Journal of Science and Mathematics Education
Vol. 2 No. 2, June 2026, pp. 37-43
E-ISSN 3090-0336

Analyzing Computational Thinking Skills in Mathematics Education: Evidence from Eleventh Grade Students at SMA Negeri 3 Mataram

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ARTICLE INFO

Article history
Received : March 20, 2025
Revised : April 25, 2026
Accepted : June 20, 2026
Published: March 23, 2026

Keywords
Computational Thinking
Mathematics Education
Secondary School Students
Problem Solving Skills

ABSTRACT

Computational thinking has emerged as a fundamental competency in 21st-century education, particularly within mathematics learning, where problem-solving, abstraction, and algorithmic reasoning are essential. However, empirical evidence regarding students' computational thinking skills in secondary education, especially in developing country contexts, remains limited. This study aims to analyze the level and characteristics of computational thinking skills among eleventh grade students at SMA Negeri 3 Mataram, Indonesia. A quantitative descriptive research design was employed, involving 120 students selected through stratified random sampling. Data were collected using a validated computational thinking test instrument encompassing four key dimensions: decomposition, pattern recognition, abstraction, and algorithmic thinking. The data were analyzed using descriptive statistics and inferential analysis to identify trends and variations in students' performance. The findings reveal that students' overall computational thinking skills are at a moderate level, with relatively higher achievement in pattern recognition and lower performance in abstraction and algorithmic thinking. Furthermore, differences in computational thinking skills were observed based on students' academic achievement levels. These results highlight the need for integrating computational thinking-oriented instructional strategies in mathematics classrooms to enhance students' higher-order thinking skills. The study contributes to the growing body of literature on computational thinking in mathematics education and provides practical implications for curriculum development and instructional design in similar educational contexts.

How to cite: Rahman, Pratama, A., R., Putri, D., L., & HIdayat, M., F. (2026). Analyzing Computational Thinking Skills in Mathematics Education: Evidence from Eleventh Grade Students at SMA Negeri 3 Mataram. *Journal of Science and Mathematics Education. 2*(2). 37-43. https://doi.org/10.70716/josme.v2i2.593

INTRODUCTION

Computational thinking has become a central competency in 21st-century education, particularly in mathematics learning, where analytical reasoning and structured problem-solving are essential. It is widely recognized as a fundamental skill that supports students in understanding complex problems through logical and systematic approaches. Recent studies highlight that computational thinking encompasses key dimensions such as decomposition, pattern recognition, abstraction, and algorithmic thinking, which are closely aligned with mathematical processes (Juliangkary et al., 2025).

The integration of computational thinking into mathematics education has gained significant global attention over the past decade. Educational systems across various countries have begun embedding computational thinking into curricula to enhance students' cognitive and problem-solving abilities. This trend reflects a growing awareness that computational thinking is as essential as traditional literacies such as reading and numeracy (Suarsana et al., 2024).

In recent years, research on computational thinking in mathematics education has shown a rapid increase, particularly in Scopus-indexed publications. Bibliometric studies indicate that the number of studies has grown significantly since 2016, with a peak in recent years, demonstrating the expanding interest in this field (Sumarno et al., 2025).

This increasing attention is driven by the need to equip students with skills relevant to a technology-driven world. Computational thinking enables learners to approach mathematical problems in a structured and efficient manner, making it highly relevant in the era of digital transformation. Moreover, it supports interdisciplinary learning, particularly within STEM and STEAM education frameworks (Chaabi et al., 2025).

Mathematics education provides an ideal context for developing computational thinking skills because of its inherent emphasis on logical reasoning and problem-solving. The processes involved in mathematical thinking naturally align with computational thinking practices, allowing for meaningful integration in classroom instruction (Fauzi et al., 2024).

Despite its importance, the implementation of computational thinking in mathematics classrooms remains inconsistent. Many studies report that while the concept is widely acknowledged, its practical integration into teaching and learning activities is still limited due to various challenges, including lack of teacher readiness and insufficient instructional resources (Zahid, 2025).

Furthermore, the integration of computational thinking often requires innovative pedagogical approaches. Strategies such as problem-based learning, project-based learning, and the use of digital tools have been identified as effective methods for fostering computational thinking in mathematics education (Nabila & Rosjanuardi, 2025).

Another critical issue is the variation in students' computational thinking abilities. Research indicates that students tend to perform better in basic computational thinking components such as pattern recognition, while higher-level skills like abstraction and algorithmic thinking remain underdeveloped (Juliangkary et al., 2025).

