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Analysis of Students' Thinking Processes in Solving Algebraic Problems Using a Computational Approach

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ABSTRACT

This study aims to analyze students' thinking processes in solving algebraic problems using a computational approach. The study responds to the problem that many students can follow procedural examples in algebra but still struggle to explain their reasoning, represent unknown quantities, organize solution steps, and evaluate their answers. A qualitative approach with a descriptive case study design was used. The research involved eighth-grade students at a junior high school in Indonesia, with six key informants selected through purposive sampling based on high, medium, and low ability categories. Data were collected through algebraic problem-solving tests, semi-structured interviews, classroom observations, documentation, and field notes. The data were analyzed using an interactive model consisting of data reduction, data display, and conclusion drawing, supported by thematic coding based on computational thinking indicators. The findings reveal five main themes in students' thinking processes: problem decomposition, pattern recognition, abstraction, algorithm construction, and solution evaluation. Students with stronger computational thinking were more systematic in identifying information, forming algebraic representations, arranging solution steps, and checking answers. Students with weaker computational thinking tended to rely on surface features, incomplete procedures, and limited evaluation. These findings contribute to a deeper understanding of the relationship between algebraic thinking and computational thinking. The study implies that teachers need to design algebra learning that emphasizes reasoning processes, strategy explanation, error revision, and reflective evaluation.

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1. Introduction

The development of mathematics education at the global level increasingly places critical thinking, problem solving, and computational thinking as essential competencies for twenty-first-century learning. Mathematics learning can no longer focus only on memorizing formulas and applying mechanical procedures. It must also help students understand problems, identify patterns, construct strategies, and evaluate solutions logically. Ye et al. (2023) explain that the integration of computational thinking into mathematics can strengthen the relationship between mathematical reasoning and computational reasoning. Lv et al. (2023) show that the integration of mathematics and computational thinking has gained increasing scholarly attention because both are closely related to modeling, abstraction, and problem solving. Rich et al. (2020) state that mathematical thinking and computational thinking share important similarities in the use of structure, symbols, and problem representation. Montuori et al. (2024) also demonstrate that computational thinking contributes to students' cognitive processes in organizing information and developing solution strategies.

In mathematics learning, algebra is one of the topics that often creates difficulties for students because it requires them to understand symbols, variables, patterns, relations, and generalization. Students do not only need to perform algebraic operations. They also need to explain the reasons behind each step of their solution. Bråting and Kilhamn (2021) argue that algebraic thinking and computational thinking intersect in the use of variables, patterns, generalization, and procedural representation. Sand et al. (2022) show that students connect mathematics and computing through representation, step construction, and reasoning about solutions. Lehmann (2025) emphasizes that mathematical problem solving involves the interaction between computational thinking skills and heuristic strategies. Rodríguez-Martínez et al. (2020) also found that mathematics activities supported by computational approaches can help students understand problem structures through more systematic steps.

In the Indonesian context, the need to analyze students' thinking processes in solving mathematical problems has become increasingly important because classroom learning still tends to focus on final answers. Many students can follow examples given by teachers, but they struggle when they have to explain their process, choose an appropriate strategy, or connect symbols with the meaning of the problem. Salwadila and Hapizah (2024) found that students' computational thinking ability in mathematics remains uneven, especially in decomposition, pattern recognition, abstraction, and algorithmic thinking. Nurwita et al. (2022) show that students still need scaffolding when solving mathematical problems that require abstraction and generalization. Utami et al. (2024) found that students' computational thinking skills in solving algebraic problems are influenced by their ability to understand context and organize solution steps. Sukowati and Masduki (2024) also indicate that students' learning characteristics can influence how they demonstrate computational thinking indicators in mathematical problem solving.

Field problems show that students' difficulties in algebra are not only related to weak calculation skills. They are also related to unstructured thinking processes. Students often fail to break complex problems into simpler parts, identify relevant patterns, and determine which information should be used to build a solution. Lee et al. (2023) explain that mathematics learning plays an important role in predicting students' computational thinking competence because mathematics requires organized thinking structures. Chytas et al. (2024) show that computational approaches in mathematics learning can help students understand concepts through visual representation and exploration of solution steps. Nordby et al. (2022) emphasize that computational thinking activities in mathematics classrooms should be viewed as learning processes that involve communication, exploration, and reflection. Abidi et al. (2023) also show that analyzing computational thinking indicators can help explain variations in students' ability to solve contextual mathematical problems.

