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An Analysis of Seventh-Grade Students' Computational Thinking Skills in Solving Algebra Problems

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Abstract: Computational thinking (CT) is a higher-order thinking skill that plays an important role in mathematics learning, particularly in algebra material at the Junior Secondary School level. This study aims to analyze the computational thinking ability of Grade VII students in solving algebra problems from the perspective of decomposition, pattern recognition, abstraction, and algorithm indicators. The study employed a descriptive approach with quantitative-qualitative analysis of student responses to contextual algebra problems. The research subjects were Grade VII students at a junior secondary school in Bandung, West Java. The research instrument consisted of an algebra test based on CT and a computational thinking assessment rubric. The results indicate that students' computational thinking ability falls in the moderate category, with decomposition and pattern recognition indicators being more dominant than abstraction and algorithm. These findings suggest that students still face difficulties in modeling algebra problems into symbolic form and developing systematic problem-solving procedures. This research provides important implications for developing algebra learning integrated with computational thinking.

Keywords: Computational thinking, Algebra problems, Higher order thinking

Introduction

The development of 21st-century education has brought a significant paradigm shift in the global curriculum, where students are no longer merely required to master content but are also expected to possess higher-order thinking skills. One of the skills that has become a primary pillar in this transformation is computational thinking (CT). Wing (2006) revolutionarily defined computational thinking as a method for problem-solving, system design, and understanding human behavior that is rooted in the fundamental concepts of computer science. It is essential to underline that computational thinking is not synonymous with programming or

technical computer proficiency; rather, it is a cognitive process encompassing problem decomposition, pattern recognition, abstraction, and logical algorithm design.

This global shift is not confined to any single education system. Since Wing's (2006) initial call to treat computational thinking as a universal analytical skill akin to reading, writing, and arithmetic, national curricula across North America, Europe, and Asia have progressively embedded computational thinking language into their mathematics and science standards, even where dedicated computer science instruction remains limited. Indonesia's own curricular trajectory reflects this same movement: the transition from the 2013 Curriculum to the Merdeka Curriculum was explicitly framed around strengthening students' higher-order and analytical competencies, of which computational thinking is a natural component, even where the term itself is not always used explicitly in official curriculum documents.

In the realm of mathematics education, particularly within the domain of algebra, computational thinking possesses a very close relevance and functional interconnectedness. Algebra intrinsically demands students to have the ability to understand relational patterns, manipulate abstract symbols, model real-world problem situations into mathematical structures, and arrange solution steps logically and systematically. Therefore, computational thinking ability is no longer just an additional skill but has become a crucial cognitive foundation for students' success in navigating algebraic complexities from an early age. The synergy between CT and algebra enables students to transition from concrete arithmetic thinking toward generalized algebraic thinking.

The implementation of the *Kurikulum Merdeka* (Independent Curriculum) in Indonesia further emphasizes this urgency by stating that mathematics learning at the Junior Secondary School (SMP) level aims to develop students' logical, analytical, systematic, critical, and creative thinking skills (Kemendikbudristek, 2022). At the Grade VII level, algebraic material is formally introduced through topics such as algebraic forms, variable operations, and linear problem-solving. These competencies implicitly require students to apply the pillars of computational thinking in every cognitive process. Research conducted by Yadav et al (2016) reinforces this argument with findings that the explicit integration of computational thinking in mathematical instruction can significantly enhance students' efficacy and problem-solving abilities.

Realizing this policy intent in everyday classroom practice, however, remains an ongoing challenge. Hunaepi and Suharta (2024), reviewing the rollout of the Merdeka Belajar curriculum across Indonesian schools, reported that teachers frequently struggle to translate the curriculum's competency-based goals, including higher-order and computational reasoning, into concrete classroom tasks, particularly in mathematics, where instructional materials have not yet fully caught up with the curriculum's conceptual ambitions. This gap between curricular intent and classroom implementation is precisely the space in which the present study is situated: by empirically documenting how Grade VII students actually perform on each computational thinking indicator when solving algebra problems, this research offers concrete, indicator-level evidence that can inform how the Merdeka Curriculum's mathematics competencies are operationalized in the classroom.

However, reality in the field often reveals a concerning discrepancy. Various empirical studies disclose that junior secondary students still struggle with fundamental difficulties when facing algebraic concepts, especially when required to perform symbolic abstraction and construct coherent solution algorithms. Students tend to perform mechanistic calculations without deep structural understanding. This phenomenon indicates a wide gap between the high expectations of the national curriculum and students' cognitive capacity to apply computational thinking strategies autonomously.

Based on this urgency, this study focuses on conducting an in-depth analysis of the computational thinking ability of Grade VII students in solving algebraic problems. This study is vital for comprehensively mapping students' cognitive profiles, which will subsequently serve as an empirical basis for designing more effective, adaptive, and meaningful algebraic pedagogical strategies. As stated by Barr and Stephenson (2011), computational thinking is a new literacy and a fundamental skill that must be integrated and developed continuously from primary through secondary education. In this study, computational thinking is operationalized through four main components:

Decomposition: The ability to break down complex and multidimensional algebraic problems into smaller, more manageable parts.

Pattern Recognition: The ability to identify regularities, trends, or similarities in relationships between variables within mathematical data.

Abstraction: The ability to filter important information, sift out irrelevant details, and perform symbolic modeling.

