



Development of a Problem-Solving-Based Mathematics E-Module to Enhance Students' Critical Thinking Skills

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ABSTRACT

Critical thinking skills are essential competencies in twenty-first-century mathematics education. However, numerous studies indicate that students' mathematical critical thinking abilities remain relatively low due to the limited availability of instructional materials that facilitate systematic problem-solving activities. This study aimed to develop a problem-solving-based mathematics e-module that is valid, practical, and effective in improving students' critical thinking skills. The research employed a Research and Development (R&D) method using the ADDIE model consisting of analysis, design, development, implementation, and evaluation stages. The participants were 72 eighth-grade junior high school students. Research instruments included expert validation sheets, student response questionnaires, and critical thinking tests. Data were analyzed using descriptive statistics and N-Gain tests. The findings revealed that the developed e-module achieved a validity level of 92.4%, practicality of 89.7%, and effectiveness with an N-Gain score of 0.74 categorized as high. Students' average critical thinking score increased from 61.32 in the pretest to 84.78 in the posttest. These findings indicate that problem-solving-based mathematics e-modules effectively enhance students' critical thinking skills. This study contributes to the development of digital instructional materials supporting twenty-first-century learning and the implementation of the Independent Curriculum.

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Introduction

The development of 21st-century education has positioned critical thinking as one of the essential competencies that students must possess to face the complexity of problems in the digital era. Critical thinking skills are not only related to the ability to understand information but also involve the ability to analyze, evaluate, interpret, and make rational decisions based on available evidence. In mathematics learning, critical thinking skills are particularly important because mathematics inherently requires reasoning, problem-solving, decision-making, and the ability to connect various concepts logically. Therefore, the development of critical thinking skills should become a primary focus in mathematics instruction so that students can apply learned concepts to solve various contextual problems effectively.

Although critical thinking has become one of the primary competencies emphasized in various educational policies, its implementation in practice indicates that students' mathematical critical thinking skills remain relatively low. This condition is reflected in the dominance of instructional practices that focus on information delivery, procedural exercises, and obtaining final answers without providing sufficient opportunities for students to engage in exploration, analysis, argumentation, and reflection on the problem-solving process. Consequently, students often encounter difficulties when faced with non-routine problems that require higher-order thinking skills. This situation highlights the need for instructional innovations capable of encouraging students' active engagement in constructing knowledge and continuously developing critical thinking skills.

One factor contributing to the low level of students' critical thinking skills is the limitation of instructional materials used in learning activities. Conventional teaching materials generally focus on presenting concepts and routine exercises, providing limited opportunities for students to conduct investigations and solve problems independently. Along with the rapid advancement of information technology, numerous studies have begun developing digital learning materials that are more interactive and adaptive to students' needs. In the context of mathematics education, e-modules have emerged as a form of digital instructional material capable of supporting independent learning, enhancing learning interactions, and facilitating the development of higher-order thinking skills. E-modules enable the integration of various learning media, including text, images, animations, videos, simulations, and interactive assessments, making the learning process more engaging and meaningful.

Several studies have demonstrated that the use of e-modules positively impacts students' critical thinking skills. Anjarsari et al. (2023) reported that the development of e-modules improved elementary school students' critical thinking skills through a more interactive and structured learning process. Their findings suggest that the integration of technology into instructional materials can help students achieve a deeper understanding of concepts while enhancing their analytical abilities in problem-solving. Similar results were reported by Hasanah et al. (2024), who developed an e-module for the topic of sequences and series. Their study revealed that the use of e-modules significantly improved mathematical critical thinking skills, with a high effectiveness category indicated by an N-Gain score of 0.71. These findings indicate that e-modules possess considerable potential as learning tools capable of fostering students' higher-order thinking skills.

Research on e-modules has also shown a growing tendency to integrate innovative learning approaches to enhance the effectiveness of mathematics instruction. One widely adopted approach is Problem-Based Learning (PBL). Rohmatulloh et al. (2023) found that an interactive e-module based on Problem-Based Learning demonstrated high levels of validity, practicality, and effectiveness in improving students' mathematical critical thinking skills. Their study showed that student involvement in identifying problems and seeking solutions could foster critical thinking more optimally. Similar findings were reported by Cahyaningsih and Nahdi (2025), who found that PBL-based e-modules improved elementary school students' critical thinking skills through discussion, collaboration, and problem exploration activities integrated into digital modules.

