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Developing Interactive E-Module to Enhancing Mathematical Problem-Solving Ability through Computational Thinking

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Abstract

This study aims to develop an interactive e-module oriented towards computational thinking to enhance the problem-solving skills of 10th-grade high school students in the topic of number sequences and series. The e-module was developed using the Plomp model, which consists of four stages: preliminary investigation, design, realization/construction, and test, evaluation, and revision. The e-module was developed using the Moodle platform with integration of H5P features and Scratch. The research was conducted at SMA Negeri 1 Singaraja, involving three 10th-grade science classes. Research instruments included validation sheets, student and teacher response questionnaires, and a problem-solving ability test. The results show that the developed e-module met the validity criteria with an average score of 3.7 based on expert assessment. The e-module also met the practicality criteria with an average student response score of 4.56 and teacher response score of 4.71. The effectiveness of the e-module was demonstrated through a significant improvement in students' problem-solving abilities (p-value = 2.8293e-6 < 0.05) with a large effect size (Cohen's d = |-1.23537|). In conclusion, the developed interactive e-module oriented towards computational thinking is valid, practical, and effective in improving students' mathematical problem-solving skills in the topic of number sequences and series.

Keywords: E-Module, Computational Thinking, Mathematical Problem-Solving, Number Sequences and Series

INTRODUCTION

The 21st century, problem-solving skills have become a critical skills for students to navigate an increasingly complex and technology-driven world. Mathematics, as a foundational subject, plays a pivotal role in developing these skills. However, students in Indonesia often face challenges in mastering mathematical problem-solving, as evidenced by the country's performance in international assessments. For instance, in the 2018 Programme for International Student Assessment (PISA), Indonesia ranked 72nd out of 78 participating countries, with a mathematics score of 379, well below the international average of 489 (OECD, 2019). This underscores the urgent need for innovative teaching approaches that can address these gaps and enhance students' mathematical abilities.

One promising approach to improving problem-solving skills is the integration of computational thinking (CT) into mathematics education. Computational thinking, a concept popularized by (Liu et al., 2024; Peters-Burton et al., 2022; J. M. Wing, 2006), involves problem-solving techniques such as decomposition, pattern recognition, abstraction, and algorithmic thinking. These skills are not only essential in computer science but also highly applicable in mathematics, where they can help students break down complex problems into manageable parts and develop systematic solutions (Lee et al., 2014; Shute et al., 2017). Research has shown that integrating CT into mathematics education can enhance students' logical reasoning, creativity, and ability to tackle non-routine (Calao et al., 2015; Costa et al., 2017). (Ye et al., 2023) further support this by emphasizing the reciprocal relationship between computational thinking and mathematical learning, where CT-based instruction fosters deeper engagement and understanding.

Despite its potential, the application of computational thinking in Indonesian mathematics classrooms remains limited. Traditional teaching methods often focus on rote memorization and procedural problem-solving, which do not prepare students for the demands of modern tasks (Latifah & Afriansyah, 2021) Additionally, the lack of engaging learning materials further worse the problem, as students struggle to connect mathematical concepts with real-world cases (Sintawati & Margunayasa, 2021). Studies such as (Erol & Çırak, 2022) demonstrate that integrating programming tools like Scratch can significantly improve students' problem-solving abilities, suggesting a promising avenue for enhancing mathematics education. Furthermore, Fang et al. (2023) found that incorporating Scratch-based CT activities into primary school mathematics improved students' understanding of fractions and CT competencies, reinforcing the value of interactive, coding-enhanced learning tools. To address these challenges, there is a growing need for innovative learning tools that can make mathematics more accessible and engaging for students.

This study focuses on the development of an interactive e-module designed to integrate computational thinking into the teaching of number sequences and series, a topic that is often perceived as challenging by students (Fauzi et al., 2022). The e-module is developed using the Moodle platform, incorporating interactive features such as H5P for multimedia content and Scratch for coding-based activities. These tools are chosen for their ability to create an engaging and interactive learning environment, allowing students to explore mathematical concepts through hands-on activities and simulations (Rahmi et al., 2024). (Triantafyllou et al., 2024) that gamification strategies, when paired with CT elements, significantly enhance student engagement, particularly in STEM disciplines. This aligns with the motivation behind incorporating interactive components into the e-module.

The development of the e-module follows the Plomp model, which includes four stages: preliminary investigation, design, realization/construction, and test, evaluation, and revision. This model ensures that the e-module is systematically developed and rigorously tested to meet the needs of both students and teachers. The study aims to create an e-module that is not only valid and practical but also effective in enhancing students' problem-solving skills in mathematics.

