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ELEMENTARY STUDENTS' COMPUTATIONAL THINKING IN FRACTION PROBLEM-SOLVING PROFILE: IMPLICATIONS FOR 21ST-CENTURY LEARNING

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Abstract
Computational thinking (CT) has become a central competency for twenty-first-century education, yet its integration into mathematics learning, particularly fractions, remains underexplored in the elementary context. This study aimed to profile elementary students' CT in solving fraction problems using a mixed-methods design. A total of 380 students completed a multiple-choice test on fractions, with items mapped to four CT dimensions: decomposition, pattern recognition, abstraction, and algorithmic thinking. Descriptive statistics and categorization placed students into low, medium, and high CT levels. To complement these findings, essay responses from representative students in each category were qualitatively analyzed. The quantitative results indicated a mean CT score of 73.87, with abstraction emerging as the strongest dimension and pattern recognition as the weakest. Most students (68.16%) demonstrated medium-level CT, 19.47% were categorized as low, and only 12.37% achieved high CT. The qualitative findings highlighted distinct reasoning profiles: high-CT students displayed systematic problem decomposition, accurate algorithmic execution, abstraction, and explicit verification; medium-CT students showed procedural fluency but incomplete reasoning; and low-CT students often presented conclusions without revealing their processes. These results suggest that while elementary students possess foundational procedural skills, many lack higher-order CT processes such as verification, justification, and generalization. The study extends CT research into fraction learning and offers implications for instructional design, emphasizing the need to embed CT explicitly into mathematics education to prepare students for twenty-first-century learning demands. These findings also contribute to the global agenda of Sustainable Development Goal (SDG) 4 by highlighting the importance of integrating computational thinking into mathematics education to promote quality and equitable learning.

Keywords: Computational thinking; Fraction problem-solving; Elementary education; Mathematics learning; Student profiles; 21st-century skills; Mixed-methods research

Introduction

In the era of rapid technological advancement and globalization, education systems worldwide face increasing pressure to cultivate competencies that transcend traditional subject knowledge. The framework of twenty-first-century skills identifies a set of abilities essential for learners' success in the digital age, including creativity, critical thinking, problem-solving, collaboration, communication, and computational thinking (CT). Computational thinking, in particular, has gained significant attention because of its relevance not only to computer science but also to broader domains such as mathematics, science, and everyday problem-solving (Wing, 2006; Adorni et al., 2024; Assaf et al., 2024). Defined as a problem-solving process involving decomposition, pattern recognition, abstraction, algorithmic thinking, verification, and communication, CT equips students with the capacity to approach complex tasks systematically and flexibly. Evidence increasingly shows that fostering CT in schools enhances students' ability to apply mathematical knowledge creatively and critically, thereby supporting their readiness for future challenges (Bocconi, Chioccariello, & Earp, 2018; Angeli et al., 2016). This emphasis on equipping learners with higher-order thinking skills is also aligned with the United Nations

Sustainable Development Goal (SDG) 4, which calls for inclusive, equitable, and quality education that prepares students to thrive in the challenges of the twenty-first century.

Mathematics education represents a particularly fertile context for integrating CT, as mathematical tasks inherently require reasoning, abstraction, and structured problem-solving. CT contributes to mathematics learning by encouraging students to not only carry out procedures but also to design strategies, test alternative solutions, and reflect on their reasoning processes (Grover & Pea, 2013; Shute, Sun, & Clarke, 2017). In this way, CT is not an additional subject to be taught in isolation but a set of practices embedded within the learning of core concepts, including arithmetic, algebra, geometry, and particularly fractions. By leveraging CT in mathematics instruction, educators can help students bridge the gap between procedural fluency and conceptual understanding, fostering deeper engagement and long-term retention of knowledge.