In addition to Problem-Based Learning, several studies have developed e-modules using other approaches aimed at improving critical thinking skills. Zulfa et al. (2023) developed a mathematics e-module based on guided inquiry and found that the product significantly enhanced students' critical thinking skills. Domina et al. (2024) developed an inquiry-based e-module on number patterns and demonstrated that the resulting module met the criteria of validity, practicality, and effectiveness. Meanwhile, Maziyah and Hidayati (2022) developed a STEM-based e-module on trigonometry and found that the approach facilitated the development of students' critical thinking skills through the integration of science, technology, engineering, and mathematics concepts. These studies collectively indicate that e-module designs integrating specific instructional models can contribute positively to improving the quality of mathematics learning.

In recent years, research on Problem-Based Learning-based e-modules has continued to expand. Musa'ad et al. (2025) reported that the developed PBL-based e-module significantly improved students' critical thinking scores from an average of 30.10 to 84.50. Bayu et al. (2026) also found that interactive e-modules based on Higher-Order Thinking Skills (HOTS) effectively enhanced secondary school students' critical thinking abilities. Furthermore, Nurissamawati et al. (2024) reported that a PBL-based e-module achieved a validity level of 92.56%, practicality of 90.39%, and effectiveness of 76.33%. These findings strengthen the argument that digital instructional materials designed according to active and student-centered learning principles can positively influence the development of critical thinking skills.

Although numerous studies have confirmed the effectiveness of e-modules in enhancing critical thinking skills, most research has focused on implementing specific instructional models, particularly Problem-Based Learning, guided inquiry, or STEM. These studies

generally use problems as triggers for learning activities but do not explicitly integrate mathematical problem-solving stages as the primary structure of e-module design. In fact, critical thinking in mathematics is closely related to the ability to perform systematic problem-solving processes, including understanding the problem, planning solution strategies, implementing the chosen strategies, and evaluating the obtained results. Therefore, developing e-modules that specifically integrate a problem-solving approach is essential.

A review of previous studies indicates that e-module development has predominantly focused on product validity, practicality, and effectiveness. Studies conducted by Hendriko et al. (2024), Pujiono et al. (2024), and Juniati and Jamaan (2024) revealed that instructional materials based on Problem-Based Learning effectively improved both critical thinking and mathematical problem-solving abilities. However, these studies have not extensively developed digital instructional materials that position the problem-solving process as the core component of every learning activity undertaken by students. This condition reveals a research gap that remains open for the development of e-modules specifically designed based on mathematical problem-solving stages.

Based on the literature review, three research gaps underpin the present study. First, most previous studies have developed e-modules based on Problem-Based Learning, whereas the development of problem-solving-based e-modules in mathematics education remains relatively limited. Second, previous research has primarily focused on improving learning outcomes and general critical thinking skills without integrating critical thinking indicators into every stage of the problem-solving process. Third, studies developing mathematics e-modules based on problem-solving approaches that align with digital learning needs and the implementation of the Merdeka Curriculum remain scarce.

To address these gaps, this study offers a novel contribution through the development of a problem-solving-based mathematics e-module that systematically integrates mathematical problem-solving stages into all digital learning activities. These stages include problem identification, information analysis, solution strategy planning, solution implementation, solution evaluation, and learning reflection. Unlike previous studies that primarily emphasized the use of specific instructional models as learning frameworks, this study positions mathematical problem-solving processes as the core instructional design supported by interactive digital features, HOTS-based exercises, automated feedback, and reflective activities. Such integration is expected to provide a more meaningful learning experience while continuously strengthening students' critical thinking skills.

In addition to contributing to the development of digital instructional materials, this study is highly relevant to the implementation of the Merdeka Curriculum, which emphasizes student-centered learning, competency development, and the cultivation of the Pancasila Student Profile. Through the problem-solving-based e-module, students are provided with opportunities to learn independently, develop critical reasoning skills, and construct more effective problem-solving strategies. Therefore, the findings of this study are expected to contribute theoretically to technology-enhanced mathematics learning and practically to teachers in providing digital instructional materials that support the improvement of students' critical thinking skills.

Based on the foregoing discussion, the objective of this study is to develop a problem-solving-based mathematics e-module that meets the criteria of validity, practicality, and effectiveness in improving students' critical thinking skills. The findings are expected to enrich the literature on mathematics digital instructional material development and provide an alternative learning solution that aligns with the demands of 21st-century education.