This disparity suggests the need for a deeper understanding of students' computational thinking profiles. By analyzing students' strengths and weaknesses in different components, educators can design more targeted instructional strategies to improve learning outcomes.

In addition, the development of computational thinking skills is closely related to students' overall academic performance. Studies have shown that students with higher academic achievement tend to demonstrate better computational thinking abilities, indicating a strong correlation between these variables (Fauzi et al., 2024).

The role of teachers is also crucial in facilitating computational thinking development. Teachers need to possess adequate knowledge and skills to integrate computational thinking into mathematics instruction effectively. However, many teachers still face challenges in understanding and applying computational thinking concepts in classroom practice (Zahid, 2025).

Moreover, technological advancements have provided new opportunities for integrating computational thinking into mathematics education. Tools such as programming environments, simulations, and digital platforms can enhance students' engagement and support the development of computational thinking skills (Santaengracia et al., 2026).

Despite these opportunities, there are still significant gaps in the literature, particularly in the context of developing countries. Most existing studies focus on developed countries, leaving a lack of empirical evidence on computational thinking in regions such as Southeast Asia, including Indonesia.

Indonesia, as a developing country, faces unique challenges in integrating computational thinking into mathematics education. These challenges include limited infrastructure, varying levels of teacher competence, and differences in students' learning contexts (Irawan et al., 2024).

In addition, the rapid development of digital technology requires educational systems to adapt quickly. Integrating computational thinking into mathematics learning is essential to prepare students for future challenges and to enhance their competitiveness in the global workforce.

However, empirical studies that specifically analyze students' computational thinking skills at the secondary school level in Indonesia remain limited. This gap highlights the need for further research to provide a clearer understanding of students' computational thinking abilities in this context.

Understanding students' computational thinking skills is important for informing curriculum development and instructional design. By identifying students' strengths and weaknesses, educators can develop more effective teaching strategies that support the development of higher-order thinking skills.

Furthermore, analyzing computational thinking skills can contribute to improving the quality of mathematics education. It provides insights into how students process information, solve problems, and apply mathematical concepts in real-world contexts.

Therefore, this study aims to analyze the computational thinking skills of eleventh grade students at SMA Negeri 3 Mataram, Indonesia. The study focuses on four key components of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic thinking.

By conducting this analysis, the study is expected to contribute to the existing body of knowledge on computational thinking in mathematics education. It also aims to provide practical implications for teachers, curriculum developers, and policymakers in improving the integration of computational thinking into mathematics learning.

METHOD

This study employed a quantitative descriptive research design aimed at analyzing the computational thinking (CT) skills of eleventh grade students in mathematics learning. The descriptive approach was chosen to provide a comprehensive overview of students' abilities across key computational thinking dimensions without manipulating variables. This design is appropriate for identifying patterns, trends, and distributions of skills within a specific population, particularly in educational settings where the focus is on measuring existing competencies. The study emphasizes objective measurement and statistical analysis to ensure the reliability and validity of the findings.

The research was conducted at SMA Negeri 3 Mataram, Indonesia, involving eleventh grade students as the target population. A total of 120 students participated in the study, selected using a stratified random sampling technique to ensure representation across different academic achievement levels. Students were grouped into high, medium, and low achievement categories based on their mathematics scores from the previous semester. This sampling method was employed to capture variability in computational thinking skills and to allow for comparative analysis among different student groups.

Data were collected using a computational thinking test instrument specifically developed and adapted for mathematics learning contexts. The instrument consisted of essay and problem-solving items designed to measure four core dimensions of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic thinking. Each dimension was represented by multiple indicators to ensure comprehensive assessment. Prior to data collection, the instrument underwent content validation by experts in mathematics education and educational assessment, as well as a pilot test to evaluate its clarity, reliability, and level of difficulty.

The validity of the instrument was assessed using expert judgment and construct validation, while reliability was tested using Cronbach's Alpha coefficient to ensure internal consistency. The results of the reliability test indicated that the instrument was highly reliable, with a coefficient exceeding the acceptable threshold of 0.70. Additionally, item analysis was conducted to examine item difficulty and discrimination indices, ensuring that all test items were suitable for measuring students' computational thinking skills accurately.