Fractions, however, continue to pose persistent difficulties for learners across different educational systems. Numerous studies document that elementary students struggle with understanding part–whole relationships, interpreting the role of numerators and denominators, identifying equivalent fractions, and performing operations with unlike denominators (Yuırtsever & Nilgün, 2012; Deringöl, 2019; Fittriyanti, Zubainur, Anwar, & Novianti, 2020). For instance, research in Indonesian primary schools indicates that students frequently make errors in simplifying fractions, equating denominators, and translating verbal problems into fractional form, leading to fragmented and proceduralized knowledge (Murjani, Kartini, & Elhawwa, 2022). Ratnasari (2020) also found that students often misapply operations with fractions, such as confusing the rules for adding and multiplying fractions, reflecting deeper conceptual misconceptions. Similar findings emerge across different contexts, where both students and even pre-service teachers show limited ability to represent fractions on number lines, use visual models effectively, or connect symbolic representations with conceptual meaning (Fittriyanti et al., 2020; Deringöl, 2019). These studies collectively demonstrate that fraction knowledge is fragile, often confined to surface-level procedures without deeper conceptual grounding.

Given these challenges, researchers argue that cultivating CT processes can play a transformative role in learning fractions. Decomposition helps students break down fraction problems into manageable sub-tasks; pattern recognition enables them to see relationships among equivalent fractions; abstraction allows them to focus on structural properties of ratios rather than superficial features; algorithmic thinking supports systematic procedures for operations; and verification encourages them to check their reasoning against benchmarks such as one-half or one whole (Weintrop et al., 2016; Kong & Abelson, 2019). Without these competencies, students are likely to rely on rote memorization of rules, leading to brittle understanding and frequent misconceptions. Thus, integrating CT into fraction instruction aligns with the call for mathematics education that equips students with twenty-first-century competencies while addressing long-standing difficulties in one of the most foundational mathematical domains.

Despite growing interest in CT, research on its implementation in mathematics particularly in primary education remains limited. Many studies have examined CT development in contexts such as computer science education, robotics, or programming (Brennan & Resnick, 2012; Grover & Pea, 2013), while fewer have focused on mathematical problem-solving in elementary schools. Within mathematics, most investigations employ either quantitative designs using multiple-choice instruments or purely qualitative analyses such as interviews and open-ended tasks (Adiyastuti, Sutama, & Hidayati, 2024; Priharvian & Ibrahim, 2024). While such studies provide valuable insights, they rarely capture the full spectrum of CT skills across learners of varying proficiency levels. Mixed-methods approaches, which combine large-scale quantitative data with in-depth qualitative analysis, are particularly promising for profiling students' CT comprehensively. Through quantitative assessment, students can be categorized into levels such as low, medium, and high CT, while qualitative exploration of representative responses reveals the underlying reasoning processes that differentiate these categories.

Internationally, the integration of CT into twenty-first-century learning frameworks underscores its growing recognition as a foundational literacy alongside reading, writing, and numeracy (Voogt et al., 2015; Cajandig & Ledesma, 2025). Countries revising their mathematics curricula increasingly highlight competencies related to problem-solving, algorithmic design, and abstraction, embedding CT across grade levels (Stephens & Keqiang, 2014). Yet, empirical studies profiling CT in specific mathematical domains, such as fractions, remain scarce. This lack of evidence limits teachers' ability to design targeted interventions and policy-makers' efforts to align curriculum goals with twenty-first-century demands.

Against this backdrop, the present study seeks to profile elementary students' computational thinking in solving fraction problems using a mixed-methods approach. First, students' CT levels are categorized quantitatively based on multiple-choice tests, providing a broad picture of distribution across low, medium, and high categories. Next, representative essay responses from each category are analyzed qualitatively to uncover how CT manifests in actual problem-solving processes. By triangulating these findings, the study aims to provide a nuanced understanding of students' strengths and weaknesses in computational thinking as it relates to fraction learning. Ultimately, the results are expected to inform pedagogical practices, curricular development, and future research agendas aimed at strengthening both mathematical proficiency and twenty-first-century competencies from an early age. Beyond its contribution to filling research gaps, this study also supports global educational priorities by strengthening the evidence base for improving mathematics education quality in line with SDG 4, thereby promoting inclusive and equitable learning opportunities for elementary students.

Method

Research Design

This study employed a mixed-methods design, combining quantitative and qualitative approaches to provide a comprehensive profile of elementary students' computational thinking (CT) in solving fraction problems. The quantitative strand aimed to categorize students into levels of CT (low, medium, and high) based on their performance in multiple-choice questions (MCQs). The qualitative strand further explored the reasoning processes of representative students from each category through essay-type tasks. The integration of these strands provided both breadth and depth in understanding students' CT, consistent with recommendations for mixed-methods studies in mathematics education (Creswell & Plano Clark, 2017).