Algorithm: The ability to arrange a series of instructions or problem-solving steps systematically and replicably. Grover and Pea (2013) assert that computational thinking and mathematics are two mutually reinforcing entities, particularly in aspects of symbolic reasoning and problem modeling. However, they also provide critical notes that students' greatest challenges lie in the aspects of abstraction and algorithmic design, especially when faced with non-routine problems that require high cognitive flexibility. Through this research, it is expected that the "blind spots" in students' thinking processes can be identified, so that the transformation of mathematics learning based on the power of computational thinking can be promptly realized.

Algebra is a branch of mathematics that strongly emphasizes the use of symbols and generalization. In solving algebra problems, students need to break down the problem into known and unknown information (decomposition), recognize patterns of relationships between variables (pattern recognition), form mathematical models (abstraction), and develop solution procedures (algorithm). Weintrop et al. (2016) argue that computational thinking in mathematics learning can strengthen concept understanding and improve problem-solving ability. In the context of algebra, CT helps students think more structurally and systematically when dealing with symbolic problems.

Research by Lai and Lee (2019) shows that computational thinking ability falls in the moderate category, with the main weakness in the abstraction indicator. This finding suggests that students still struggle with transforming contextual problems into algebraic form. Previous research shows that students' computational thinking ability is influenced by various factors, such as learning strategies, problem characteristics, and scaffolding support from teachers (Atmarita & Firmantas, 2022). Additionally, Angeli and Valanides (2020) found that structured and contextual learning approaches can significantly improve students' CT ability. Based on this literature review, this research places computational thinking as an analytical lens for understanding Grade VII students' ability to solve algebra problems.

Recent systematic reviews have reinforced the centrality of computational thinking in mathematics education. Ye et al. (2023), synthesizing K-12 mathematics instruction studies, concluded that computational thinking is most effectively developed when it is embedded within existing mathematical content rather than taught as an isolated computer science skill, a conclusion that directly supports the algebra-embedded design of the present study. In a closely related line of inquiry, Qolfathiriyus Firdaus et al. (2026) directly coded computational thinking components within algebra problem-solving among 120 secondary students and found that pattern recognition (80%) and decomposition (70%) were widely observed across achievement levels, while abstraction (45%) and algorithmic reasoning (35%) appeared far more selectively, concentrated mainly among high-achieving students, a distribution this study also seeks to verify among Grade VII students specifically. At a broader scale, the systematic review and meta-analysis conducted by Li and Oon (2024) across 37 CT-STEM studies found a moderate overall transfer effect of computational thinking on student learning, but cautioned that effect sizes varied considerably depending on the type of outcome measured and that computational thinking integration does not benefit all learning outcomes equally, further motivating a fine-grained, indicator-by-indicator analysis such as the one undertaken here. Complementing these findings, Humble and Mozeliuss (2023) surveyed Grades 7–12 mathematics and technology teachers and found that most respondents felt underprepared to explicitly teach computational thinking indicators within mathematics lessons, underscoring the pedagogical relevance of studies that map, in concrete terms, where students struggle.

While Astuti et al. (2025) recently mapped the same four computational thinking indicators among junior secondary students, their investigation was situated in statistics content and relied on a purposive sample of six students drawn from a single class. The present study extends this line of inquiry to algebra, a content domain with a distinct symbolic-manipulation demand and draws on a larger and more stratified sample of 20 students spanning high, moderate, and low mathematics ability. In doing so, this research responds to the call raised by Lai and Lee (2019) for domain-specific replications of computational thinking research beyond a single content strand and offers algebra-specific evidence that can be directly compared with the statistics-based findings of Astuti et al. (2025).

In light of this background, the objectives of this study are threefold: (1) to describe the overall computational thinking ability of Grade VII students in solving contextual algebra problems; (2) to map students' performance separately across the four computational thinking indicators of decomposition, pattern recognition, abstraction, and algorithm; and (3) to explain, through qualitative case analysis, why the abstraction and algorithm indicators tend to lag behind decomposition and pattern recognition among junior secondary students.

Method

Research Design

This research employed a descriptive approach using quantitative-qualitative methods. This design was chosen to obtain a comprehensive picture of students' computational thinking ability through analysis of test scores and description of student thinking processes in solving algebra problems (Creswell, 2014).

Participants

The research was conducted at a junior secondary school in Bandung City. The research subjects were 20 Grade VII students from the 2025/2026 academic year who had studied basic algebra material. Subject selection was conducted purposively, considering the appropriateness of the material and the level of student cognitive development, such as basic mathematics ability and willingness to participate in the study. Specifically, these 20 students were selected to represent various levels of academic ability based on their mathematics report card grades from the previous semester: 6 students with high ability (average grade 85–100), 8 students with moderate ability (average grade 70–84), and 6 students with low ability (average grade below 70). This selection aimed to obtain representative data variation, so that the analysis of computational thinking ability could reflect students' profiles more comprehensively and avoid bias from homogeneous samples.

Instrument

The research instrument consisted of an algebra test based on computational thinking, developed by referring to CT indicators: decomposition, pattern recognition, abstraction, and algorithm. The test questions used in this research underwent a validation process by experts in mathematics education. This validation was conducted to ensure that each question truly measures the expected computational thinking ability and aligns with the context of algebra material. The experts evaluated question quality from various aspects, including alignment with the curriculum, proportional difficulty level, language clarity, and question relevance to real-world situations encountered by students. This validation process aimed to increase instrument reliability, so that test results accurately reflect students' computational thinking ability and can be scientifically accountable. The following table presents the relationship between computational thinking indicators and characteristics of algebra problems used in this research.