Method

Research Design

This study employed a Research and Development (R&D) method aimed at producing a problem-solving-based mathematics e-module and evaluating its validity, practicality, and effectiveness. The development model adopted in this study was the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) due to its systematic, flexible, and widely recognized framework for developing digital instructional materials. The selection of the ADDIE model was based on its ability to integrate needs analysis, product design,

development, implementation, and evaluation processes continuously, thereby ensuring that the resulting product aligns with users' needs and learning objectives.

The study was conducted during the first semester of the 2025/2026 academic year. The development focused on designing a problem-solving-based mathematics e-module capable of facilitating the improvement of students' critical thinking skills through systematic, interactive, and problem-oriented learning activities.

Research Participants and Setting

The study was conducted at a public junior high school in Padang City, West Sumatra, Indonesia. The research site was selected purposively based on the availability of technological facilities supporting digital learning and the school's readiness to implement electronic instructional materials.

The population consisted of all eighth-grade students, totaling 216 students distributed across several classes. The sample comprised 72 students selected through purposive sampling. This sampling technique was employed to ensure that participants possessed characteristics relevant to the research objectives, particularly regarding the use of digital devices during the learning process. In addition to students, the study involved three expert validators, including a mathematics content expert, an educational media expert, and a language expert, to evaluate the quality of the developed product.

Research Instruments

The research instruments consisted of validation instruments, practicality instruments, and effectiveness instruments.

The validation instrument was used to assess the feasibility of the product in terms of content, media, and language aspects. The validation sheet was developed using a five-point Likert scale encompassing indicators such as the alignment of content with learning outcomes, mathematical concept accuracy, media display quality, ease of navigation, language readability, and the suitability of the e-module with problem-solving-based learning characteristics.

The practicality instrument consisted of a student response questionnaire designed to collect information regarding the ease of use of the e-module, clarity of instructions, visual appearance, level of interactivity, and the benefits of the e-module in supporting the learning process. The questionnaire was administered after students completed all learning activities using the developed e-module.

The effectiveness instrument was a mathematical critical thinking skills test administered before and after the implementation of the e-module. The test was constructed based on critical thinking indicators, including problem identification, information analysis, logical reasoning, selection of solution strategies, and evaluation of obtained solutions. The test consisted of essay questions requiring students to explain their reasoning processes and solution steps systematically.

ADDIE Development Procedure

The development of the e-module was carried out through the five stages of the ADDIE model.

Analysis Stage

The analysis stage aimed to identify learning needs, student characteristics, and challenges encountered in mathematics instruction. Data were collected through classroom observations, interviews with mathematics teachers, and reviews of students' learning outcomes. The analysis revealed that students' critical thinking skills required improvement and that the instructional materials currently used had not optimally facilitated problem-solving activities.

Design Stage

The design stage involved developing the e-module framework, determining learning outcomes, designing a problem-solving-based learning sequence, and creating the product interface. At this stage, the research instruments, e-module storyboard, learning activities, Higher-Order Thinking Skills (HOTS)-based exercises, and learning assessments integrated with critical thinking indicators were also developed.

Development Stage

The development stage involved transforming the design into a functional e-module product that could be utilized in mathematics learning. The developed product was subsequently validated by content, media, and language experts. Feedback and suggestions from the validators served as the basis for revising and refining the product before implementation.

Implementation Stage

The implementation stage involved testing the e-module with eighth-grade students who served as the research sample. Learning activities were conducted according to the problem-solving syntax embedded within the e-module. During this stage, practicality data were collected through student response questionnaires, while effectiveness data were gathered through the administration of pretests and posttests measuring students' critical thinking skills.

Evaluation Stage

Evaluation was conducted both formatively and summatively. Formative evaluation was carried out at each stage of development to identify and address weaknesses in the product throughout the development process. Summative evaluation was conducted after implementation to assess the overall validity, practicality, and effectiveness of the developed e-module.

Data Analysis Techniques

Validation data were analyzed using descriptive statistics in the form of percentages to determine the feasibility level of the product. The validity percentage was calculated based on the scores assigned by validators for each assessment indicator. The results were then categorized into very valid, valid, moderately valid, less valid, or invalid criteria.

Practicality data were analyzed using the average percentage scores obtained from the student response questionnaires. Higher percentages indicated greater ease of use and more positive student acceptance of the developed e-module.