Participants

The participants consisted of 380 elementary school students from grades five and six in Indonesia. These students were selected using cluster random sampling across several schools to ensure diversity in background and academic achievement. All participants had received prior instruction in fractions as part of the national mathematics curriculum. The sample size was considered adequate for quantitative analysis and ensured sufficient variation to identify students across different CT levels.

Instruments

Two instruments were developed to measure students' computational thinking in the context of fractions:

1. Multiple-Choice Test (10 items)

   The test assessed students' ability to apply CT skills such as decomposition, pattern recognition, abstraction, and algorithmic thinking in fraction problem-solving. Each item was aligned with at least one CT indicator. Example items included identifying equivalent fractions, solving word problems involving addition or subtraction of fractions, and reasoning about part–whole relationships. Item validity was reviewed by three mathematics education experts, and reliability analysis indicated acceptable internal consistency (Cronbach's α = 0.78).
2. Essay Task (1 item)

   A single open-ended problem was designed to capture deeper reasoning processes: *"A water tank is filled 2/5 full. Then, 1/4 more of the tank is added. Is the tank now half full? Justify your answer with calculations and explanations."* This item was selected for its potential to elicit multiple CT dimensions, including decomposition of tasks, recognition of patterns, use of abstraction, sequencing of steps, and verification of results.

Data Collection

Data collection occurred in two stages. In the first stage, all 380 students completed the multiple-choice test under standardized classroom conditions within a 45-minute period. Based on their test scores, students were classified into three categories of CT ability: low, medium, and high. In the second stage, representative students from each category (one exemplar response per level) were purposively selected to complete the essay task. Their written responses were transcribed and prepared for qualitative analysis.

Data Analysis

Quantitative data were analyzed using descriptive statistics, including mean scores, frequency distributions, and percentages of students in each CT category. Each MCQ was mapped to specific CT dimensions, enabling calculation of average performance across decomposition, pattern recognition, abstraction, and algorithmic thinking.

Qualitative data were analyzed using thematic coding aligned with the CT framework (Weintrop et al., 2016). Responses were examined for evidence of: (a) decomposition, (b) pattern recognition, (c) abstraction, (d) algorithmic thinking, (e) verification, and (f) communication. A coding rubric was developed with four levels of proficiency for each construct (0 = absent, 1 = minimal, 2 = partial, 3 = explicit/complete). To ensure reliability, two independent coders applied the rubric to 20% of the sample, achieving a Cohen's Kappa of 0.82, which indicates strong agreement (Landis & Koch, 1977). Discrepancies were resolved through discussion before proceeding with full coding.

Integration of findings occurred during the interpretation phase, where quantitative distributions of CT levels were triangulated with qualitative exemplars to provide a holistic understanding of students' computational thinking.

Ethical Considerations

The study was conducted in accordance with ethical research guidelines. Informed consent was obtained from school authorities, parents, and students prior to data collection. Participation was voluntary, and students were assured that their performance would not affect their school grades. Data were anonymized to protect participants' privacy.

Results

Quantitative Findings

A total of 380 elementary students completed the multiple-choice test on fractions, designed to assess computational thinking (CT) skills. Descriptive statistics of the overall CT scores are shown in Table 1.

Table 1. Descriptive statistics of CT scores (N = 380)

N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
380	90.00	10.00	100.00	28070.0	73.87	20.55	422.20

The results indicate that students' CT scores ranged widely from 10 to 100, with a mean of 73.87, reflecting a moderate overall ability. The relatively high standard deviation (20.55) and variance (422.20) suggest substantial variation in student performance, with some students demonstrating strong CT while others showed considerable weaknesses.

To provide further insight, the test items were mapped to specific CT dimensions. The average performance across these dimensions is summarized in Table 2.

Table 2. Average scores of computational thinking dimensions

CT Dimension	Items	Mean Score (%)	Overall Average (%)
Decomposition	1, 4, 9	93.4; 67.4; 77.9	79.6
Pattern recognition	5, 8	64.2; 55.3	59.8
Abstraction	2, 10	88.4; 80.0	84.2
Algorithmic thinking	1, 3, 4, 6, 7, 9, 10	93.4; 85.0; 67.4; 59.7; 67.4; 77.9; 80.0	75.8

Among the CT dimensions, abstraction was the strongest (M = 84.2%), showing that most students could effectively filter out irrelevant details and represent fraction problems symbolically. In contrast, pattern recognition was the weakest (M = 59.8%), revealing difficulties in identifying relationships among fractions and generalizing procedures. Performance in decomposition (M = 79.6%) and algorithmic thinking (M = 75.8%) was moderate, suggesting that students could generally break down problems and follow procedures but with variability in accuracy and completeness.