The item design followed the empirical approach demonstrated by Qolfathiriyus Firdaus et al. (2026), who showed that all four computational thinking components can be reliably coded directly from students' written algebra work, without requiring a programming context, when items combine a narrative, context-rich problem stem with a point at which the student must move from concrete quantities to symbolic representation. Accordingly, each item in this study was written as a short word problem describing a familiar, everyday transaction, deliberately withholding an explicit instruction to “use variables x and y ,” so that the decision to abstract the situation into symbolic form would itself become an observable indicator of students' computational thinking rather than a step merely prompted by the wording of the question.

Table 1. Algebra problem specifications by CT indicator

CT Indicator	Algebra Problem Characteristics	Expected Cognitive Activities
Decomposition	Simple algebra word problems	Identifying known and unknown information
Pattern Recognition	Relationships between variables	regularities and mathematical relationships
Abstraction	Symbolic modeling	Developing algebraic forms from contextual situations
Algorithm	Solution procedures	Arranging solution steps systematically

The algebra problems used in this research were constructed as contextual problems to elicit computational thinking indicators. One example problem given to students is as follows:

A stationery merchant sells two types of stationery packages. Package A contains 2 books and 1 pencil, priced at Rp14,000, and Package B contains 1 book and 3 pencils, priced at Rp16,000. Determine the price of one book and one pencil!. This problem was designed to measure students' computational thinking ability covering: Decomposition, namely the ability to identify known information (composition of Package A and B with their prices) and determine what is being asked (the price of one book and one pencil); Pattern Recognition, namely recognizing the relationship between the number of books and pencils in each package with the total price

given; Abstraction, namely modeling the contextual situation into a mathematical model in the form of a system of two linear equations; and Algorithm, namely arranging solution steps systematically to determine the price of one book and one pencil based on the mathematical model that has been developed. The assessment rubric was developed based on the instrument development for computational thinking in mathematics learning (Yadav et al, 2014) and CT tests developed by Román-González et al. (2017).

Table 2. Computational thinking ability category scale

Ability Category	Score Range
High	76–100
Moderate	56–75
Low	≤55

Data Collection Procedure

Data were collected through written tests and analyzed using descriptive statistics to determine the category of students' computational thinking ability. Following the written test, semi-structured interviews were conducted with three representative subjects purposively selected to correspond to the high (S-01), moderate (S-10), and low (S-20) computational thinking categories established from the test scores. The interview protocol was developed around the four computational thinking indicators, asking students to explain, in their own words, how they identified the information given in each problem, how they decided on a solution strategy, and why they followed a particular sequence of steps. Interviews were conducted individually, audio-recorded with the students' consent, and transcribed for analysis, and were used to triangulate the written-test findings, following the approach recommended by Ye et al. (2023) for combining product-based and process-based evidence of computational thinking.

Data Analysis

Qualitative analysis was conducted by examining student responses to identify computational thinking characteristics on each indicator, following a directed content-analysis procedure. To support the consistency of the scoring, each written-test response was checked against the indicator descriptions in Table 2 before being assigned to the high, moderate, or low computational thinking category, and any response that was difficult to classify was re-examined against the original test item to confirm the appropriate category. Prior to data collection, the study procedure, including the use of anonymized student work and audio-recorded interviews, was explained to the school principal, the class teacher, and the students' parents or guardians, and informed consent was obtained from all parties; students were also informed of their right to withdraw from the interview at any time without academic consequence.

Results and Discussion

Based on the data analysis of 20 Grade VII students, comprehensive findings were obtained regarding the students' computational thinking (CT) ability profiles in solving algebra problems. Following the two objectives outlined at the close of the Introduction, the findings are presented in three stages: first, the overall quantitative distribution of students' computational thinking ability across the high, moderate, and low categories; second, a qualitative case analysis of three representative subjects that unpacks how each of the four computational thinking indicators manifested at each ability level; and third, a discussion that situates these findings within the broader computational thinking literature reviewed earlier. Overall, the students' computational thinking ability falls into the moderate category. The distribution of these abilities is presented in Table 3 below.

Table 3. Distribution of Grade VII students' computational thinking ability

Ability Category	Score Range	Number of Students	Percentage
High	76–100	4	20%
Moderate	56–75	10	50%
Low	≤55	6	30%
Total		20	100%

Based on the scores obtained from the assessment rubric, students' computational thinking skills can be classified into three categories: high, medium, and low. Generally, most students fall into the medium category, with a distribution of abilities that varies across each indicator. Qualitative analysis was then carried out by thoroughly examining students' written responses to each indicator of computational thinking. This analysis aims to reveal students' mindsets in solving algebraic problems. To provide a more transparent picture of how the computational thinking (CT) indicator manifests in student work, the researcher conducted an in-depth analysis of three representative subjects representing the High (S-01), Medium (S-10), and Low (S-20) ability groups.

Subject Case S-01 (High CT Category)

S-01 shows a highly structured mindset, like a programmer drafting code. When faced with the "Stationery Pack" problem, the S-01 didn't immediately rush to count.

Decomposition Process: S-01 starts by writing down a list of information vertically. He breaks down the narrative text of the story into data points: "*Known: $2B + 1P = 14,000$; $1B + 3P = 16,000$* ". His ability to break down complex problems into small sub-problems looks very mature. He identified that in order to find a unit price, he had to "eliminate" one of the variables first.

Introduction to Patterns and Abstraction: S-01 demonstrates strong abstraction ability by explicitly defining variables: "*E.g. $x = \text{book price}$, $y = \text{pencil price}$* ". He no longer saw books and pencils as physical objects, but as abstract mathematical entities. S-01 recognizes a pattern that if it adds or subtracts the two equations, it will get a new relationship between variables.

