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Integration of Computational Thinking Abilities in Ring Theory Learning: Analysis of Students' Answer Process

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ABSTRACT

Purpose – This study aims to analyze students' computational thinking skills in solving problems in ring theory material and to describe their thinking processes using computational thinking indicators.

Methodology – This study engages Mathematics Education students undertaking the Ring Theory course in the even semester of the 2024/2025 academic year at a private university in Medan. This study used a dominant qualitative mixed-methods approach. The research instrument was a computational thinking ability test compiled based on four indicators: decomposition, pattern recognition, abstraction, and algorithmic thinking, as well as an interview guide to explore students' answer processes.

Findings – The results showed that students' computational thinking skills were generally in the sufficient category (47%), with 28% in the poor category and 25% in the good category. Students were relatively capable of decomposing problems and recognizing patterns, but still experienced difficulties with abstraction and developing algorithmic solution steps. These findings indicate that integrating computational thinking into ring theory learning can help develop students' analytical and systematic thinking skills.

Contribution – Implicitly, this study provides evidence of students' computational thinking profiles in ring theory learning and highlights the importance of integrating computational thinking to enhance analytical and systematic thinking skills in higher mathematics education.

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INTRODUCTION

The development of science and technology in the 21st century demands that individuals possess high-level thinking skills capable of addressing complex problems systematically and logically. One such skill that has received significant attention in education is Computational Thinking (CT). Computational thinking is a thought process used to formulate problems and systematically design solutions to resolve them effectively and efficiently. This ability encompasses several key components, namely problem decomposition, pattern recognition, abstraction, and algorithm design, to solve a problem in a structured manner. (Adiyastuti & Surakarta, 2024; Wu et al., 2024).

Modern educational paradigms no longer confine Computational Thinking exclusively to the domain of computer science. However, it has become a cross-disciplinary approach applicable across various fields of science, including mathematics. (Altın, 2025; Dohn, 2025). Integrating Computational Thinking into mathematics curricula actively enhances students' problem-solving abilities, mathematical reasoning, and systematic thinking. (Ahmad Lutfi Fauzi, Y.S. Kusumah, Elah Nurlaelah, 2024; Fitrah et al., 2025; Ye et al., 2023).

Although Computational Thinking has great potential for supporting the mathematics learning process, in practice, various problems persist in students' thinking skills, especially in abstract courses such as Ring Theory in abstract algebra. This course requires students to understand formal definitions, connect various mathematical concepts, and construct proofs logically and systematically. However, many students struggle to understand these concepts due to limitations in abstract reasoning and in organizing the logical structure of the mathematical proof process. (Munawwaroh et al., 2025; Mutia, 2025; Panerio & Delideli, 2025). In addition, other research shows that students often have difficulty understanding the structure of abstract algebraic concepts and connecting formal definitions to their applications in mathematical proofs. (Alam & Mohanty, 2024; Banik, 2025; Feudel & Unger, 2025). This condition shows that students' systematic thinking skills in understanding mathematical concepts have not yet developed optimally.

Students' difficulties in understanding abstract algebraic concepts can impact their ability to solve complex mathematical problems. Students often focus solely on the final answer without demonstrating a systematic thought process in solving a problem. As a result, the answers they provide tend to be procedural and lack clear reasoning steps. Research shows that limited analytical and systematic thinking skills can impact students' ability to solve mathematical problems that require strong deductive reasoning. (Putu et al., 2025; Suryawan et al., 2023; Wang, 2025). In addition, the inability to decompose problems and recognize mathematical patterns can hinder effective problem-solving. (Lehmann, 2025; Maulana et al., 2025; Wu et al., 2024).

Developing computational thinking skills in mathematics learning is crucial because they help students systematically organize their thinking when faced with complex mathematical problems. By applying components of computational thinking, such as decomposition, pattern recognition, abstraction, and algorithms, students can better understand the structure of a problem and design logical, focused solution strategies (Jaya, 2025; Susanti, 2023). Several studies show that integrating Computational Thinking into mathematics learning can improve problem-solving skills, mathematical reasoning, and a deeper understanding of concepts. (Lya et al., 2025; M. Mitrayana, 2023; Mendrofa, 2024). Therefore, integrating Computational Thinking into mathematics learning, especially in abstract algebra courses, is an important step toward improving students' thinking processes.