Based on composite CT scores, students were classified into three categories: low, medium, and high. Table 3 presents the distribution.

Table 3. Distribution of students across CT categories

CT Category	Frequency	Percentage
Low	74	19.47%
Medium	259	68.16%
High	47	12.37%
Total	380	100%

The findings indicate that the majority of students (68.16%) were in the medium CT category, demonstrating procedural competence but lacking consistency in verification and communication. A smaller proportion (19.47%) were in the low category, often unable to display systematic reasoning, while only 12.37% reached the high category, showing strong mastery across CT dimensions.

Taken together, these results highlight three key patterns: (1) students' CT performance was highly variable, as shown by the wide score range; (2) abstraction emerged as the relative strength, whereas pattern recognition was the most significant weakness; and (3) most students were clustered at the medium CT level, with relatively few reaching high proficiency.

Qualitative Findings

To further illuminate these results, one representative essay response was analyzed from each CT level. The open-ended problem asked: *"A water tank is filled 2/5 full. Then, 1/4 more of the tank is added. Is the tank now half full? Justify your answer with calculations and explanations."*

High-CT Response

A high-performing student demonstrated comprehensive CT skills. The solution was structured into sub-tasks (decomposition): converting 2/5 and 1/4 to equivalent fractions with denominator 20, adding to obtain 13/20, and comparing with the benchmark 1/2 = 10/20. The student explicitly explained each step, verified the result, and concluded correctly that the tank was more than half full. This response scored the maximum across all CT dimensions, illustrating mastery of algorithmic thinking, abstraction, and verification.

Medium-CT Response

A medium-level student successfully converted and added fractions (2/5 + 1/4 = 13/20) but did not explicitly compare the result with 1/2. While the calculation was correct, the reasoning was incomplete, and the final explanation was ambiguous ("already 13, which is more than 20"). This suggests procedural fluency in algorithmic steps but weaknesses in verification and communication.

Low-CT Response

A low-level student wrote only: *"Because 13/20 > 10/20, the tank is more than half full."* While the final conclusion was correct, the response omitted essential intermediate steps such as converting and adding fractions. This indicates reliance on memorized results rather than systematic reasoning, with decomposition and algorithmic thinking largely absent.

Summary of Findings

The combined results suggest three key insights:

1. CT is unevenly distributed across dimensions, with abstraction relatively strong but pattern recognition weak.
2. Most students operate at a medium CT level, able to execute procedures but struggling with verification, flexibility, and communication.
3. Qualitative profiles highlight distinct patterns: high-CT students exhibit systematic, explicit, and reflective reasoning; medium-CT students demonstrate partial but incomplete reasoning; and low-CT students often jump to results without showing processes.

These findings provide evidence that while elementary students possess foundational skills in fractions, their computational thinking is still developing, with critical gaps that need targeted pedagogical interventions.

Discussion

This study aimed to profile elementary school students' computational thinking (CT) in solving fraction problems through both quantitative and qualitative analyses. The findings revealed that the average CT score was moderate (M = 73.87, SD = 20.55), with considerable variability (range = 10–100). Most students (68.16%) fell into the medium CT category, while only a small proportion (12.37%) demonstrated high CT. A dimension-level analysis further revealed that abstraction was the strongest area, whereas pattern recognition was the weakest. The essay responses from selected students provided qualitative confirmation of these patterns: high-level students showed systematic reasoning and verification, medium-level students displayed partial reasoning, and low-level students often presented results without demonstrating their processes. These findings must be interpreted in the broader context of existing research on computational thinking, mathematics education, and twenty-first-century skills.

Uneven Development Across CT Dimensions

The finding that students performed relatively well in abstraction but struggled with pattern recognition reflects an uneven development of CT dimensions. Abstraction, defined as the ability to filter out irrelevant information and focus on essential features (Wing, 2006; Weintrop et al., 2016), was particularly evident in high-performing students who successfully converted fractions into equivalent denominators before performing operations. This demonstrates that even at the elementary level, many students can engage in symbolic reasoning, which is central to mathematics learning.