Effectiveness data were analyzed using students' pretest and posttest scores on mathematical critical thinking skills. Improvements in critical thinking skills were calculated using the Normalized Gain (N-Gain) formula to determine the extent of learning improvement after the implementation of the e-module.

$$N\text{-Gain} = \frac{\text{Posttest} - \text{Pretest}}{\text{Maximum Score} - \text{Pretest}}$$

The resulting N-Gain values were categorized into high, moderate, or low improvement levels. In addition, descriptive analysis was conducted to compare the average critical thinking scores before and after the implementation of the e-module, enabling an assessment of the product's contribution to enhancing students' critical thinking abilities.

Through these analytical procedures, comprehensive information was obtained regarding the quality of the developed problem-solving-based mathematics e-module in terms of validity, practicality, and effectiveness as a digital instructional material designed to improve students' critical thinking skills.

Results and Discussion

Results

This study produced a problem-solving-based mathematics e-module developed using the ADDIE model, which consists of the Analysis, Design, Development, Implementation, and Evaluation stages. The resulting product was designed to facilitate the improvement of students' critical thinking skills through learning activities oriented toward systematic mathematical problem-solving. The research findings focus on three primary aspects: validity, practicality, and effectiveness of the developed product.

E-Module Validation Results

The validation process was conducted by a content expert, a media expert, and a language expert to ensure that the developed product met the quality standards of digital instructional materials. The validation results indicated that the e-module achieved an overall

validity score of 92.4%, which falls within the very valid category. These findings demonstrate that the content accuracy, media design, and language usage were highly appropriate and aligned with the intended learning objectives as well as the characteristics of the target learners.

Table 1. Validation Results of the Problem-Solving-Based Mathematics E-Module

Validation Aspect	Percentage (%)	Category
Content Validity	93.2	Very Valid
Media Validity	91.7	Very Valid
Language Validity	92.3	Very Valid
Overall Average	92.4	Very Valid

The content validation results indicate that the mathematical concepts presented in the e-module were accurate, relevant to the learning outcomes, and appropriately integrated with the stages of problem solving. The media validation results show that the visual design, navigation system, interactive features, and overall appearance of the e-module effectively supported the learning process. Meanwhile, the language validation results confirm that the instructions, explanations, and learning activities were written in a clear, understandable, and student-friendly manner.

Feedback from the validators suggested several minor revisions, including improving the consistency of mathematical notation, refining the layout of several learning activities, and simplifying certain instructional sentences to enhance readability. These recommendations were incorporated into the final version of the e-module before implementation.

Overall, the validation findings indicate that the developed problem-solving-based mathematics e-module possesses a high level of content accuracy, usability, and instructional quality, making it suitable for classroom implementation. The high validity score also suggests that the integration of mathematical problem-solving stages into digital learning activities was successfully achieved and aligned with the principles of effective mathematics instruction.

This study produced a problem-solving-based mathematics e-module developed through the ADDIE model, consisting of the Analysis, Design, Development, Implementation, and Evaluation stages. The resulting product was designed to facilitate the enhancement of students' critical thinking skills through learning activities oriented toward systematic mathematical problem-solving. The research findings focus on three main aspects: validity, practicality, and effectiveness of the developed product.

E-Module Validation Results

The validation process involved content experts, media experts, and language experts to ensure that the developed product met the quality standards of digital instructional materials. The validation results indicated that the e-module achieved a validity level of 92.4%, which falls into the very valid category.

Table 1. Validation Results of the E-Module

Assessment Aspect	Percentage (%)	Category
Product Validity	92.4	Very Valid

The high validity level indicates that the learning materials presented in the e-module were aligned with mathematics learning outcomes and the critical thinking indicators targeted in this study. Furthermore, the organization of content, learning activities, exercises, and assessments was systematically integrated with the stages of problem solving, enabling the module to support students' learning processes effectively.

E-Module Practicality Results

The practicality of the product was evaluated through students' responses after using the e-module during the learning process. The questionnaire analysis revealed that the e-module obtained a practicality score of 89.7%, categorized as very practical.

Table 2. Practicality Results of the E-Module

Assessment Aspect	Percentage (%)	Category
Product Practicality	89.7	Very Practical

These results indicate that students were able to use the e-module easily, understand the instructions provided, access learning materials independently, and complete the available learning activities without significant difficulties. The high practicality score suggests that the developed product achieved a strong level of user acceptance and usability.