Preliminary empirical evidence from sixth-semester Mathematics Education students at a private university in Medan strongly underscores this problem. Based on an analysis of students' answers to several Ring Theory problems, most students were unable to demonstrate a systematic thought process in solving them. Students tended to write answers immediately without first breaking the problem into simpler parts. Furthermore, students also experienced difficulty recognizing patterns in the given algebraic structure and abstracting mathematical concepts related to ring properties. This finding aligns with previous research, which stated that students often experience difficulty in understanding abstract algebraic concepts due to limitations in organizing the mathematical proof process and a lack of abstract thinking skills (Gnawali, 2024; Kania et al., 2025).

Various previous studies have examined the application of computational thinking in mathematics learning. However, most of these studies still focus on elementary and secondary education levels and on procedural mathematics materials. Research examining the integration of computational thinking into advanced mathematics learning in higher education, particularly in abstract algebra courses such as Ring Theory, remains relatively limited. Furthermore, most previous studies have focused on measuring computational thinking abilities through quantitative test results, while studies that in-depth analyze students' thinking processes by analyzing answers to solving abstract mathematical problems are still rare (Nyoman et al., 2024; Richardo et al., 2025; Titiffaffani et al., 2025).

Based on these research gaps, this study offers novelty by examining the integration of Computational Thinking into Ring Theory learning and analyzing students' answer processes using Computational Thinking indicators, including decomposition, pattern recognition, abstraction, and algorithmic thinking. This study not only measures students' Computational Thinking abilities through test results but also analyzes in depth how students' thinking processes solve abstract mathematical problems. Consequently, this study offers a more comprehensive paradigm of students' Computational Thinking capacities within advanced mathematics education.

Previous studies on Computational Thinking mostly focus on elementary and secondary mathematics learning, while those investigating its integration in higher mathematics, particularly abstract algebra and Ring Theory, remain limited. In addition, prior studies tend to emphasize quantitative measurement of Computational Thinking skills rather than exploring students' reasoning processes and strategies in solving abstract mathematical proof problems.

The novelty of this study lies in integrating Computational Thinking into Ring Theory learning through an in-depth analysis of students' answer processes, using indicators of decomposition, pattern recognition, abstraction, and algorithmic thinking. This study also combines quantitative categorization with qualitative exploration of students' mathematical proof-reasoning processes.

METHODOLOGY

Research Design

This study deploys a quantitative approach to categorize students' Computational Thinking proficiency levels, while simultaneously utilizing a qualitative approach to explore their underlying reasoning and problem-solving pathways in Ring Theory.

Participants

The participants in this study were 12 sixth-semester students of the Mathematics Education Study Program at a private university in Medan enrolled in the Ring Theory course during the 2024/2025 academic year. The participants were selected purposively based on their Computational Thinking ability categories from the initial test results: high, medium, and low. The participants had previously studied introductory abstract algebra courses, making them suitable subjects for analyzing computational thinking processes in the construction of advanced mathematical proofs.

Data Collection

This study paired written assessments with semi-structured interviews to gather data, employing the written test across all participants to effectively map their specific Computational Thinking ability levels. Subsequently, selected students from each category participated in think-aloud-based interviews. During the interviews, students were asked to explain their reasoning processes while solving Ring Theory problems. The interviews were audio-recorded and transcribed for analysis.

Instruments

The research instruments consisted of (1) computational thinking-based ring theory test consisting of four essay items and (2) semi-structured interview guide. This assessment operationalizes four critical dimensions of Computational Thinking: decomposition, pattern recognition, abstraction, and algorithmic thinking. Validation metrics confirmed the rigor of all test items, yielding a mean validity score of 3.71 out of 4.00, which establishes a highly valid classification. In detail, item 1 obtained a validity score of 3.75, item 2 obtained 3.67, item 3 obtained 3.70, and item 4 obtained 3.72. The validators stated that the test items were appropriate for the Computational Thinking indicators and capable of measuring students' abilities to construct proofs in Ring Theory material.