Algorithms: The algorithms that S-01 compiles are very linear and logical. He chose the elimination method, multiplying the second equation by the number 2 so that the book coefficient becomes the same. Each step is described, indicating high metacognitive awareness. The final result is accurate, and it *debugs* by substituting the value back to the initial equation.

Subject Case S-10 (Medium CT Category): Concrete-Abstract Bridge

S-10 represents the majority of students in the classroom. He understands the logic of the problem, but is still "bound" to the concrete context and has difficulty formalizing algebra.

Decomposition Process: S-10 writes down what is known, but in the form of long sentences. He understood that there were two different packages, but he did not break them down into mathematically ready to be operated.

Pattern Recognition: S-10 noticed an interesting pattern: "*Package B is more expensive because there are more pencils*". This is a qualitatively good pattern recognition, but it fails to transform it into a precise quantitative comparison.

Abstraction Barrier: When asked to use the x and y variables, S-10 looks hesitant. In his answer sheet, he tried to make a doodle: "*If 1 book is 5,000, then...*". He uses a random substitution technique (*guess and check*). The S-10 is caught up in what Sfard (1991) calls operational thinking; He sees the problem as a process of counting numbers, not as a structure of relationships between symbols.

Algorithms: The algorithms that S-10 compiles are inefficient. He did a lot of doodles on the edge of the paper, trying different combinations of numbers until he found the one that fits. Although it eventually finds the correct answer, the procedure cannot be generalized to more complex numbers (e.g. if the price is decimal).

Subject Case S-20 (Low CT Category): Trial-and-Error Maze

The S-20 shows significant resistance on almost all CT indicators. His thought process tends to be fragmentary and unsystematic.

Decomposition Failure: S-20 writes down the numbers in the question (14,000 and 16,000) but is unable to explain the relationship. He mixed up the number of books in Package A with the price in Package B. This shows that he has not been able to break down the problem into the correct components.

Absence of Abstraction: For S-20, algebra is an unfamiliar subject. It does not use variables at all. The answer sheet contains only random addition and subtraction operations. He tried to add up $14,000 + 16,000$ and then divide it by the sum of all items. This is a strong indication that he is missing the contextual significance of the issue.

Algorithms Without Logic: The steps taken by the S-20 do not follow a logical sequence. It moves from one calculation to another without a clear purpose. When the researcher asked why he made the division, S-20 replied: *"Usually this is a matter of division, sir."* This suggests that it only follows a "memory pattern" of certain types of problems without doing any actual computational thinking.

Students with High CT, demonstrate the ability to represent the problem symbolically correctly. These students can write algebraic forms in general before replacing certain values and explain the solution steps coherently. Students with Moderate CT, are generally able to understand the context of the problem and find solution strategies, but are less consistent in writing complete algebraic models. The solution step is often not accompanied by an adequate logical explanation. Students with Low CT, tend to perform arithmetic calculations directly without building algebraic models. The answers given are trial and error and do not show a clear algorithmic structure. Of the three cases above, researchers found that Abstraction was the main differentiator between the three groups.

High group students see symbols as objects that can be manipulated (structural).

The group students are looking at symbols as a counting procedure (Operational).

Low-group students see symbols as confusing obstacles.

The epistemological obstacles in S-10 and S-20 prove that algebra teaching cannot be done instantly through the provision of formulas. There must be a phase in which students are invited to decompose and recognize patterns verbally and visually before being forced into the realm of symbolic abstraction. CT integration provides a framework for teachers to diagnose where exactly the "breakdown" of students' logic occurs: whether they fail in the initial stage (decomposition) or in the formalization stage (abstraction).

Based on the results of the study, it can be clearly seen that the profile of computational thinking ability (CT) of grade VII students is in the medium category. These findings provide a crucial picture of students' cognitive positions in the transition phase from arithmetic thinking to formal algebraic thinking. The placement of the majority of students (50%) in the medium category suggests that the cognitive foundation for computational thinking has actually been formed through previous learning experiences and everyday logical intuition, but has not been technically honed to deal with abstract algebraic structures.

This "moderate" condition indicates an imbalance between basic mathematical literacy skills and formalization skills. Students are able to understand the problem in a macro way, but lose direction when it comes to technical specifications. This is in line with the view of Grover and Pea (2013) who emphasized that CT at the secondary school level is not just about "being able to answer questions", but about how students manage the complexity of information. The transition from concrete to abstract thinking at the age of 12-13 years old (grade VII) often creates a "comprehension gap" where students have their own logic that is not necessarily aligned with the formal mathematical system.

The results showed that the decomposition and pattern recognition indicators had a much higher score than the other two indicators. This phenomenon is interesting to dissect in more depth. In decomposition, grade VII students show a strong tendency to break down problems into smaller units of information. For example, in the "Stationery Package" question, students are able to separate the entities "Books" and "Pencils" as different cost components.

This good decomposition ability is rooted in everyday life experiences. Students are often exposed to transactional situations (buying and selling), so they intuitively know that the total price is the accumulation of the unit price. However, the decomposition carried out by students is still informational, not yet functional

decomposition. They know the information, but they don't know how each piece of information functions in a system of equations.

Meanwhile, in pattern recognition, students show the ability to see "order". They realized that if the number of pencils increases while the number of books remains, then the increase in prices is caused by pencils. Angeli and Valanides (2020) state that pattern recognition is the most primitive and powerful human cognitive ability. However, obstacles arise when the patterns found have to be presented formally. Low-category students are able to see patterns visually/intuitively, but fail to generalize. Without the ability to generalize, the pattern becomes just a "*lucky guess*" instead of being the basis for the invention of formulas.