E-Module Effectiveness Results

The effectiveness of the e-module was determined based on improvements in students' critical thinking skills before and after the implementation of the product. Measurements were conducted using pretests and posttests administered to 72 students participating in the study.

Table 3. Improvement of Students' Critical Thinking Skills

Variable	Pretest	Posttest	N-Gain	Category
Critical Thinking Skills	61.32	84.78	0.74	High

The findings indicate that the average score of students' critical thinking skills increased from 61.32 in the pretest to 84.78 in the posttest. The increase of 23.46 points demonstrates a substantial improvement following the implementation of the e-module. Moreover, the N-Gain score of 0.74 falls into the high category, indicating that the e-module contributed significantly to enhancing students' critical thinking skills.

The comparison between pretest and posttest scores clearly demonstrates that students' critical thinking abilities improved after engaging with the e-module. The increase in scores suggests that the learning activities embedded within the module successfully facilitated students' abilities to analyze, reason, evaluate, and reflect upon mathematical problem-solving processes.

Discussion

The findings demonstrate that the developed problem-solving-based mathematics e-module met the criteria of validity, practicality, and effectiveness. These results reinforce the view that the quality of digital instructional materials is determined not only by technological aspects but also by the alignment between instructional design, learner characteristics, and higher-order thinking skill development objectives. The high validity score obtained in this study indicates that the e-module was designed based on mathematics learning needs and complied with the principles of systematic instructional material development. The integration of problem-solving activities throughout the module enabled students to actively engage in the learning process rather than merely acting as passive recipients of information.

The findings are consistent with those reported by Rohmatulloh et al. (2023), who found that interactive e-modules based on Problem-Based Learning exhibited high validity and effectively improved students' mathematical critical thinking skills. The similarity of findings suggests that mathematics learning centered on meaningful problems provides richer learning experiences than traditional approaches focused primarily on direct instruction. When students are confronted with problems requiring independent analysis and solution development, they are encouraged to employ critical thinking skills to identify relevant information, formulate solution strategies, and evaluate outcomes.

The practicality level of 89.7% indicates that students were able to utilize the e-module effectively throughout the learning process. This finding suggests that the interface design, navigation system, and content presentation were well aligned with users' characteristics and needs. In technology-enhanced learning environments, practicality is a critical factor because user acceptance significantly influences the successful implementation of instructional products. Even high-quality content may fail to achieve its intended objectives if learners encounter difficulties in accessing or using the learning materials. Therefore, the high practicality score obtained in this study indicates that the developed e-module possesses strong potential for broader educational implementation.

These findings support the study conducted by Nurissamawati et al. (2024), which reported that Problem-Based Learning-based e-modules achieved very high practicality levels. Their study demonstrated that students tend to be more motivated when using digital instructional materials that enable independent learning and provide immediate feedback. Similar conditions were observed in the present study, where students expressed positive responses toward the e-module because the learning materials could be accessed flexibly and studied according to individual learning pace and preferences.

The most significant finding of this study concerns the effectiveness of the e-module in enhancing students' critical thinking skills. The increase in average scores from 61.32 to 84.78 indicates that the implementation of the e-module produced a meaningful impact on the development of students' mathematical critical thinking abilities. Furthermore, the N-Gain value of 0.74, classified as high, suggests that the observed improvement was not merely incremental but represented a substantial enhancement in students' learning outcomes.

These findings support the results of Musa'ad et al. (2025), who found that the use of PBL-based e-modules significantly improved students' critical thinking scores. Similarly, Bayu et al. (2026) reported that HOTS-based interactive e-modules positively influenced secondary school students' critical thinking abilities. The consistency of these findings highlights the considerable potential of digital instructional materials designed to stimulate higher-order thinking activities in improving the quality of mathematics education.

From a theoretical perspective, the improvement in critical thinking skills can be explained through the characteristics of the problem-solving approach integrated into the e-module. Within this approach, students are not merely required to identify correct answers but are guided to understand problems comprehensively, select appropriate solution strategies, test obtained solutions, and reflect on their reasoning processes. Such activities directly engage critical thinking components, including analysis, evaluation, inference, interpretation, and logical reasoning. Consequently, the learning process contributes not only to conceptual understanding but also to the development of transferable thinking skills applicable across various contexts and disciplines.