However, the weakness in pattern recognition (M = 59.8%) indicates that students had difficulty identifying similarities and generalizing relationships among fractions. Prior research has consistently found that pattern recognition is one of the more advanced CT dimensions and develops later than procedural competence (Grover & Pea, 2013; Rittle-Johnson, Schneider, & Star, 2015). For example, Ratnasari (2020) found that Indonesian students often fail to recognize fraction equivalence unless it is explicitly taught. Similarly, Lamon (2007) argued that proportional reasoning and pattern generalization are the cornerstones of rational number understanding, yet they are also the most challenging aspects for students worldwide.

Profiles of Computational Thinking Levels

High-CT Profile

The high-CT group, comprising only 12.37% of the total participants, provides a clear illustration of how computational thinking can be successfully integrated into mathematical problem-solving at the elementary level. These students approached the fraction task in a structured and systematic manner. Their work typically began with a clear decomposition of the problem into smaller sub-tasks: first, identifying that the two fractions involved (2/5 and 1/4) must be expressed in equivalent denominators; second, performing the addition operation; and third, comparing the result with the benchmark of 1/2. This three-step process demonstrates an ability to plan and execute a strategy before carrying out calculations, which reflects the problem structuring emphasized in computational thinking frameworks (Brennan & Resnick, 2012; Wing, 2006).

Algorithmic thinking was another prominent strength of this group. Students not only selected the correct algorithm (finding least common denominators and aligning fractions) but also executed it in a systematic and accurate order. Their solutions often included intermediate steps such as showing 2/5 = 8/20 and 1/4 = 5/20, then adding to obtain 13/20. This sequential reasoning is consistent with Shute, Sun, and Clarke’s (2017) description of algorithmic design as the construction of clear, ordered steps toward problem resolution. Such fluency with algorithms also indicates that high-CT students were not simply applying memorized rules; rather, they demonstrated procedural understanding integrated with reasoning.

Perhaps the most striking characteristic of high-CT students was their ability to use abstraction effectively. These students were able to move seamlessly between the contextual problem (“a tank is 2/5 full, then 1/4 more is added”) and the symbolic representation required for solution. They showed comfort in representing contextual information as fractions, converting those fractions into equivalent forms, and manipulating them symbolically. Weintrop et al. (2016) describe abstraction as one of the defining features of CT, enabling learners to filter out extraneous details and focus on the mathematical essence of a problem. High-CT students demonstrated precisely this skill, revealing a maturity in mathematical reasoning not commonly observed at this age.

Verification and justification set this group apart from their peers. After computing 13/20, high-CT students did not stop at the numerical answer; they explicitly compared the result with 1/2 = 10/20 and articulated that the tank was more than half full. Many went further by providing verbal explanations in complete sentences, showing awareness that their solution must be communicated clearly. This verification process aligns with the debugging stage in computational thinking (Wing, 2006) and reflects metacognitive engagement with the problem.

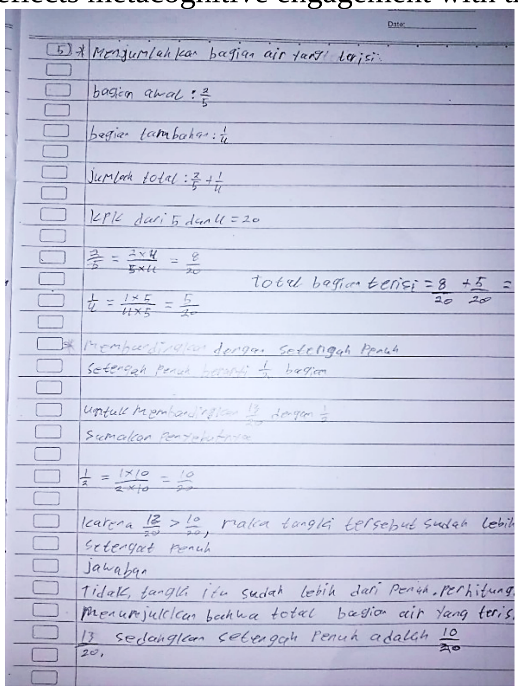

Figure 1. Representative solution from a high-CT student showing systematic reasoning in solving a fraction problem