The abstraction indicator was found to be the weakest point in the student's CT profile. Why is abstraction so difficult for grade VII students? Epistemologically, abstraction requires students to perform a "release of meaning" from physical objects. Students should stop seeing "Books" as objects with sheets of paper and start seeing them as the variable x that represents monetary value.

Many students in this study refused to use variables. They prefer to write "Book Price" instead of the " x " symbol. This shows the existence of symbolic fear. Variables are considered foreign entities that actually add complexity, not simplify. Weintrop et al. (2016) emphasize that symbolic modeling is at the core of CT. If students fail in abstraction, then the computational process they are doing is just a repetitive arithmetic activity, not a scalable problem-solving activity. Furthermore, this failure of abstraction has an impact on the failure to form a mathematical model. Students tend to immediately perform calculation operations without making a "blueprint" (equation) first. This is a common characteristic of students who have not yet reached the full formal operational stage according to Piaget (Piaget & Inhelder, 1972). They still need a real "grip" to think.

In the algorithm indicators, students show a tendency to jump directly to the final answer (*result-oriented*). This shows that students' understanding of algorithms is still limited to "sequence of counts", not "procedural logic". Algorithms in CT should include coherent, testable, and systematic steps. The findings of the study show that students with high abilities are able to devise neat elimination/substitution algorithms. However, middle group students often lose their step halfway. They start off right (step 1: elimination), but get confused in the next step (step 2: substitution). This algorithmic chaos is often caused by a high cognitive load due to the absence of a strong abstraction model beforehand.

The tendency of low-category students to trial *and error* is actually a primitive algorithm called "Brute Force" in computer science. While this method can find answers, it is very inefficient and does not reflect computational intelligence. Atmarita and Firmantas (2022) state that the low ability of algorithms indicates that students are not used to thinking procedurally-logically; they are more used to memorizing formulas without knowing why the step was taken. To understand why there are obstacles in the Abstraction and Algorithm indicators, researchers conducted in-depth interviews with three subjects representing each category. Here is an excerpt of the dialogue that reveals their metacognition process:

Interview Excerpt: Subject S-01 (High CT Category)

Researcher: "How do you start solving this stationery package?" *S-01*: "First I will separate the book with the pencil, sir. Then I gave him the name, the book x , the pencil y . "If you write a long book, it's going to be confusing." *Researcher*: "Why did you think of using elimination?" *S-01*: "Because in the first equation there are two books, in the second equation there is only one. So the second time I did it was two. Keep reducing, then only the pencil will be left. That's faster than I guessed."

Researcher Analysis: S-01 demonstrates mature Abstraction skills. He sees variables not as a burden, but as a tool for simplification. It also has an efficient algorithm; it does not do *trial and error*, but follows systematic and purposeful procedures.

Interview Excerpt: Subject S-10 (Medium CT Category)

Researcher: "You know that Package A costs 14 thousand and Package B 16 thousand. What did you do first?" *S-10*: "Let me calculate the difference, sir. Package B is 2 thousand more expensive, even though the pencils are 2 more pieces. So I think maybe 1 pencil costs a thousand." *Researcher*: "Why don't you write down equations x

and y like your friend?" S-10: "Oh, I'm confused if you use x and y. I'm afraid of miscalculating the letters. Just try and get the numbers right, it's more real to see the money."

Researcher Analysis: S-10 is very strong in Pattern Recognition, however it suffers from Abstraction Barriers. He is stuck in operational-concrete thinking. To him, numbers have real meaning, while algebraic symbols feel like obstacles. This is what causes the algorithm to score low, as the steps are not based on a solid mathematical model.

Interview Excerpt: Subject S-20 (Low CT Category)

Researcher: "Look at this, what are you looking for?" S-20: "The price of a book is the same as one pencil, sir."
Researcher: "Then why do you add 14,000 and 16,000 in your answer?" S-20: "Yes, because the number is in the question, sir. Then I divide it in two, to be fair."

Researcher's Analysis: S-20 fails at the Decomposition stage. It is not able to understand the relationship between components (items) and value (price). The algorithm is a "random guess" with no clear logical basis. He was not yet able to do computational thinking because the basis of his algebraic logic had not yet been formed.

The finding that abstraction is the most difficult part is in line with Sfard's (1991) theory of *structural vs procedural thinking*. Students in the medium category see algebra as a computational (operational) procedure, not as a mathematical (structural) object. When students are asked to abstract a Stationery Pack problem to $2x+y=14,000$, they feel they are missing the "meaning" of the problem. For them, the number 14,000 is something to work on, not part of a balance structure. The inability to see variables as representations of unknown values (but still having rules) is a major epistemological obstacle. In addition, if referring to Grover and Pea (2013), CT demands the ability to model problems. This modeling problem is closely related to the ability of abstraction. Grade VII students still tend to focus on contextual details (books and pencils as physical objects) rather than the logical relationships between elements. As a result, when those details are omitted and replaced with the x symbol, they lose orientation. Why do students tend to avoid systematic algorithms and prefer *trial and error*? The researchers' analysis found that teaching mathematics at the elementary level often places too much emphasis on "correct answers" rather than "completion processes." Students feel that as long as they find the correct number, then the method is not important.