The significance of this study lies in its potential to contribute to the growing topics on the integration of computational thinking into mathematics education. By developing an interactive e-module that aligns with the principles of CT, this study seeks to provide a practical solution for improving students' problem-solving abilities while also fostering a deeper understanding of mathematical concepts. Previous research, such as (Supriyadi et al., 2024) has demonstrated the effectiveness of ethnomathematics-based digital modules in enhancing student engagement. This study builds on that foundation by extending the concept to computational thinking-oriented e-modules. Furthermore, the use of technology in the e-module reflects the shift towards digital learning tools, which have become increasingly important in the context of modern education.

In summary, this study addresses the critical need for innovative teaching tools that can enhance students' problem-solving skills in mathematics. By integrating computational thinking into an interactive e-module, the study aims to provide a practical and effective solution for teaching number sequences and series, ultimately contributing to the improvement of mathematics education in Indonesia.

METHODS

Research Flow

This study employs a research and development (R&D) approach, following the Plomp, which consists of four main stages: preliminary investigation, design, realization/construction, and test, evaluation, and revision. The preliminary investigation stage involved analyzing the curriculum, conducting student needs assessments, interviewing teachers, and reviewing relevant literature to identify challenges and needs in teaching number sequences and series. Previous research (Acevedo-Borrega et al., 2022) highlights the importance of teacher readiness and resource availability in computational thinking integration. To gather relevant data, document analysis was conducted on the national curriculum to align the e-module with learning objectives, while teacher and student interviews were carried out to identify difficulties in problem-solving and engagement. A literature review was also performed to explore best practices for integrating computational thinking into mathematics education (Ye et al., 2023). The design stage focused on defining learning objectives, developing content, integrating computational thinking skills, and selecting the Moodle platform as the hosting environment for the e-module. The module incorporated H5P-based interactive content, such as videos, quizzes, and simulations, to support conceptual understanding (Rahmi et al., 2024). The realization/construction stage involved creating interactive content, integrating feedback mechanisms, and conducting pilot testing to refine the e-module. To ensure a structured approach to mathematical problem-solving, Polya's four-step method was embedded within the module, as research has demonstrated its effectiveness in improving students' ability to approach mathematical problems systematically (Al Kayyis et al., 2024; Amrullah et al., 2024; Nico Pradana, 2024). The final stage, test, evaluation, and revision, included three phases of trials (limited trial, field trial I, and field trial II) to assess the validity, practicality, and effectiveness of the e-module. Validity was evaluated using the Learning Object Review Instrument (LORI), with experts assessing content accuracy, alignment with objectives, and usability. Practicality was measured through student and teacher feedback questionnaires, focusing on ease of use, engagement, and relevance (Supriyadi et al., 2024). Effectiveness was determined by comparing students' problem-solving skills before and after using the e-module, with statistical analysis (t-tests) used to identify significant improvements (Fitria et al., 2024).

Research Criteria

The evaluation categories included validity, practicality, effectiveness, and implementation, each with specific criteria and evaluation tools. The Table 1 below summarizes the evaluation categories and their respective criteria.

Table 1 Summary of Aspect Criteria

Aspect	Indicator	Criteria	Evaluation Tool
Validity	Content accuracy, alignment with objectives, usability	Valid (score ≥ 3.4)	LORI (Learning Object Review Instrument)
Practicality	Ease of use, engagement, relevance	Practical (score ≥ 3.4)	Student and teacher questionnaires
Effectiveness	Improvement in problem-solving skills	Significant (p-value < 0.05)	Problem-solving test

RESULTS

Validity

The e-module was validated by experts in mathematics education and instructional media using the Learning Object Review Instrument (LORI). The validation process assessed aspects such as content accuracy, alignment with learning objectives, and usability of interactive features. The average validity score was 3.7, which falls within the "Valid" category (score ≥ 3.4). Experts noted that the e-module effectively integrated computational thinking skills, such as decomposition, pattern recognition, and algorithmic thinking, into the learning activities. The content was well-structured, and the use of H5P and Scratch enhanced the interactivity and engagement of the module. These findings align with previous studies that emphasize the importance of integrating computational thinking into mathematics education to improve problem-solving (J. Wing, 2017).