This study also strengthens the findings of Hasanah et al. (2024), Zulfa et al. (2023), and Hidayat et al. (2022), who reported that interactive digital instructional materials effectively enhance students' higher-order thinking skills. However, the present study differs from previous research by positioning problem-solving stages as the core framework of all learning activities. The integration of stages such as understanding problems, planning solutions, implementing strategies, and evaluating outcomes provided students with continuous opportunities to develop critical thinking skills systematically and progressively.

From a practical perspective, the findings offer important implications for mathematics teachers. The use of problem-solving-based e-modules can serve as an alternative instructional resource supporting the implementation of the Merdeka Curriculum, which emphasizes student-centered learning and competency development. Teachers can utilize the e-module to extend learning activities beyond classroom boundaries while simultaneously encouraging students to engage in independent learning. Furthermore, digital instructional materials contribute to creating more engaging and relevant learning experiences aligned with current educational technology developments.

Overall, the findings indicate that the developed problem-solving-based mathematics e-module represents a high-quality instructional innovation in terms of validity, practicality, and effectiveness. These results contribute to the growing body of knowledge on digital mathematics instructional materials while providing empirical evidence that integrating a problem-solving approach into e-modules constitutes an effective strategy for enhancing students' critical thinking skills. Consequently, the developed product is not only suitable for mathematics instruction but also has the potential to serve as a model for digital instructional material development across various subjects and educational levels.

Conclusion

This study successfully developed a problem-solving-based mathematics e-module that met the criteria of validity, practicality, and effectiveness for improving students' critical thinking skills. The development results demonstrated that the product achieved a validity

level of 92.4%, categorized as very valid, indicating that the content, media, and language components were aligned with learning objectives and learner characteristics. In addition, the practicality score of 89.7% indicated that the e-module was easy to use, visually appealing, and capable of supporting both independent and guided learning processes.

In terms of effectiveness, the implementation of the e-module significantly improved students' critical thinking skills. This was evidenced by the increase in the average score from 61.32 on the pretest to 84.78 on the posttest, with an N-Gain value of 0.74 categorized as high. These findings suggest that integrating problem-solving stages into digital learning activities effectively encourages students to engage in analysis, reasoning, evaluation, and reflection more systematically when solving mathematical problems.

Theoretically, this study strengthens the literature concerning the effectiveness of digital instructional materials that integrate problem-solving approaches to foster mathematical critical thinking skills. Practically, the developed e-module can serve as an alternative instructional resource that supports the implementation of the Merdeka Curriculum and promotes 21st-century student-centered learning. Future research is recommended to examine the implementation of the e-module across different mathematics topics, involve larger and more diverse samples, and explore the integration of more adaptive educational technologies to further enhance students' learning experiences.

References

- Anjarsari, D., Wardani, S., & Prasetya, A. T. (2023). Development of e-modules to improve critical thinking skills of Grade IV elementary school students. *International Journal of Research and Review*, 10(1). <https://doi.org/10.52403/ijrr.20230164>
- Bayu, B. R., Arvy, B. R., & Nasrullah, A. (2026). Enhancing high school students' critical thinking through HOTS-based interactive e-modules. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*. <https://doi.org/10.51574/kognitif.v6i1.4492>
- Cahyaningsih, U., & Nahdi, D. S. (2025). Development of an interactive e-module based on PBL to enhance elementary students' critical thinking. *Jurnal Ilmiah Pendidikan Dasar*, 12(2), 251–270. <https://doi.org/10.30659/pendas.12.2.251-270>
- Domina, L. W., Darma, Y., & Ardiawan, Y. (2024). Pengembangan e-modul berbasis model pembelajaran inquiry terhadap kemampuan berpikir kritis dalam materi pola bilangan. *Jurnal Karya Pendidikan Matematika*. <https://doi.org/10.26714/jkpm.11.1.2024.18-28>
- Hasanah, U., Siswono, T. Y. E., & Prastiti, T. D. (2024). E-modul barisan dan deret sebagai sarana peningkatan kemampuan berpikir kritis matematis. *Science Education Journal*. <https://doi.org/10.51878/science.v4i3.3128>
- Hendriko, N., Syafriandi, S., Armianti, A., et al. (2024). Praktikalitas e-modul berbasis problem based learning untuk meningkatkan kemampuan pemecahan masalah matematis siswa. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, 13(3). <https://doi.org/10.24127/ajpm.v13i3.8921>
- Hidayat, W., Rohaeti, E. E., Ginanjar, A., et al. (2022). An ePub learning module and students' mathematical reasoning ability: A development study. *Journal on Mathematics Education*, 13(1), 103–118. <https://doi.org/10.22342/jme.v13i1.pp103-118>
- Hulu, F. P. M., Mendrofa, R. N., Mendrofa, N. K., et al. (2025). Pengembangan modul pembelajaran berbasis problem based learning dalam Kurikulum Merdeka untuk meningkatkan kemampuan berpikir kritis siswa. *Venn: Jurnal Pendidikan dan Matematika*. <https://doi.org/10.53696/venn.v4i3.349>
- Juniati, H., & Jamaan, E. Z. (2024). Problem-based learning in improving critical mathematical thinking skills: Independent curriculum teaching module. *Al-Jabar: Jurnal Pendidikan Matematika*, 15(2). <https://doi.org/10.24042/ajpm.v15i2.23788>
- Kalista. (2025). Systematic literature review: Pengembangan e-modul interaktif untuk meningkatkan kemampuan pemecahan masalah matematis siswa. *Jurnal Pendidikan Matematika Undiksha*, 16(1). <https://doi.org/10.23887/jipm.v16i1.90873>
- Maziyah, K. N., & Hidayati, F. H. (2022). Pengembangan e-modul dengan pendekatan STEM untuk memfasilitasi kemampuan berpikir kritis siswa pada materi trigonometri. *Jurnal*