In CT, the algorithm is precisely the most important part. Algorithms allow a solution to be replicated. This obstacle arises because students are not used to writing down their thinking steps explicitly. The culture of quick calculation without writing down a logical description makes the students' algorithm abilities dull. This study also shows that the scaffolding given by teachers so far may be too focused on calculating techniques (computing) rather than thinking techniques (computational thinking). Teachers often teach "elimination methods" as a memorization of steps, rather than as logic to reduce the complexity of variables.

Based on the finding that the majority of students are stuck in the "medium" category with glaring weaknesses in the abstraction and algorithm design aspects, this study emphasizes the need for a radical paradigm shift in the teaching of algebra in grade VII. Learning must no longer be just a transmission of calculation procedures but must be transformed into a laboratory of cognitive development. Here is an in-depth elaboration of the proposed intervention strategies:

Bridging the Concrete-Abstract Gap through Algebraic Block Manipulatives

The systematic difficulties experienced by students on abstraction indicators prove that the jump from real number arithmetic to variable symbols x and y often occurs too quickly without adequate *scaffolding*. To overcome this, the use of physical and digital manipulatives, such as algebra *blocks*, becomes absolutely necessary. Theoretically, this strategy is rooted in Jean Piaget's theory of cognitive development (Piaget & Inhelder, 1972) and Jerome Bruner's stage of representation (Enactive-Iconic-Symbolic) (Bruner, 1966). By holding and manipulating physical blocks where one large block represents the variable x and one small block represents a constant students slowly learn that mathematical symbols have "weight," "space," and "value." This process facilitates a more seamless cognitive transition from the concrete operational stage to the formal operation. When students move blocks from one side of the equation "scale" to the other, they are actually performing an elimination algorithm operation in physical form. This reduces the *cognitive load* because

students no longer need to imagine variables in the air; They can see and touch the mathematical relationship before finally reducing it to a written symbol.

Internalization of Logic through Natural Language Programming

One of the key findings in this study is the tendency of students to go straight to the final result without systematic steps. To remedy this, teachers should apply the writing habit of "natural language algorithms" before introducing formal algebraic notation. This concept borrows from an approach in computer science where a programmer writes *pseudocode* before writing the actual program code. In the context of algebra, before forcing students to use the symbols x and y , students are asked to describe their logical steps in a narrative sentence. For example: *"The first step, I'm going to match the number of books in both packages so that I can compare the price differences. The second step is that I will reduce the total price of the two packets to find out the price of one pencil."* This strategy forces students to consciously decompose problems and algorithm planning in their minds. When this verbal logic is established, then algebraic symbols are introduced as "short language" or stenography of the logic they already have. In this way, students will not view algebra as a collection of formulas that come down from the sky, but rather as an efficiency tool for expressing their own logical thoughts.

Instructional Differentiation in the Independent Curriculum Framework

The implementation of the Independent Curriculum in Indonesia, which focuses on the development of the Pancasila Student profile especially in the critical reasoning dimension is very relevant to strengthening computational thinking. The findings of this study recommend that teachers design tasks with *Low Floor High Ceiling* characteristics. This type of assignment is designed to be accessible to all students (including low-ability groups through simple decomposition indicators), but has very deep exploration potential for high-ability groups at the abstraction and algorithm optimization stages. For example, in the matter of stationery packages, the teacher not only asks about the price of one item, but can develop the question into: *"If you have 50 thousand money, which combination of packages is the most optimal to get the most items?"* These kinds of questions encourage students to iterate on algorithms and analyze more complex patterns. Through this approach, CT is no longer seen as additional material, but as the spirit of every learning activity that triggers students' independent thinking and critical power in dealing with non-routine problems.

Comparison with Recent Studies

These indicator-level findings both parallel and instructively diverge from the results reported by Astuti et al. (2025) among junior secondary students working with statistics content. In both studies, decomposition was the most consistently mastered indicator across ability groups, and low-ability students in both content domains struggled broadly across the remaining three indicators. However, the two studies diverge on abstraction: Astuti et al. (2025) found that their moderate-ability group actually excelled at abstraction while struggling more with pattern recognition and algorithmic thinking, whereas the moderate-ability subject examined in the present study (S-10) showed the opposite pattern, struggling specifically with abstraction, an inability to treat x and y as free-standing symbolic entities, while showing at least partial success in pattern recognition. This divergence suggests that the cognitive demand of abstraction is not uniform across mathematical content: symbolic variable manipulation in algebra appears to place a distinctly heavier abstraction burden on moderate-ability students than the numerical abstraction required in introductory statistics, a content-specific effect consistent with the broader observation of Li and Oon (2024) that computational thinking's transfer effects vary considerably across different types of learning outcomes and are not uniformly transferable across contexts.

This case-level evidence also speaks to a gap identified by Wu et al. (2024) in their systematic review of 37 studies on computational thinking and problem-solving: despite widespread conceptual agreement that computational thinking supports problem-solving, the review found that the literature has not yet clearly documented how computational thinking actually functions as a problem-solving skill in concrete, real-world tasks. The fine-grained, indicator-by-indicator case analysis undertaken in this study, particularly the detailed account of how S-20 abandoned systematic decomposition in favor of unstructured guesswork, is offered as a small contribution toward closing precisely that documentation gap. Separately, the meta-analysis by Montuori et al. (2024), synthesizing experimental studies on computational thinking and children's executive functions, found that the largest cognitive effects of computational thinking instruction were observed on problem-solving

and on higher-order executive functions such as planning, rather than on more elementary cognitive skills. Because algorithm design and abstraction draw most heavily on exactly this kind of planning and higher-order executive control, this finding helps explain why these two indicators, rather than decomposition or pattern recognition, were the ones most sensitive to differences in students' prior mathematics ability in the present study. Taken together, these converging strands of evidence, from statistics-content comparison, systematic review, and cognitive-ability research, reinforce the conclusion that abstraction is a genuine and domain-sensitive bottleneck in junior secondary students' computational thinking development, a conclusion also consistent with Miswanto (2024), who linked computational thinking characteristics in mathematical problem solving to students' learning styles.