Although studies on computational thinking in mathematics education continue to grow, there are still limitations in research that specifically explores students' thinking processes when solving algebraic problems. Previous studies have often focused on intervention effectiveness, media design, application use, or quantitative measurement of students' abilities. Nordby et al. (2022) argue that research on computational thinking in mathematics classrooms still requires more diverse approaches to understand students' activities, interactions, and learning experiences. Bråting and Kilhamn (2021) emphasize that the relationship between algebra and computational thinking cannot be fully understood by looking only at final answers. Lehmann (2025) adds that the analysis of problem-solving strategies needs to consider how students choose, test, and revise solution steps. Braun and Clarke (2022) also explain that qualitative inquiry can help researchers develop a deeper understanding of meaning patterns in data.

Based on this background, this study aims to analyze students' thinking processes in solving algebraic problems using a computational approach. The study focuses on how students decompose problems, recognize patterns, perform abstraction, construct solution algorithms, and evaluate their answers. A qualitative approach is used because students' thinking processes need to be understood through explanations, reasons, experiences, and strategies that appear during problem solving. Rich et al. (2020) show that integrating mathematical and computational thinking can enrich the understanding of mathematics learning processes. Sand et al. (2022) emphasize that the relationship between mathematics and computing can be seen from how students represent problems and build solutions. Montuori et al. (2024) explain that computational thinking contributes to students' cognitive processes in managing information. Ahmed (2024) highlights that qualitative research needs to maintain trustworthiness so that the interpretation produced has a strong methodological foundation. This study is expected to provide theoretical contributions to the development of algebraic thinking studies and practical contributions for teachers in designing learning that emphasizes process, strategy, and student reflection.

2. Materials and Methods

This study used a qualitative approach with a descriptive case study design. This design was selected because the study focused on gaining an in-depth understanding of students' thinking processes in solving algebraic problems using a computational approach. A case study design was considered appropriate because the researcher aimed to explore students' strategies, reasons, difficulties, and thinking patterns in a real mathematics learning context. Sukowati and Masduki (2024) show that case studies can be used to explore students' computational thinking skills in mathematical problem solving. Abidi et al. (2023) used a descriptive qualitative approach to analyze students' computational thinking ability in solving contextual mathematical problems. Salwadila and Hapizah (2024) also used test and interview data to explain students' computational thinking ability based on specific indicators. Johnson et al. (2020) emphasize that qualitative research requires a clear design so that data collection and analysis procedures can be justified.

The study was conducted at one junior high school in Indonesia during the second semester of the 2025/2026 academic year. The research period was planned from March to April 2026. This period was used for classroom observation, algebraic problem-solving tests, interviews, documentation, and data verification. The subjects of the study were eighth-grade students who had learned algebraic expressions and systems of linear equations in two variables. Grade VIII was selected because algebra at this level requires students to understand symbols, variables, patterns, relations, and systematic solution steps. Bråting and Kilhamn (2021) explain that algebraic thinking is closely related to computational thinking because both involve patterns, structures, variables, and procedural representations. Ye et al. (2023) emphasize that integrating computational thinking into mathematics helps students build connections between mathematical reasoning and problem-solving strategies. Lee et al. (2023) also show that mathematics learning experiences contribute to the development of students' computational thinking competence.

Participants were selected using purposive sampling. In the initial stage, one class consisting of approximately 24 to 30 students completed an algebraic problem-solving test. Based on the test results, the researcher selected six students as key informants representing high, medium, and low ability categories. Each category was represented by two students so that the researcher could more deeply compare variations in students' thinking processes. The criteria for selecting informants included active participation in learning, willingness to participate in interviews, completeness of written answers, and ability to explain the reasons behind solution steps. This selection procedure follows Abidi et al. (2023), who grouped students based on their achievement in computational thinking components of mathematical problem solving. Nurwita et al. (2022) show that differences in students' abilities can lead to variations in decomposition, abstraction, and generalization. Utami et al. (2024) also emphasize that analyzing students' thinking processes in algebraic problems requires considering their ability to understand the context and construct solution strategies.

Data were collected through algebraic problem-solving tests, semi-structured interviews, classroom observation, documentation, and field notes. The algebraic problem-solving test was used to identify how students wrote solution steps, selected important information, recognized patterns, developed strategies, and evaluated answers. Semi-structured interviews were conducted after students completed the test to explore their reasons, confusion, strategies, and considerations at each stage of the solution process. Classroom observation was used to record students' behavior while reading, discussing ideas, asking questions, testing strategies, and revising answers. Documentation included students’ answer sheets, interview guidelines, classroom activity photos, and researcher notes. Stahl and King (2020) explain that qualitative research needs to pay attention to credibility and data traceability. Ahmed (2024) emphasizes the importance of documenting the research process to maintain transparency. Braun and Clarke (2022) also state that qualitative analysis must be supported by a deep understanding of data context.