Two mathematics education experts and an abstract algebra specialist validated the instruments to ensure methodological and content rigor. The validation results indicated that the instruments were valid in terms of both content and construct validity. Furthermore, the reliability test using Cronbach's Alpha yielded a coefficient of 0.82, indicating high reliability. Therefore, the instruments were considered appropriate for use in measuring students' Computational Thinking abilities in solving Ring Theory problems.

Data Analysis

Quantitative data were analyzed descriptively using percentage analysis to categorize students' Computational Thinking abilities into poor, sufficient, and good categories. The qualitative phase driving this research operationalizes data reduction, thematic coding, framework-based categorization of Computational Thinking, data presentation, and final synthesis to extract meaningful conclusions. Quantitative and qualitative data were integrated through triangulation, comparing students' test results with interview findings to obtain comprehensive interpretations of students' thinking processes.

FINDINGS

Based on the questions given during the ring theory course, the results of the analysis of the integration of computational thinking abilities can be stated in the following table.

Table 1. Results of Computational Thinking Ability Integration

Ability Category	Mark
Not enough	28%
Enough	47%
Good	25%

Based on the analysis of the integration of Computational Thinking skills in Ring Theory learning in Table 1, 28% of students were in the poor category, 47% in the sufficient category, and 25% in the good category. These results indicate that the majority of students have sufficient Computational Thinking skills. However, there are still students in the lower category, indicating that Computational Thinking skills for solving Ring Theory problems still need to be improved through more structured learning and more intensive problem-solving exercises. For this reason, the above data are described in four indicators of computational thinking skills as follows:

Table 2. Results of Analysis of Computational Thinking Ability Indicators

Observation Indicator	Category		
	Poor	Sufficient	Good
Decomposition	25%	45%	30%
Pattern Recognition	20%	50%	30%
Abstraction	35%	40%	25%
Algorithm	20%	55%	25%

Based on the analysis of students' Computational Thinking abilities in the Ring Theory course in Table 2, the decomposition indicator showed that 25% of students were in the poor category, 45% in the sufficient category, and 30% in the good category. In the pattern recognition indicator, 20% of students were in the poor category, 50% in the sufficient category, and 30% in the good category. Furthermore, in the abstraction indicator, 35% of students were in the poor category, 40% in the sufficient category, and 25% in the good category. Meanwhile, in the algorithm indicator, 20% of students were in the poor category, 55% in the sufficient category, and 25% in the good category. The students' answer patterns for the computational thinking ability questions are based on the indicators. The following is the answer pattern for the computational thinking ability decomposition indicator:

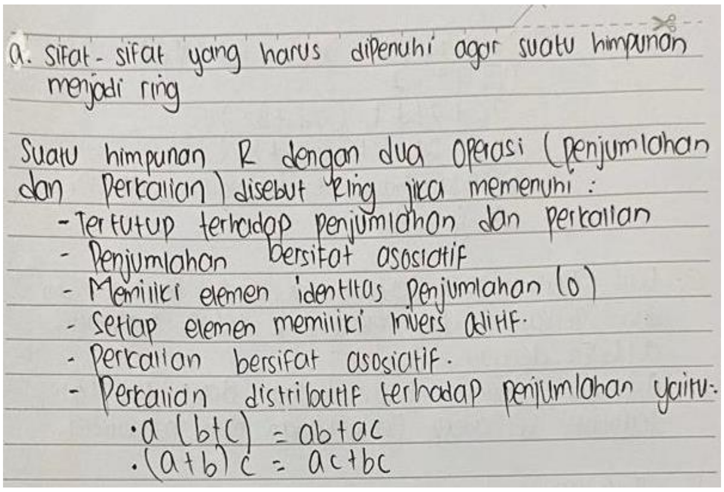

Figure 1. Decomposition Indicator Answer Pattern

Students' empirical responses demonstrate that they successfully decompose the complex ring structure problem into distinct, manageable components for systematic evaluation. Students list the properties that a set must satisfy to be a ring, such as closure under the operations, additive identities, additive inverses, and associative and distributive properties. This indicates that students have carried out the decomposition process by dividing the problem into several smaller parts. However, students have not fully linked each component to the proof process on the given set. Therefore, students' decomposition ability is in the sufficient category. This is in line with the results of the researcher's interviews with several students, as follows:

Researcher: *When you first read the question, what did you understand about the problem that had to be solved?*

Student: *I understand that I am being asked to determine whether a set is a ring. So I have to see if the set satisfies the properties of a ring.*

Next, the answer pattern for the computational thinking ability pattern recognition indicator

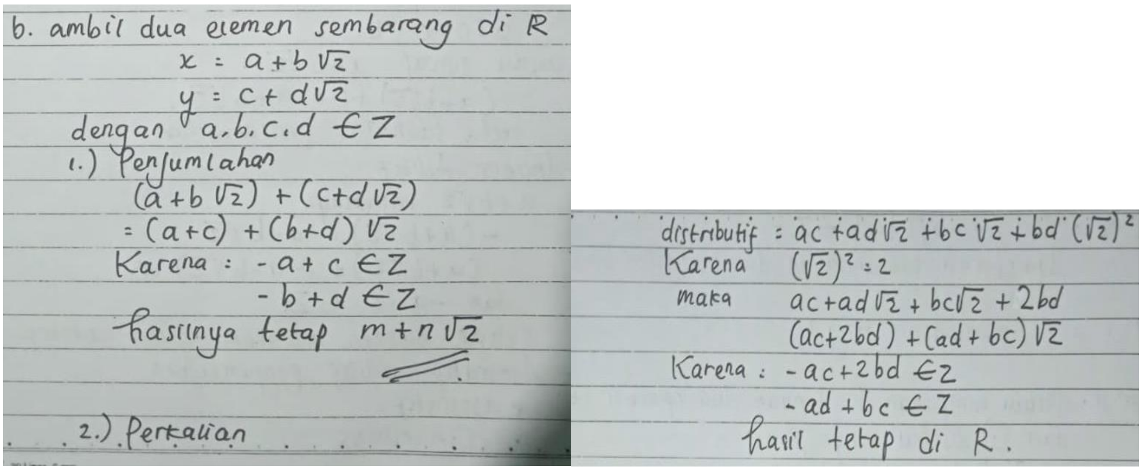

Figure 2. Pattern Recognition Indicator Answer Pattern

Based on the analysis of students' answers, it can be seen that students are able to recognize the pattern of element shapes in the set R, namely a+b√2. Students then perform addition and multiplication operations on two arbitrary elements of the set and obtain results that still have the same form, namely (a+c)+(b+d)√2 on addition and (ac+2bd)+(ad+bc)√2 on multiplication. The student then concludes that the results of the operation still follow the general pattern m+n√2. This indicates that students are able to identify similar patterns from several operational results, thus categorizing their pattern recognition skills as good. This aligns with the following findings from interviews with several students:

Researcher: *When you take two elements x=a+b√2 and y=c+d√2, why did you choose that shape?*

Student : *I understand that the general form of the elements in the set R. So if I want to check its properties, I have to take two random elements with that form.*

Next, the answer pattern for the Abstraction indicator for computational thinking ability.