Practicality

The practicality of the e-module was evaluated through feedback from students and teachers. The average student response score was 4.56, and the teacher response score was 4.71, both of which fall within the "Very Practical" category (score ≥ 4.2). Students reported that the interactive elements, such as video tutorials, quizzes, and coding activities, made the learning process more engaging and enjoyable. Teachers appreciated the ease of use and the ability to monitor student progress through the Moodle platform. The high practicality scores indicate that the e-module is user-friendly and suitable for classroom implementation. This finding is consistent with research by (Sintawati & Margunayasa, 2021), which highlights the effectiveness of interactive e-modules in enhancing student engagement and learning outcomes.

Effectiveness

The effectiveness of the e-module was measured by comparing students' problem-solving skills before and after using the module. The results showed a significant improvement in students' problem-solving abilities, with a p-value of 2.8293e-6 (< 0.05). The effect size, measured using Cohen's d, was $|-1.23537|$, indicating a large effect. This suggests that the e-module not only improved students' mathematical problem-solving skills but also fostered a deeper understanding of computational thinking concepts. The improvement was particularly evident in students' ability to break down complex problems, recognize patterns, and develop systematic solutions. These results are supported by studies such as (Calao et al., 2015), which demonstrate the positive impact of integrating computational thinking into mathematics education.

Implementation

The implementation of the e-module was observed during the trial phases, with an average implementation score of 4.96, categorized as "Very Well Implemented" (score ≥ 4.2). The e-module was successfully integrated into the classroom, with students actively participating in the interactive activities. Teachers reported that the module was easy to use and effectively supported the learning process. The high implementation score reflects the successful adoption of the e-module in a real classroom setting. The Table 2 below summarizes the key findings from the evaluation:

Table 2 Summary of Findings

Aspect	Indicator	Result	Criteria
Validity	Expert validation score (LORI)	3.7 (average)	Valid
Practicality	Student response score	4.56 (average)	Very Practical
	Teacher response score	4.71 (average)	Very Practical
Effectiveness	Improvement in problem-solving skills	p-value=2.8293e-6 (< 0.05)	Significant
	Effect size (Cohen's d)	|-1.23537|	Large Effect

DISCUSSION

The results of this study demonstrate that the interactive e-module is a valid, practical, and effective tool for enhancing students' problem-solving skills in mathematics. The integration of computational thinking into the e-module provided students with a structured approach to solving complex problems, which is consistent with findings from previous studies (Lee et al., 2014; J. Wing, 2017). The use of interactive features, such as H5P and Scratch, made the learning process more engaging and accessible, addressing the challenges identified in the preliminary investigation.

The high practicality scores indicate that the e-module is well-suited for classroom use, with both students and teachers expressing positive feedback. This aligns with research by (Sintawati & Margunayasa, 2021), which highlights the importance of interactive and user-friendly learning materials in improving student engagement and learning outcomes. The significant improvement in students' problem-solving skills further underscores the effectiveness of the e-module, as it not only enhanced mathematical abilities but also fostered critical thinking and creativity.

In conclusion, the developed e-module represents a valuable contribution to mathematics education, particularly in addressing the challenges of teaching number sequences and series. By integrating computational thinking and interactive features, the e-module provides a practical and effective solution for improving students' problem-solving skills. Future research could explore the long-term impact of the e-module on students' learning outcomes and its applicability to other mathematical topics.

CONCLUSION

This study successfully developed an interactive e-module integrating computational thinking to enhance students' problem-solving skills in number sequences and series. The e-module demonstrated validity through expert evaluations, confirming its alignment with curriculum objectives and usability. Its practicality was affirmed by positive feedback from both students and teachers, who highlighted its engaging design and user-friendly interface. Most significantly, the e-module proved effective in fostering problem-solving abilities, as evidenced by statistically significant improvements in students' performance, underpinned by computational thinking strategies such as decomposition, pattern recognition, and algorithmic reasoning. These outcomes affirm that the integration of computational thinking into mathematics education can bridge the gap between abstract concepts and practical application, equipping students with critical skills for complex problem-solving.

Suggestions

For educators, adopting this e-module as a supplementary teaching tool is recommended to create interactive and student-centered learning experiences. Its structured approach to breaking down problems can help demystify challenging topics like sequences and series. Schools and curriculum developers should consider embedding computational thinking principles into mathematics curricula to cultivate analytical and systematic reasoning across grade levels. Researchers are encouraged to explore the adaptability of this e-module framework to other mathematical domains, such as algebra or geometry, and to investigate its long-term impact on students' cognitive development. Lastly, policymakers should prioritize funding and training programs to support the integration of technology-driven pedagogical tools in classrooms, ensuring equitable access to innovative educational resources. Collectively, these steps can advance mathematics education, preparing learners to navigate both academic and real-world challenges with confidence.

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