These findings resonate with international studies showing that students with advanced CT skills demonstrate both algorithmic precision and reflective reasoning. Grover and Pea (2013), for example, reported that high-CT learners tend to cross-check their solutions and articulate reasoning beyond procedural steps. Similarly, Angeli et al. (2016) stressed that the hallmark of CT is not merely performing operations but doing so in a way that is strategic, reflective, and generalizable. In this sense, the high-CT students in the present study exemplify the type of learner envisioned by twenty-first-century skill frameworks: capable not only of solving problems correctly but also of explaining and justifying their reasoning in ways that support transfer to new contexts.

Medium-CT Profile

The medium-CT group represented the majority of students (68.16%), offering a picture of learners who are competent in procedural execution but limited in conceptual reasoning and verification. These students often began their solutions in ways similar to the high-CT group. They could decompose the problem by recognizing the need to combine 2/5 and 1/4 and typically carried out the required algorithm of finding equivalent denominators. Many arrived at the correct result of 13/20, showing that decomposition and algorithmic thinking were present.

However, while their algorithmic steps were correct, their solutions frequently lacked completeness in abstraction and verification. Students in this group could represent the problem symbolically, but their interpretations of the symbolic result were often shallow or ambiguous. For example, after computing 13/20, some wrote statements such as “already 13, which is more than 20.” This response reveals a misunderstanding of the relationship between numerators and denominators, a common fraction misconception reported in the literature (Ratnasari, 2020; Deringöl, 2019). In terms of abstraction, these students could produce the symbols but struggled to map those symbols meaningfully onto the real-world context.

Pattern recognition was particularly weak in this group. While they could identify that 2/5 and 1/4 must be converted before addition, they rarely generalized this as a strategy for other fraction comparison problems. Their reasoning remained tightly bound to the immediate problem, with little evidence of transfer or generalization. This echoes Rittle-Johnson, Schneider, and Star’s (2015) observation that many learners can execute procedures without understanding the underlying concepts, making their knowledge fragile and context-dependent.

Verification was another area of weakness. Medium-CT students often stopped at the numerical result without explicitly comparing 13/20 to 1/2. When they did attempt verification, their explanations were incomplete or imprecise. This gap between computation and reasoning highlights what Hiebert and Grouws (2007) call the “procedural-conceptual divide,” where students succeed in following algorithms but lack the conceptual depth to check and justify their results.

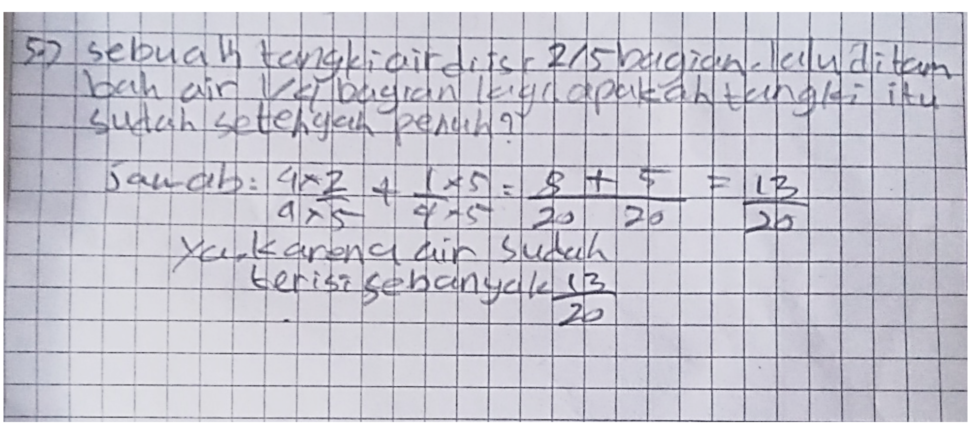

Figure 2. Representative solution from a medium-CT student demonstrating correct steps yet limited reasoning and justification

The medium-CT profile is significant because it captures the reality of most elementary learners: they can compute, but they do not yet reason flexibly or verify systematically. Prior studies in Indonesia and other countries confirm this trend. Fittriyanti et al. (2020) found that while many Indonesian elementary students could add and subtract fractions correctly, they struggled to explain why their procedures worked. Similarly, Zaenal Abidin, Herman, and Wahyudin (2023) reported that teachers observed procedural competence but weak reasoning when integrating CT into mathematics lessons. Thus, the medium-CT group represents an important target for pedagogical intervention, as these students are on the cusp of higher-level reasoning but require scaffolding to move beyond procedures.