It is also worth situating this bottleneck within the wider literature connecting computational thinking to mathematical modelling and metacognition. Zhang et al. (2024), studying 661 Chinese high school students, found that metacognitive knowledge and metacognitive monitoring significantly predicted students' mathematical modelling skills, and that this relationship was mediated specifically by the critical-thinking dimension of computational thinking, while algorithmic thinking on its own showed no significant mediating effect once metacognition was accounted for. This suggests that a well-organized, verifiable algorithm is less a standalone technical skill than a downstream product of the student's broader metacognitive monitoring of their own problem-solving process. Viewed through this lens, the difficulty subjects S-10 and S-20 experienced with algorithmic thinking may reflect not merely a technical gap in algorithm-design skill, but a more fundamental gap in the metacognitive planning and self-checking that ordinarily organizes such a technique into a coherent, verifiable procedure, a possibility consistent with this study's own finding of generally low metacognitive awareness among students in the moderate and low categories.

Theoretical and Pedagogical Implications

Theoretically, these findings can be read through Sfard's (1991) distinction between operational and structural conceptions of mathematical objects. Students in the moderate and low categories in this study treated algebraic symbols primarily as operational shorthand for a counting procedure rather than as structural objects that could be manipulated according to their own internal logic, a pattern that maps closely onto Sfard's account of why the transition from arithmetic to algebra is cognitively demanding. What the present findings add to this theoretical picture is a more granular, indicator-based account of where the operational-to-structural transition stalls: not uniformly across all algebraic reasoning, but specifically at the abstraction and algorithm stages, while decomposition and pattern recognition, which do not require students to treat symbols as autonomous objects, remain comparatively accessible.

Pedagogically, these results suggest that instructional interventions should be targeted rather than generic. Miswanto (2024) found that students' computational thinking characteristics in mathematical problem solving varied systematically with their preferred learning style, with concrete, hands-on learners showing stronger decomposition skills but weaker abstraction, a pattern broadly consistent with the profiles of subjects S-10 and S-20 in this study. This suggests that the block-manipulative and natural-language-programming strategies proposed in this discussion should be differentiated according to students' learning-style tendencies rather than applied uniformly, and that teachers may need diagnostic tools, informed by both computational thinking indicators and learning-style profiles, to decide which scaffold to prioritize for a given student.

Implications for Assessment and Curriculum Design

Beyond classroom instruction, the indicator-level profile documented in this study also has implications for how computational thinking might be assessed within the Merdeka Curriculum's competency-based framework. Ye et al. (2023) note in their systematic review that most existing computational thinking assessments in K-12 mathematics measure only an aggregate score, which conceals precisely the kind of indicator-specific weaknesses, in this case, abstraction and algorithm, that this study identifies as the primary obstacles for Grade VII students. An assessment approach that reports decomposition, pattern recognition, abstraction, and algorithm as separate sub-scores, rather than a single composite computational thinking score, would allow teachers to identify which specific indicator a student needs support with, rather than only knowing that a student's overall computational thinking ability falls in a particular category.

At the curriculum level, the Capaian Pembelajaran (learning outcomes) for Grade VII algebra under the Merdeka Curriculum already imply several computational thinking indicators, such as recognizing patterns in

variable relationships and constructing systematic solution procedures, without naming computational thinking explicitly (Kemendikbudristek, 2022). Making these connections explicit in teacher guides and lesson-planning templates, in line with the argument by Qolfathiriyus Firdaus et al. (2026) that intentional pedagogical design within conventional algebra classrooms can foster more advanced computational thinking skills, could help bridge the gap between the curriculum's competency-based aspirations and classroom practice that Hunaepi and Suharta (2024) identified as a persistent implementation challenge.

Taken together, the theoretical, pedagogical, assessment, and curriculum implications discussed in this section converge on a single practical message: computational thinking in Grade VII algebra is not a monolithic skill that either is or is not present in a student, but a composite of four distinguishable indicators that develop unevenly and respond to different kinds of instructional support. Treating computational thinking as a single score, whether in classroom assessment, textbook design, or teacher professional development, risks obscuring exactly the kind of targeted intervention that this study's indicator-level findings suggest is needed, and risks leaving the abstraction and algorithm indicators under-addressed simply because decomposition and pattern recognition make the overall picture look more capable than it is.

Overall, the discussion in this study confirms a fundamental thesis: that *computational thinking* is not just a technical skill related to computers, but a cognitive architecture that influences how students perceive, process, and conquer complex algebraic structures. The gap found between high decomposition ability and low abstraction ability is a signal that our mathematics education still often stops at the "problem recognition" stage without providing enough tools to "model solutions". Therefore, bridging this gap should be a top priority. This is done through learning that is explicitly *modeling-based learning*. We must realize that algebraic variables are the highest abstractions that require the maturity of procedural logic. Mathematics education at the junior high school level must no longer be trapped in the narrow ambition of printing a human "counting machine" that only memorizes elimination and substitution procedures. Instead, educational institutions must commit to producing "*computational thinkers*" individuals who are able to decompose real-world chaos, recognize the order behind the data, perform precise symbolic abstractions, and ultimately devise logical, systematic, and generalizable algorithms of solutions. Thus, algebra is no longer a terrifying scourge, but rather a language that empowers students to understand the world in a more structured way.