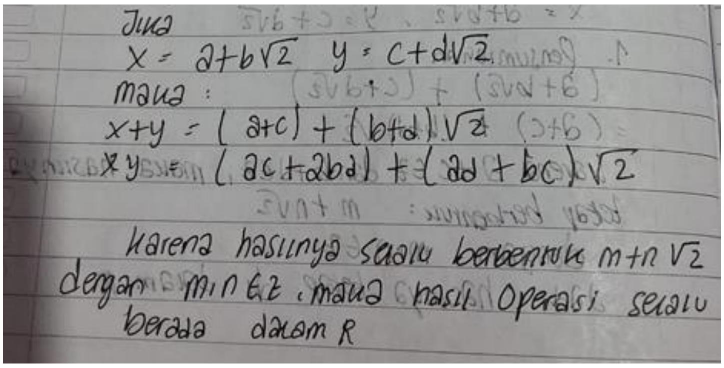

Figure 3. Answer Pattern for the Abstraction Indicator of Computational Thinking Ability

Based on the analysis of student answers, it can be seen that students use the general form of elements in the set R, namely x=a+b√2 and y=c+d√2 with a,b,c,d∈Z. Students then perform addition and multiplication operations and simplify the results into general form. m+n√2. The student then concludes that because m,n∈ Z, then the results of the operation remain in the set R. This process shows that students are able to simplify problems and draw general conclusions so that students' abstraction abilities are included in the good category. This is in line with the results of the researcher's interviews with several students as follows:

Researcher: *When you take two elements x=a+b√2 and y=c+d√2, why did you choose that shape?*

Student: *I understand that the general form of the elements in the set R. So if I want to check its properties, I have to take two random elements with that form.*

Then, the answer pattern for the computational thinking ability algorithm indicator:

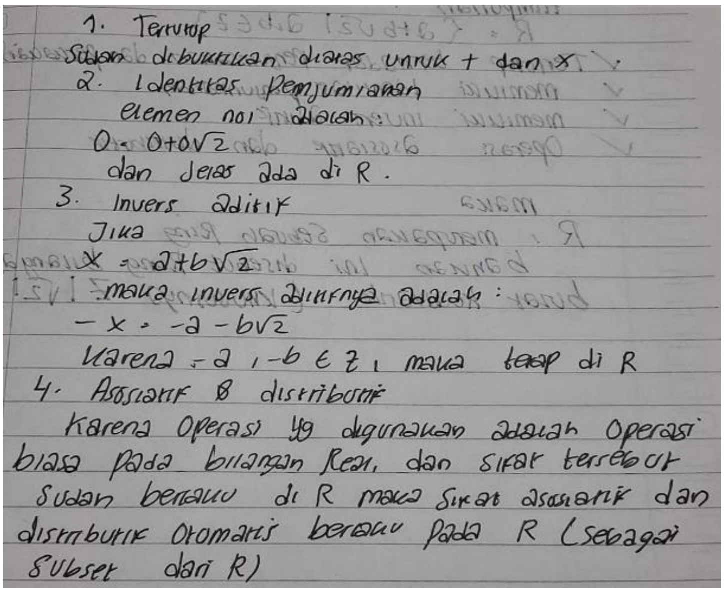

Figure 4. Answer Pattern for Computational Thinking Ability Algorithm Indicator

Based on the students' answers, they systematically outlined the solution steps for proving that the given set satisfies the properties of a ring. The students started by showing the closed nature, then determined the additive identity element, followed by determining the additive inverse of the element $x=a+b\sqrt{2}$, and explaining that the operations used satisfy the associative and distributive properties. The clear sequence of steps and the use of appropriate concepts demonstrate that students can construct logical, structured solution procedures. Therefore, students' algorithmic abilities are considered good. This aligns with the results of the researcher's interviews with several students, as follows:

Researcher: *After you find the form of the addition and multiplication results, what is the next step you take to solve the problem?*

Student: *I continued by examining other properties that must be met for a set to be called a ring.*

The findings of this study indicate that integrating computational thinking into abstract algebra instruction can be an effective approach to help students develop systematic, analytical, and structured thinking skills in understanding advanced mathematical concepts.

DISCUSSION

The findings of this study indicate that students' Computational Thinking (CT) abilities in solving Ring Theory problems were generally sufficient. Students demonstrated better performance on decomposition and pattern recognition indicators, while abstraction and algorithmic thinking remained challenging for some. These findings suggest that students were able to identify and break down mathematical structures into smaller components; however, they still experienced difficulties in constructing generalized abstractions and systematically organizing formal proof procedures in abstract algebra problems.