The main instrument in this study was the researcher, while supporting instruments included algebra test sheets, interview guidelines, observation sheets, and documentation formats. The algebra questions were designed based on computational thinking indicators, namely decomposition, pattern recognition, abstraction, algorithm construction, and solution evaluation. Before the instruments were used, the test items and interview guidelines were validated by two mathematics education experts to ensure content relevance, language clarity, difficulty level, and alignment with research indicators. Interviews were conducted individually for approximately 20 to 30 minutes with each key informant. The interview questions focused on how students understood the problem, identified important information, selected solution steps, corrected errors, and evaluated the correctness of their answers. Salwadila and Hapizah (2024) used tests and interviews to reveal students’ computational thinking indicators. Sukowati and Masduki (2024) also show that interviews can help explain thinking processes that are not visible in written answers. Johnson et al. (2020) emphasize that instruments and qualitative research procedures need to be described in detail so that readers can assess the quality of the study.

Data trustworthiness was ensured through method triangulation, source triangulation, member checking, and audit trail. Method triangulation was conducted by comparing data from written tests, interviews, observations, and documentation. Source triangulation was conducted by comparing information from students, the mathematics teacher, and learning documents. Member checking was conducted by asking key informants to confirm summaries of interview results and the researcher’s initial interpretation. The audit trail was conducted by keeping records of the research process, coding changes, discussion results, analytical decisions, and supporting documents so that the research process could be traced. Stahl and King (2020) state that credibility, transferability, dependability, and confirmability must be considered in qualitative research. Ahmed (2024) explains that audit trails help maintain the traceability of research decisions and strengthen the confirmability of findings. Braun and Clarke (2022) emphasize that researcher reflexivity is important so that interpretation remains connected to the data context.

Data analysis used an interactive model consisting of data reduction, data display, and conclusion drawing. In the data reduction stage, the researcher read all written answers, interview transcripts, observation notes, and supporting documents to select data relevant to the research focus. The researcher then coded the data based on computational thinking indicators, namely decomposition, pattern recognition, abstraction, algorithm construction, and evaluation. In the data display stage, the coded data were organized into a thematic matrix to compare each student's thinking patterns. In the conclusion-drawing stage, the researcher identified major themes related to students' thinking processes in solving algebraic problems. Braun and Clarke (2022) explain that thematic analysis involves data familiarization, coding, theme development, theme review, and report writing. Ahmed (2025) emphasizes that thematic analysis helps researchers identify meaning patterns in qualitative data in a flexible and structured way. Abidi et al. (2023) also used data classification, data display, and conclusion drawing to analyze students' indicators of computational thinking.

3. Results and Discussions

The findings show that students' thinking processes in solving algebraic problems using a computational approach emerged through five main themes: problem decomposition, pattern recognition, abstraction, algorithm construction, and solution evaluation. These themes appeared consistently in students' written answers, interview responses, classroom observations, and documentation of learning activities. However, the depth of each theme differed across students with high, medium, and low mathematical ability. Students with high ability tended to move from understanding the problem to constructing solution steps more systematically. Students with medium ability could identify several important elements of the problem but still needed guidance when connecting algebraic symbols with the meaning of the problem. Students with low ability often focused on numbers that appeared in the question without first clarifying the relationship between variables. This finding indicates that algebraic problem solving involves more than procedural calculation. It requires students to organize information, interpret symbols, and build logical steps.

The first theme was problem decomposition. Students with stronger computational thinking skills were able to break down algebraic problems into smaller and more manageable parts. They identified known information, unknown variables, and the relationship between quantities before performing calculations. One student explained, "I first wrote what was known, then I changed the unknown part into x because it was easier to continue the steps." This response shows that decomposition helped students reduce the complexity of the problem and prepare a clearer solution path. In contrast, students with weaker decomposition skills directly operated on the numbers in the question without identifying the structure of the problem. During observation, these students often reread the question several times and asked whether they should "add or multiply first." This pattern suggests that difficulty in decomposition made students dependent on surface-level cues rather than conceptual relationships.