Data analysis was carried out using both descriptive and inferential statistical techniques. Descriptive statistics, including mean, standard deviation, and percentage distributions, were used to categorize students' computational thinking skills into levels (high, moderate, and low). Inferential analysis, such as one-way ANOVA, was employed to examine differences in computational thinking skills based on students' academic achievement levels. This combination of analyses allowed for a more comprehensive interpretation of the data and supported the identification of significant patterns and relationships.

To ensure the rigor of the study, several ethical considerations were taken into account. Permission was obtained from the school administration prior to data collection, and students participated voluntarily with informed consent. Confidentiality and anonymity of participants were strictly maintained throughout the research process. Furthermore, the study adhered to academic integrity standards by ensuring that all data were collected and analyzed transparently. Through these methodological procedures, the study aims to provide valid and reliable insights into students' computational thinking skills in mathematics education.

RESULTS AND DISCUSSION

Results

This study aimed to analyze the computational thinking (CT) skills of eleventh grade students at SMA Negeri 3 Mataram across four core dimensions: decomposition, pattern recognition, abstraction, and algorithmic thinking. Data were collected from 120 students using a validated computational thinking test instrument. The results are presented descriptively and further interpreted to identify patterns and implications for mathematics education.

The descriptive analysis indicates that students' overall computational thinking skills fall into the moderate category. The mean score obtained was 68.4 (on a scale of 0–100), suggesting that while students demonstrate basic competency, their higher-order computational skills remain underdeveloped. This finding aligns with previous studies indicating that secondary school students often exhibit moderate levels of computational thinking, particularly in developing country contexts (Grover & Pea, 2020; Shute et al., 2021).

To provide a clearer picture of students' computational thinking abilities, the results were analyzed across the four CT dimensions. The findings are summarized in Table 1.

Table 1. Students' Computational Thinking Skills by Dimension

CT Dimension	Mean Score	Category
Decomposition	70.2	Moderate
Pattern Recognition	74.5	High
Abstraction	63.1	Moderate-Low
Algorithmic Thinking	65.8	Moderate
Overall	**68.4**	**Moderate**

As shown in Table 1, pattern recognition achieved the highest mean score (74.5), indicating that students are relatively proficient in identifying similarities and regularities in mathematical problems. This is consistent with research suggesting that pattern recognition is often the most accessible computational thinking component for students due to its close relationship with prior mathematical knowledge (Weintrop et al., 2021).

In contrast, abstraction recorded the lowest mean score (63.1), indicating that students struggle to generalize problems and extract essential information. This finding reflects a common challenge in mathematics education, where students find it difficult to move from concrete representations to abstract reasoning (Wing, 2020; Bocconi et al., 2022).

Further analysis was conducted to examine differences in computational thinking skills based on students' academic achievement levels. Students were categorized into high, medium, and low achievement groups based on their mathematics scores.

The results show that students in the high-achievement group consistently outperformed those in the medium and low groups across all CT dimensions. The difference was particularly significant in abstraction and algorithmic thinking, suggesting that higher academic achievement is associated with stronger higher-order computational skills.

This finding supports previous research indicating a strong correlation between academic performance and computational thinking ability (Román-González et al., 2021; Korkmaz et al., 2022). Students with higher academic achievement tend to have better problem-solving strategies and cognitive flexibility, which are essential for computational thinking.

Discussion

The findings of this study provide important insights into the state of computational thinking skills among secondary school students in Indonesia, particularly in the context of mathematics education. Overall, the moderate level of computational thinking observed in this study indicates that while students possess basic competencies, there is significant room for improvement, especially in higher-order thinking dimensions.

The overall moderate level of CT skills suggests that current mathematics instruction has not fully integrated computational thinking principles. This is consistent with global findings that highlight the challenges of embedding computational thinking into traditional curricula (Voogt et al., 2021; Hsu et al., 2022). In many cases, mathematics teaching still emphasizes procedural knowledge rather than conceptual understanding and problem-solving.

The moderate performance may also be influenced by limited exposure to computational thinking-oriented learning activities. As noted by Bers et al. (2022), students require consistent and structured opportunities to develop computational thinking through practice and application.

The relatively high performance in pattern recognition indicates that students are capable of identifying relationships and regularities in mathematical problems. This skill is often developed through repeated exposure to mathematical exercises, which typically involve recognizing patterns and applying known formulas.

However, while pattern recognition is important, it represents only one aspect of computational thinking. Without the ability to abstract and generalize, students may struggle to apply their knowledge to new or unfamiliar problems (Weintrop et al., 2021).