The results of this study support previous research stating that Computational Thinking can improve students' analytical and systematic problem-solving abilities in mathematics learning. Computational Thinking integration encourages students to organize information, recognize patterns, simplify complex structures, and develop logical solution procedures. This finding aligns with the studies by Rossalina et al. (2025) and Aminah (2024), which reported that Computational Thinking contributes positively to mathematical reasoning and structured problem-solving processes. In this study, students who decomposed Ring Theory problems into several ring properties tended to demonstrate more organized reasoning when proving mathematical structures.

Furthermore, the findings also reveal that abstraction remains one of the most difficult indicators for students. Many students were still unable to generalize algebraic structures consistently and connect symbolic representations with formal mathematical proofs. This finding is consistent with the studies by Ozmantar & Bozkurt (2025) and Maudy (2025), which show that abstract algebra learning can be challenging because students must shift from procedural reasoning to formal, generalized mathematical thinking. The difficulty with abstraction observed in this study indicates that students still require scaffolding in constructing generalized mathematical representations and in interpreting formal symbolic structures in Ring Theory.

The interview findings also strengthen the quantitative results. Students with strong Computational Thinking skills were able to explain why they selected arbitrary elements and how they systematically verified ring properties. In contrast, students in the low category tended to focus only on obtaining final answers without explaining the logical reasoning behind each proof step. This demonstrates that Computational Thinking is not merely about procedural completion but also about the ability to construct meaningful, logically connected mathematical arguments.

The findings of this study have important implications for mathematics learning, especially in abstract algebra courses. Lecturers should design learning activities that explicitly integrate Computational Thinking indicators into mathematical proof activities. For instance, educators can guide students to decompose proof problems into smaller sub-problems, identify recurring algebraic patterns, formulate generalized abstractions, and arrange proof procedures systematically. Learning strategies emphasizing reflective reasoning, collaborative discussion, and structured proof construction may help students improve their abilities in abstraction and algorithmic thinking in higher mathematics.

The novelty of this study lies in its focus on analyzing students' answer processes in Ring Theory learning using Computational Thinking indicators within a qualitative-dominant mixed-methods approach. Unlike previous studies that mainly emphasized quantitative measurement of Computational Thinking abilities, this study explored in depth how students construct reasoning patterns, mathematical abstractions, and proof procedures in the context of abstract algebra. Therefore, this study contributes to expanding the implementation of Computational Thinking beyond procedural mathematics learning into advanced mathematical proof learning.

However, this study has several limitations. The research involved a limited number of participants from one private university in Medan. Therefore, these specific outcomes do not yet allow for broader generalization across diverse academic settings. In addition, the study focused solely on Ring Theory material and analyzed students' Computational Thinking abilities over a limited period of time during the learning activities. Therefore, we recommend that future studies involve larger, more diverse participant cohorts, explore other abstract mathematical domains such as Group Theory or Real Analysis, and investigate how specific learning models enhance Computational Thinking abilities in advanced mathematics education.

CONCLUSION

Based on the results of this study, we conclude that the research aimed to analyze students' Computational Thinking abilities and their problem-solving processes in solving Ring Theory problems, using decomposition, pattern recognition, abstraction, and algorithmic thinking as indicators. The findings revealed that students' Computational Thinking abilities varied across indicators: most students demonstrated relatively strong abilities in decomposition and pattern recognition, but still experienced difficulties with abstraction and with systematically constructing solution algorithms in abstract algebra proofs. The findings also indicate that integrating Computational Thinking into Ring Theory learning can support the development of students' analytical, logical, and systematic thinking skills in understanding abstract mathematical concepts. However, this study was limited to sixth-semester Mathematics Education students at one private university in Medan and focused only on Ring Theory material. Therefore, these specific outcomes do not yet allow for broader generalization across diverse mathematics education settings. In addition, the analysis was limited to students' written answers and interview results during a limited period of the learning activities. Therefore, we recommend that future studies involve larger, more diverse participants, explore additional advanced mathematics subjects such as Group Theory or Real Analysis, and investigate the effectiveness of specific learning models in strengthening students' Computational Thinking abilities in higher mathematics.