Low-CT Profile

The low-CT group, comprising 19.47% of the students, showed minimal evidence of computational thinking processes in their responses. Their work was typically characterized by incomplete decomposition, weak or incorrect algorithmic application, superficial abstraction, and absent verification.

In terms of decomposition, these students often failed to break the problem into sub-tasks. Instead of converting fractions to equivalent denominators and then adding, they sometimes jumped directly to a conclusion. Others attempted decomposition but did so incorrectly, for example, by misaligning denominators or confusing the roles of numerator and denominator. Such errors reflect deep misconceptions about fractions, which have been extensively documented in mathematics education research (Lamon, 2007; Deringöl, 2019).

Algorithmic thinking was fragile. When algorithms were attempted, they were often applied incorrectly, leading to computational errors. In some cases, students produced no intermediate steps at all, suggesting either guesswork or rote reliance on partial knowledge. Abstraction was equally weak; many students failed to translate the contextual problem into meaningful symbolic expressions. Even when they wrote “2/5 + 1/4,” they were unable to manipulate these fractions correctly, showing a lack of symbolic reasoning skills.

Verification and justification were almost entirely absent. One illustrative response was “Because 13/20 > 10/20, the tank is more than half full.” While correct in conclusion, the solution did not include any of the preceding steps necessary to arrive at 13/20. This highlights an important caution: correct answers do not necessarily reflect strong CT. Brennan and Resnick (2012) warned that without examining process evidence, educators may overestimate students’ CT proficiency.

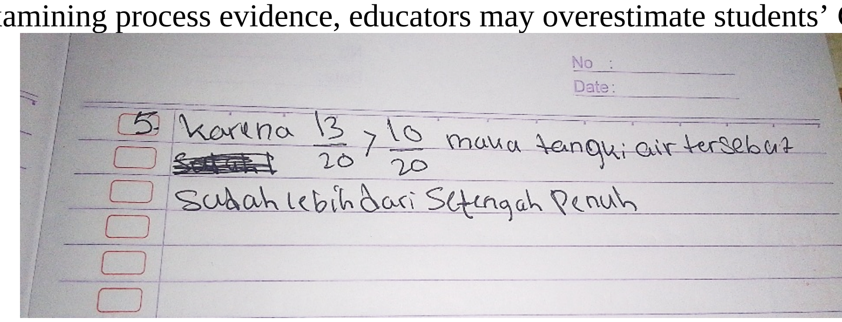

Figure 3. Representative solution from a low-CT student revealing fragmented reasoning and reliance on guessing rather than systematic problem-solving

The low-CT profile aligns with findings from Adiyastuti, Sutama, and Hidayati (2024), who reported that elementary students with weak CT often omit reasoning steps and rely heavily on memorization. It also illustrates the importance of formative assessment practices that evaluate not only outcomes but also the reasoning processes leading to those outcomes.

Comparative Synthesis

When considered together, the three profiles illustrate a developmental continuum of CT in fraction problem-solving. High-CT students demonstrate integrated mastery of all dimensions, combining procedural fluency with abstraction, pattern recognition, and verification. Medium-CT students show strong procedural competence but weak reasoning and generalization, reflecting a transitional stage between algorithmic fluency and conceptual understanding. Low-CT students display fragmented or absent CT processes, with responses that are either incomplete, incorrect, or superficially correct without supporting reasoning.

This continuum supports the idea of CT as a progressive construct rather than a binary skill (Voogt et al., 2015; Kong & Abelson, 2019). It also underscores the importance of analyzing not only test scores but also student work artefacts. By examining how students structure problems, apply algorithms, and justify solutions, educators can better identify strengths and weaknesses in CT development. The inclusion of student artefacts in research provides authentic evidence of reasoning processes and makes visible the often-hidden dimensions of CT.