The second theme was pattern recognition. Students who could identify patterns were more capable of connecting the algebraic problem with previous examples or familiar mathematical structures. They recognized repeated relationships, proportional changes, or forms that resembled linear equations. One participant stated, "This problem is similar to the previous one because both have two unknown values, so I tried to make two equations." This statement shows that pattern recognition supported students in selecting an appropriate strategy. However, not all students used patterns productively. Some students matched the problem with a previous example only because the numbers looked similar, not because the mathematical structure was the same. This caused errors in forming equations. The finding indicates that pattern recognition must involve structural understanding, not only visual similarity or memory of previous exercises.

The third theme was abstraction. In this study, abstraction appeared when students selected relevant information, ignored unnecessary details, and represented real situations using algebraic symbols. Students with high ability could explain why a certain variable was used and how it represented the unknown quantity. For example, one student said, "I used x for the first number and y for the second number because the question asked two different values." This explanation shows that the student understood the role of symbols in representing mathematical relationships. Students with lower ability often wrote variables without knowing their meaning. Some students used x only because they were familiar with it from classroom examples. This condition shows that abstraction remains a major challenge in algebra learning. Students may use algebraic notation correctly in form, but not necessarily in meaning.

The fourth theme was algorithm construction. Students with stronger thinking processes arranged their solution steps in a logical sequence. They started from defining variables, forming equations, simplifying expressions, solving the equation, and checking the result. Their written answers showed more complete reasoning and fewer disconnected procedures. One student explained, “After I made the equation, I solved it step by step, then I substituted the value again to check whether it matched the question.” This statement indicates that algorithmic thinking helped students create an ordered procedure and monitor each step. In contrast, students with weaker algorithmic thinking often skipped important stages. They wrote calculations without explaining where the equation came from. Some students also changed operations without a clear reason. These findings show that algorithm construction in algebra is not only about following procedures. It also involves the ability to justify the sequence of actions.

The fifth theme was solution evaluation. Evaluation appeared when students reviewed their answers, checked the accuracy of calculations, and reflected on whether the final result made sense in the context of the problem. Students with high ability tended to recheck their solutions by substituting the answer into the original equation. Students with medium ability checked the calculation but rarely checked the meaning of the answer. Students with low ability often stopped once they obtained a numerical result. One student stated, “I thought the answer was finished because I already found the value of x.” This response shows that some students viewed problem solving as ending with an answer, not with verification. Observation also showed that students rarely evaluated alternative strategies unless the teacher asked guiding questions. This finding indicates that evaluation is the least spontaneous component of students’ computational thinking in algebraic problem solving.

Overall, the results reveal that students’ thinking processes were not linear. Several students moved back and forth between reading the problem, trying a strategy, revising the equation, and checking the result. This recursive process was more visible among students who were willing to explain their reasoning during interviews. The findings also show that students’ computational thinking was shaped by their classroom learning habits. Students who were accustomed to explaining their steps were more confident in describing their reasoning. Students who were used to short procedural answers found it difficult to verbalize their thinking. Therefore, the use of a computational approach in algebra learning can help reveal hidden aspects of students’ reasoning that are not visible from written answers alone.

Discussion

The findings support the view that algebraic thinking and computational thinking are closely connected. Students who could decompose problems, identify patterns, abstract information, construct algorithms, and evaluate solutions showed stronger algebraic reasoning. This is consistent with Bråting and Kilhamn (2021), who argue that algebraic thinking and computational thinking intersect in the use of variables, patterns, structures, and procedural representations. The present study extends this view by showing how these intersections appear in students’ actual problem-solving processes. Algebraic problem solving does not only require students to manipulate symbols. It also requires them to understand the meaning of symbols and organize solution steps in a logical way.

The results also align with Ye et al. (2023), who explain that computational thinking integration in mathematics strengthens the relationship between mathematical reasoning and computational reasoning. In this study, students who demonstrated stronger computational thinking did not simply calculate faster. They showed clearer reasoning in identifying information, choosing strategies, and checking answers. This finding supports the idea that computational thinking should not be treated only as a digital skill. It can also function as a cognitive approach that helps students structure mathematical reasoning. This is important for algebra learning because students often face difficulties when translating contextual information into symbolic forms.

The finding on decomposition is consistent with previous research showing that students often struggle to break complex mathematical problems into smaller parts. Nurwita et al. (2022) found that students needed scaffolding when solving mathematical problems that required decomposition, abstraction, and generalization. The present study confirms this pattern in the context of algebraic problems. Students who failed to decompose problems tended to rely on guessing operations or imitating previous examples. This suggests that teachers need to provide explicit learning activities that train students to identify known information, unknown quantities, and relationships before applying algebraic procedures.