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REFERENCES

Adiyastuti, N. N., & Surakarta, U. M. (2024). Computational thinking analysis in solving elementary school AKM numeracy problems. *Premiere Educandum: Jurnal Pendidikan Dasar Dan Pembelajaran*, *14*(December), 121–137.

Ahmad Lutfi Fauzi, Y.S. Kusumah*, Elah Nurlaelah, D. J. (2024). Computational Thinking in Mathematics Education: A Systematic Literature Review on its Implementation and Impact on Students' Learning Ahmad. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *10*(2), 640–653.

Alam, A., & Mohanty, A. (2024). Unveiling the complexities of 'Abstract Algebra' in University Mathematics Education (UME): fostering 'Conceptualization and Understanding' through advanced pedagogical approaches. *Cogent Education*, *11*(1), 2355400.

Altın, R. (2025). Improving Computational Thinking Skills with the Collaboration of Computer Science and Mathematics. *Bilgisayar Bilimleri ve Teknolojileri Dergisi*, *6*(1), 29–36.

Aminah, N. (2024). Integration of computational thinking in mathematics learning in Senior Secondary Education from 2019-2023: Systematic Literature Review. *Pattimura International Journal of Mathematics (PIJMath)*, *3*(01), 31–38.

Banik, S. (2025). The Structural Foundations of Abstract Algebra: A Modern Perspective on Unifying Concepts and Interdisciplinary Connections. *Research Review International Journal of Multidisciplinary* |, *10*(8), 251–265.

Dohn, N. B. (2025). Towards a conceptualization of computational thinking as situated. *Journal of Philosophy of Education*, qhaf065.

Feudel, F., & Unger, A. (2025). Development and implementation of Concept-Test questions in abstract algebra. *International Journal of Mathematical Education in Science and Technology*, *56*(5), 869–898.

Fitrah, M., Sofroniou, A., Setiawan, C., Widihastuti, W., Yarmanetti, N., Jaya, M. P., Panuntun, J. G., Arfaton, A., Beteno, S., & Susianti, I. (2025). The Impact of Integrated Project-Based Learning and Flipped Classroom on Students' Computational Thinking Skills: Embedded Mixed Methods. In *Education Sciences* 15(4), 448.

Gnawali, Y. P. (2024). Difficulties in Studying Abstract Algebra at the Undergraduate Level. *Pragyaratna*, *6*(1), 110–122.

Jaya, S. (2025). Enhancing Problem-Solving Abilities of Teachers and Students through Integrated Computational Thinking Training in the Curriculum. *Sebatik*, *29*(1), 96–102.

Kania, N., Saepudin, A., & Gürbüz, F. (2025). Assessing cognitive obstacles in learning number concepts: Insights from preservice mathematics teachers. *Journal of Research and Advances in Mathematics Education*, *10*(3), 146–166.

Lehmann, T. H. (2025). Examining the interaction of computational thinking skills and heuristics in mathematical problem solving. *Research in Mathematics Education*, *27*(2), 269–290.

Lya, S., Pramesti, D., Mariani, S., Hendikawati, P., Waluya, S. B., Dewi, H. L., Semarang, U. N., Java, C., & Java, C. (2025). A Systematic Literature Review of: Computational Thinking in Mathematics Classrooms. *RANGE: Jurnal Pendidikan Matematika.*, *7*(1), 172–186.

M. Mitrayana*, E. N. (2023). Computational Thinking in Mathematics Learning: Systematic Literature Review. *Indonesian Journal of Teaching in Science 3(2)*, *3*(2), 133–142.

Maudy, S. Y. (2025). Many paths, one unknown: Uncovering the diverse minds behind algebraic thinking.

Union: Jurnal Ilmiah Pendidikan Matematika, *13*(2), 434–454.

