-modules in the curriculum as part of technology-based learning strategies, guiding educators and curriculum developers to create digital learning media that support deep understanding. However, this study has limitations, namely the module was tested on only one subject (civic education) and one specific age group, so the results may be different if applied to other subjects or different age groups. Secondly, comparison with traditional learning methods has not been measured directly, so further research is needed to compare interactive e-modules with conventional learning methods to understand the advantages and limitations of each approach. For future research, it is recommended that similar studies be conducted on more diverse student populations and different contexts to test the validity of the results, as well as explore the impact of this e-modules on other cognitive aspects, such as creativity and problem-solving. Further research could also evaluate the long-term effect of this e-modules on student motivation and compare its effectiveness with other teaching methods to understand the advantages of each approach.

CONCLUSIONS

This study shows that the application of interactive e-modules significantly improves the critical thinking skills of elementary school students. The validation of the e-module showed a category of 'very valid,' with the classical completeness rate reaching 89% and the improvement of critical thinking skills, measured through the N-gain value, in the high category. These results confirm that the interactive e-module is effective in supporting the development of students' critical thinking skills. Based on these results, this study makes a significant contribution to technology-based education literature. The findings demonstrate the effectiveness of interactive e-modules in improving critical thinking skills at the basic education level. In addition, the results of this study also provide an empirical basis for further development of interactive module-based learning methods specifically designed to improve critical thinking skills in the context of basic education. However, this study has some limitations. Firstly, the module was only tested on one subject (civic education) and one particular age group, so the results may differ if applied to other subjects or different age groups. Secondly,

this study has not directly compared the effectiveness of interactive e-modules with traditional learning methods, so the advantages and limitations of each approach have not been fully revealed. For future research, it is recommended to evaluate the impact of the interactive e-module not only on critical thinking skills but also on students' overall academic achievement. In addition, future research could explore the application of this learning approach to other subjects to see if this interactive approach produces similar effects on critical thinking skills or other cognitive abilities, such as creativity, collaboration and digital literacy. Comparing the effectiveness of interactive e-modules with conventional learning methods will also provide deeper insights into the advantages and disadvantages of each approach.

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