The finding on pattern recognition also strengthens the argument that students need to understand mathematical structure, not only memorize solution models. Rich et al. (2020) explain that mathematical thinking and computational thinking share similarities in recognizing structures and representing problems. In this study, students who recognized structural patterns could form equations more accurately. However, students who relied only on surface similarity often selected inappropriate strategies. This finding offers a critical insight for classroom practice. Pattern recognition should be taught through comparison of problem structures, not merely through repetition of similar exercises.

The difficulty in abstraction found in this study reflects a central problem in algebra learning. Students often use variables without fully understanding their representational meaning. This finding is in line with Utami et al. (2024), who showed that students’ computational thinking in solving algebraic problems is influenced by their ability to understand context and organize solution steps. The present study adds that abstraction becomes difficult when students cannot decide which information is relevant and how it should be represented symbolically. This implies that teachers need to connect algebraic symbols with concrete situations before moving to formal procedures.

The findings on algorithm construction show that students need support in building ordered and meaningful solution procedures. Lehmann (2025) emphasizes that mathematical problem solving involves the interaction between computational thinking skills and heuristic strategies. The present study supports this view because students did not always move through fixed steps. They tested, revised, and adjusted their strategies during problem solving. However, students with weaker algorithmic thinking often produced fragmented solutions. This shows that algorithmic thinking in mathematics should be developed as a reasoning process, not as rigid memorization of steps.

The limited evaluation shown by several students also deserves attention. Many students stopped after finding a numerical answer and did not check whether the answer matched the original problem. This finding is consistent with Nordby et al. (2022), who emphasize that computational thinking activities in mathematics classrooms need to involve reflection and communication. In this study, reflection appeared only when students were guided through interview questions or teacher prompts. This suggests that evaluation should become an explicit part of mathematics instruction. Teachers can ask students to substitute answers, compare alternative strategies, or explain why their solution is reasonable.

The findings also offer a methodological contribution. Written answers alone could not fully capture students’ thinking processes. Some students produced incomplete written solutions but were able to explain their reasoning orally. Other students wrote correct answers but could not justify their steps during interviews. This supports Braun and Clarke’s (2022) view that qualitative analysis can reveal patterns of meaning that are not visible from surface-level data. The use of interviews, observation, documentation, and answer-sheet analysis helped provide a richer understanding of students’ thinking processes. This also confirms the importance of triangulation in qualitative research, as emphasized by Ahmed (2024).

From a theoretical perspective, this study contributes to the development of algebraic thinking research by positioning computational thinking as an analytical lens for understanding students’ problem-solving processes. The five indicators used in this study provide a useful framework for examining how students move from understanding a problem to evaluating a solution. From a practical perspective, the findings suggest that mathematics teachers should design algebra learning that gives students opportunities to explain, compare, revise, and reflect on their solution strategies. Learning should not only ask students to find the correct answer. It should also guide them to clarify how and why the answer is obtained.

Future research can expand this study by involving students from different school levels, comparing students with different mathematical achievement profiles, or examining how teacher scaffolding affects each component of computational thinking. Further studies may also use classroom intervention designs to explore how specific learning models improve students' decomposition, abstraction, algorithmic thinking, and evaluation skills in algebra. A longitudinal qualitative study could provide deeper insight into how students' computational thinking develops over time. These directions are important because students' thinking processes are shaped not only by individual ability, but also by classroom culture, teacher questioning, learning tasks, and opportunities for reflection.

4. Conclusions

This study concludes that students' thinking processes in solving algebraic problems using a computational approach are reflected in five main patterns: problem decomposition, pattern recognition, abstraction, algorithm construction, and solution evaluation. Students with stronger thinking processes were able to identify relevant information, represent unknown quantities symbolically, organize solution steps, and check the reasonableness of their answers. In contrast, students who experienced difficulty tended to focus on numbers, imitate previous examples, or stop after obtaining a final answer without evaluating the solution. These findings show that algebraic problem solving is not only a procedural activity, but also a cognitive process that requires structured reasoning, symbolic understanding, and reflective thinking.

The study contributes theoretically by strengthening the connection between algebraic thinking and computational thinking in mathematics education. Practically, the findings suggest that teachers need to design algebra learning that encourages students to explain their reasoning, compare strategies, revise errors, and evaluate answers. The results also imply that mathematics instruction should not only assess final answers, but also examine the process students use to reach those answers. Future research may expand this study by involving different grade levels, broader school contexts, or intervention-based learning models that specifically develop decomposition, abstraction, algorithmic thinking, and evaluation skills in algebraic problem solving.

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