Maulana, U. I. N., Ibrahim, M., Edu, M., Mataram, U., Maulana, U. I. N., & Ibrahim, M. (2025). Transformation Of The Computational Thinking Process of Students to Solve Mathematical Problems Through Reflection. *Matematika Dan Pembelajaran*, *13*(1), 129–154.

Mendrofa, N. K. (2024). Computational Thinking Skills in 21st Century Mathematics Learning. *JIIP (Jurnal Ilmiah Ilmu Pendidikan)*, *7*(1), 792–801.

Munawwaroh, A. G., Pramudya, I., & Nurhasanah, F. (2025). Epistemological Obstacles in the Process of Learning Mathematical Abstraction: A Systematic Literature Review. *KnE Social Sciences*, *10*(1), 272–294.

Mutia, I. (2025). Exploring Students' Challenges in Understanding Mathematical Concepts. *Psychology and Education: A Multidisciplinary Journal*, *14*(10), 1418–1439.

Nyoman, I. G., Hartawan, Y., Putri, L. H., & Mahayukti, G. A. (2024). Junior High School Students' s Computational Thinking Ability in Solving Mathematical Problems. *Jurnal Pedagogi Dan Pembelajaran*, *7*(1), 124–133.

Ozmantar, M. F., & Bozkurt, A. (2025). Algebraic Thinking and Habits of Mind: A Systematic Review of Conceptual Foundations and Pedagogical Challenges. *The Eurasia Proceedings of Educational & Social Sciences (EPESS)*, *47*, 296–305.

Panerio, A. M., & Delideli, J. (2025). Geometric Proof Struggles on Academic Achievements in Mathematics among Third Year College Students. *International Journal for Multidisciplinary Research*, *7*(2), 1–8.

Putu, I. G., Buditjahjanto, A., & Anifah, L. (2025). The Effect of Analytical Thinking and Critical Thinking on Mathematical Problem-Solving Ability. *JIIP (Jurnal Ilmiah Ilmu Pendidikan)*, *8*(2), 1648–1652.

Richardo, R., Irene, S., Dwiningrum, A., Murti, R. C., Wijaya, A., Ihwani, I. L., Ardiyaningrum, M., Aryani, A. E., & Richardo, R. (2025). Computational thinking skills profile in solving mathematical problems based on computational thinking attitude. *Journal of Education and Learning (EduLearn)*, *19*(2), 1157–1166.

Rossalina, C. R., Zubainur, C. M., Subianto, M., & Fadhiliani, D. (2025). Unpacking research on computational thinking in mathematics education: A systematic literature review. *Journal Elemen*, *11*(2), 447–467.

Suryawan, I. P. P., Sudiarta, I. G. P., & Suharta, I. G. P. (2023). Students' Critical Thinking Skills in Solving Mathematical Problems: Systematic Literature Review. *Indonesian Journal of Educational Research and Review*, *6*(1), 120–133.

Susanti, R. D. (2023). Peirce's Semiotics in Computational Thinking for Mathematical Problem-Solving Process. *Journal of Higher Education Theory and Practice*, *23*(16), 102–112.

Titiffaffani, K., Manaf, M. R., & Efendi, R. (2025). Mathematics and Combinatorial Thinking: How Computational Ability Influences Problem-Solving in Number Patterns? *Interval: Indonesian Journal of Mathematical Education*, *3*(1), 13–25.

Veith, J. M., Bitzenbauer, P., & Girnat, B. (2022). Exploring Learning Difficulties in Abstract Algebra: The Case of Group Theory. In *Education Sciences* 12 (8), 516.

Wang, M. (2025). Analytical Thinking in Mathematics: A Systematic Literature Review on Research Types and Content. *International Journal of Instruction*, *18*(4), 153–176.

Wu, T.T., Asmara, A., Huang, Y.M., & Hapsari, I. P. (2024). Identification of Problem-Solving Techniques in Computational Thinking Studies: Systematic Literature Review. *SAGE Open*, *14*(2), 1–20.

Ye, H., Liang, B., Ng, O.L., & Chai, C. (2023). Integration of computational thinking in K-12 mathematics education: a systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(3), 1–26.