The lower performance in abstraction and algorithmic thinking highlights a critical gap in students' computational thinking development. Abstraction requires students to simplify complex problems by focusing on essential elements, while algorithmic thinking involves designing step-by-step solutions.

These skills are closely associated with higher-order thinking and are essential for advanced problem-solving. The findings of this study are consistent with previous research indicating that abstraction is one of the most challenging aspects of computational thinking for students (Bocconi et al., 2022; Shute et al., 2021).

One possible explanation for this difficulty is the lack of instructional strategies that explicitly target these skills. Traditional mathematics instruction often focuses on obtaining correct answers rather than understanding the underlying processes, which may limit students' ability to develop abstraction and algorithmic thinking (Wing, 2020).

The significant differences in computational thinking skills based on academic achievement highlight the role of prior knowledge and cognitive ability in CT development. High-achieving students demonstrated stronger performance across all dimensions, particularly in higher-order skills.

This finding is consistent with the work of Román-González et al. (2021), who found that computational thinking is strongly correlated with general cognitive abilities and academic performance. Similarly, Korkmaz et al. (2022) reported that students with higher academic achievement tend to exhibit better computational thinking skills due to their ability to process information more effectively.

However, this also raises concerns about equity in education. If computational thinking development is heavily dependent on academic achievement, lower-achieving students may be at a disadvantage. Therefore, targeted interventions are needed to support these students and ensure that all learners have the opportunity to develop computational thinking skills.

The findings of this study have several important implications for mathematics education. First, there is a need to integrate computational thinking explicitly into the mathematics curriculum. This can be achieved through the use of instructional approaches such as problem-based learning, project-based learning, and inquiry-based learning, which encourage students to engage in higher-order thinking processes (Hsu et al., 2022; Voogt et al., 2021).

Second, teachers play a crucial role in facilitating computational thinking development. Professional development programs should be designed to enhance teachers' understanding of computational thinking and equip them with effective teaching strategies (Bers et al., 2022).

Third, the use of technology can support the development of computational thinking skills. Digital tools such as simulations, programming environments, and interactive platforms can provide students with opportunities to practice computational thinking in engaging and meaningful ways (Grover & Pea, 2020).

In the Indonesian context, the integration of computational thinking into mathematics education faces several challenges, including limited resources and varying levels of teacher readiness. However, the growing emphasis on digital literacy and 21st-century skills provides an opportunity to address these challenges.

This study contributes to the limited body of research on computational thinking in Indonesia and highlights the need for further empirical studies in this area. By understanding students' computational thinking skills, educators and policymakers can develop more effective strategies to improve the quality of mathematics education.

This study adds to the growing body of literature on computational thinking in mathematics education by providing empirical evidence from a developing country context. It highlights the importance of analyzing computational thinking skills across different dimensions and emphasizes the need for targeted instructional strategies.

Furthermore, the study demonstrates the relationship between computational thinking and academic achievement, providing insights into how these skills can be developed more effectively.

CONCLUSION

This study concludes that the computational thinking skills of eleventh grade students at SMA Negeri 3 Mataram are generally at a moderate level, indicating that students have developed basic competencies but have not yet achieved optimal mastery of higher-order thinking skills. Among the four dimensions analyzed, students demonstrated the strongest performance in pattern recognition, suggesting their ability to identify regularities and relationships in mathematical problems. However, weaker performance was observed in abstraction and algorithmic thinking, highlighting significant challenges in generalizing concepts and constructing systematic problem-solving procedures. These findings confirm that while students are capable of handling routine tasks, they still struggle with more complex cognitive processes required in advanced mathematics learning.

Furthermore, the study reveals that students' computational thinking skills vary based on their academic achievement levels, with high-achieving students consistently outperforming their peers across all dimensions. This indicates a strong relationship between computational thinking and overall academic performance, particularly in higher-order cognitive domains. Such disparities suggest the need for more inclusive instructional approaches that can support students with lower academic achievement in developing essential computational thinking skills. Without targeted intervention, gaps in students' cognitive abilities may continue to widen.

In light of these findings, this study emphasizes the importance of integrating computational thinking explicitly into mathematics education through innovative pedagogical strategies and technology-enhanced learning environments. Teachers play a crucial role in facilitating this integration, and therefore require adequate training and resources to effectively foster students' computational thinking. Future research is recommended to explore intervention-based approaches and longitudinal impacts of computational thinking integration to further enhance the quality of mathematics education.

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