- Tadris Matematika*, 5(2), 241–256. <https://doi.org/10.21274/jtm.2022.5.2.241-256>
- Musa'ad, F., Hidayani, H., Rusnia, W. O., et al. (2025). Development of a PBL-based e-module to improve the critical thinking skills of deaf and speech-impaired students. *Axiom*. <https://doi.org/10.51574/kognitif.v6i1.4492>
- Munika, R. D., Marsitin, R., & Sesanti, N. R. (2021). E-LKPD berbasis problem based learning disertai kuis interaktif matematika untuk meningkatkan kemampuan berpikir kritis. *Jurnal Tadris Matematika*, 4(2), 201–214. <https://doi.org/10.21274/jtm.2021.4.2.201-214>
- Nadiman, Purnamasari, I., & Sumarno. (2023). Pengembangan e-modul menggunakan Flipbook Maker berbasis metode problem solving untuk meningkatkan keterampilan bernalar kritis siswa kelas V sekolah dasar. *Media Penelitian Pendidikan*, 17(2). <https://doi.org/10.26877/mpp.v17i2.16795>
- Nurissamawati, B., Yuniawatika, Y., & Mas'ula, S. (2024). E-module development using problem-based learning approach to learn data processing in training students' critical thinking. *Jurnal Inovasi Pembelajaran*, 10(1). <https://doi.org/10.22219/jinop.v10i1.28626>
- Pujiono, Sutiarso, S., & Dahlan, S. (2024). Pengembangan pembelajaran menggunakan e-modul problem based learning untuk meningkatkan kemampuan berpikir kritis peserta didik. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, 13(2). <https://doi.org/10.24127/ajpm.v13i2.8811>
- Putri, N. N. D., Jamaan, E. Z., Fauzan, A., et al. (2025). Pengembangan e-modul berbasis problem based learning untuk meningkatkan kemampuan literasi matematis. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, 14(4). <https://doi.org/10.24127/ajpm.v14i4.11986>
- Qoshirotutthorfi, T., Nasrudin, H., & Azizah, U. (2024). Development of problem-solving-oriented electronic module (e-module) to improve the critical thinking skills of Class XI senior high school students on acid-base material. *International Journal of Current Science Research and Review*, 7(6). <https://doi.org/10.47191/ijcsrr/v7-i6-79>
- Riyanti, V., Budhiarti, Y., & Istika, I. (2024). Developing of e-learning based mathematics learning modules to improve problem solving skills of students. *Journal of Mathematics Education*, 9(2). <https://doi.org/10.31327/jme.v9i2.2288>
- Rohmatulloh, Nindiasari, H., & Fatah, A. (2023). Pengembangan e-modul interaktif berbasis problem based learning (PBL) untuk meningkatkan kemampuan berpikir kritis matematis. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, 12(4). <https://doi.org/10.24127/ajpm.v12i4.8172>
- Zulfa, N., Zaenuri, & Wardono. (2023). Development of guided inquiry-based mathematical e-module in improving critical thinking ability and mathematical disposition ability. *International Journal of Research and Review*, 10(4). <https://doi.org/10.52403/ijrr.20230455>