Limitations

This study has several limitations that should be considered when interpreting its findings. First, the sample was limited to 20 Grade VII students from a single junior secondary school in Bandung City, which restricts the generalizability of the findings to junior secondary students in other regions or under different curricular conditions. Second, the qualitative case analysis focused on three representative subjects rather than the full sample, meaning that the depth of insight into individual reasoning processes was not uniformly available for all ability groups. Third, the scoring of written-test responses and the interpretation of interview transcripts were conducted primarily by a single researcher without a second independent rater, which introduces a degree of subjectivity typical of small-scale qualitative studies (Astuti et al., 2025). Finally, this study did not include a comparison or control group, so the moderate overall computational thinking category reported here should be read as a descriptive snapshot rather than evidence of the effectiveness of any particular instructional approach. Future studies employing larger, multi-school samples and experimental or quasi-experimental designs, as suggested by Wu et al. (2024), would help establish whether the patterns identified here generalize beyond the present context.

A further limitation concerns the instrument itself: although the algebra test items were reviewed by mathematics-education experts for content validity, the study did not conduct a formal pilot administration with a separate sample prior to the main data collection, so item-level statistics such as difficulty and discrimination indices are not available to independently confirm that each item functioned as intended across the high, moderate, and low ability groups. Future replications of this design, particularly those adopting the larger-scale mixed-methods approach demonstrated by Qolfathiriyus Firdaus et al. (2026) with 120 students, would help establish whether the patterns identified here in a much smaller sample generalize to a broader population, and a formal pilot phase would additionally allow item quality to be established quantitatively rather than through expert judgment alone.

Conclusion

Based on the entire series of data analysis, both quantitatively through test scores and qualitatively through response analysis and clinical interviews, this study came to the main conclusion that the *computational thinking* ability of grade VII students in solving algebraic problems is in the moderate (moderate) category. These findings are not just statistical numbers, but reflect the cognitive reality of students in a crucial transition phase. More specifically, the study concludes several fundamental points:

First, there is a sharp cognitive asymmetry among the four main indicators of computational thinking. Students demonstrate relatively stable and satisfactory proficiency in decomposition and pattern recognition indicators. This proves that intuitively, students have the logical ability to decompose the complexity of the story and capture the regularity of contextual data. However, success in this early stage is often stalled and does not continue with the success of the solution due to major obstacles in the abstraction and design aspects of the algorithm. Students are able to see the problem, but they lose the language tools (symbols) and the roadmap (procedure) to solve it mathematically.

Second, the obstacles in the abstraction aspect indicate the existence of a "symbolic wall" in the student's mind. The majority of students still think of algebraic variables as confusing foreign entities rather than as a tool of simplification. This confirms that operational-concrete thinking still dominates the brain workings of grade VII students, where they need physical representations to understand unknown values. Without strong abstraction skills, students' computational thinking processes become inefficient because they are stuck in *cognitively exhausting* trial-and-error methods.

Third, the low quality of the completion algorithm indicates a lack of students' metacognitive awareness. Students tend to be *result-oriented* rather than *process-oriented*. The algorithms compiled are often fragmentary, incomplete, and difficult to replicate for similar problems with higher levels of difficulty. This confirms that thinking about computing is not just a matter of "calculating", but a matter of "building logic systems" which is still a big challenge in junior high school mathematics education.

Taken together, these three findings position decomposition and pattern recognition as an accessible entry point into algebraic reasoning for Grade VII students, while abstraction and algorithm design remain the two indicators most in need of deliberate instructional attention. This pattern both confirms and refines earlier findings from Lai and Lee (2019) and extends them into a domain, algebra, that had not previously been examined at this level of indicator-specific detail, while also standing in productive contrast to Astuti et al. (2025)'s statistics-based findings, underscoring that computational thinking research in mathematics education benefits from content-specific rather than only domain-general investigation.

Recommendations

This research has only touched the surface of the CT profile of students in algebra. Future researchers are encouraged to:

Exploration of Psychological Variables: Examine the relationship between CT ability and other variables such as *self-regulated learning* (self-learning), learning style (visual, auditory, kinesthetic), or *math anxiety*. Building on Montuori et al. (2024), such research could specifically test whether targeted executive-function training, particularly planning and inhibitory control, produces measurable gains in the abstraction and algorithm indicators among Indonesian junior secondary students, which would help determine whether ability-based CT interventions should target general executive-function skills or algebra-specific instructional scaffolds.

Experimental Research: Using experimental designs (such as *Pre-test Post-test Control Group Design*) to test the effectiveness of specific learning models, such as CT-based *Problem Based Learning* or the use of *Scratch* media in algebraic learning. Such experimental work would also help establish the causal relationships that a descriptive study like the present one cannot, particularly whether targeted interventions on abstraction and algorithmic thinking produce measurable gains, and could adopt the embedded-content design principle recommended by Ye et al. (2023), in which computational thinking instruction is woven directly into regular algebra lessons rather than delivered as a separate module.

Longitudinal Study: Observed the development of students' CT abilities from the beginning of grade VII to the end of grade IX to see how cognitive maturity affected their symbolic abstraction abilities over time.

In pursuing these directions, future researchers may also draw on the systematic review methodology demonstrated by Ye et al. (2023), which offers a replicable framework for synthesizing computational thinking findings across mathematical content domains, allowing algebra-specific results such as those reported here to be more readily compared with findings from statistics, geometry, and other strands of the junior secondary mathematics curriculum.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPES Journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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