Implications for Fraction Learning

The findings also contribute to our understanding of fractions as a notoriously difficult area of mathematics. Misconceptions about fractions are well-documented, including treating numerators and denominators as independent whole numbers (Deringöl, 2019), confusing fraction size (Fittriyanti et al., 2020), and failing to see equivalence (Ratnasari, 2020). The current study suggests that CT dimensions intersect with these challenges. For example, weak pattern recognition exacerbates difficulties with recognizing equivalent fractions, while limited verification hinders students from checking whether their results make sense in context.

International assessments such as PISA have shown that Indonesian students often underperform in mathematical reasoning tasks, including fractions (OECD, 2019). The present findings help explain why: although students can perform algorithms, they struggle with higher-order CT processes like generalization, pattern recognition, and reasoning. Strengthening these areas may therefore improve not only computational thinking but also broader mathematical literacy. Integrating these strategies into classroom practice not only enhances mathematical proficiency but also supports the achievement of SDG 4 by ensuring inclusive and effective learning outcomes for all students.

CT and 21st-Century Learning

Computational thinking is increasingly recognized as a key competency for the twenty-first century (Wing, 2006; Voogt et al., 2015). Mathematics, particularly topics like fractions, provides an authentic context for developing CT because it requires decomposition, abstraction, and algorithmic design. However, the fact that only 12.37% of students demonstrated high CT suggests that current instructional practices are not sufficient to cultivate advanced CT at the elementary level. This finding aligns with Bocconi, Chioccariello, and Earp (2018), who reported that CT integration in school curricula remains uneven across countries, often limited to coding or ICT contexts rather than embedded in core subjects such as mathematics.

For Indonesia, the findings resonate with recent reforms emphasizing competencies such as problem-solving and digital literacy in the *Merdeka Curriculum*. However, Zaenal Abidin, Herman, and Wahyudin (2023) found that many teachers still lack confidence in integrating CT into daily mathematics instruction. The present study provides concrete evidence of both the promise (e.g., abstraction ability) and the gaps (e.g., pattern recognition, verification) in students' CT, offering guidance for curriculum and teacher training. This aligns with SDG 4, which emphasizes quality education, as well as SDG 9 (Industry, Innovation, and Infrastructure), given that computational thinking prepares students to actively contribute to innovation-driven societies.

Pedagogical Implications

The results suggest several instructional strategies to strengthen CT in fraction learning:

1. Emphasize verification and reasoning. Teachers should encourage students not only to compute answers but also to explain and check their results. This could be achieved through peer discussion, reflective writing, or self-assessment prompts (Shute et al., 2017).
2. Use multiple representations. Visual models such as fraction strips or number lines can support pattern recognition by helping students see equivalence and proportionality (Lamon, 2007).
3. Integrate problem-based learning. Presenting fractions in real-world contexts can foster decomposition and abstraction skills while also engaging students in meaningful mathematical practices (Priharvian & Ibrahim, 2024).
4. Leverage digital tools. Interactive simulations and apps can scaffold algorithmic thinking and visualization, making abstract fraction concepts more accessible (Korkmaz & Bai, 2019).
5. Differentiate instruction. Given the wide variance in CT performance, teachers should design tasks at varying levels of difficulty and provide tailored scaffolding for low-CT learners while extending challenges for high-CT students (Grover & Pea, 2013).

Theoretical Contributions

From a theoretical standpoint, this study contributes to computational thinking research in three ways. First, it extends the application of CT beyond programming to core mathematics content, supporting calls by Weintrop et al. (2016) and Angeli et al. (2016) to embed CT across disciplines. Second, it demonstrates the value of mixed methods: quantitative profiling provides a broad categorization, while qualitative analysis of student work reveals the nature of reasoning behind those categories. Third, it refines our understanding of CT development in fractions by highlighting the asymmetry among dimensions (abstraction > decomposition > algorithmic thinking > pattern recognition).

Limitations and Future Research

While the study offers important insights, it also has limitations. The essay analysis included only one representative response from each CT level; future studies should analyze a larger sample to capture variability within categories. In addition, the tasks were limited to basic fraction operations; extending to more complex tasks (e.g., proportional reasoning, fraction comparison in real-life contexts) may reveal further nuances in CT. Longitudinal studies are also needed to track how CT develops over time and how specific pedagogical interventions impact different dimensions.

Conclusion

This study examined elementary students' computational thinking (CT) in solving fraction problems through a mixed-methods approach. Quantitative analysis of 380 students revealed that the majority (68.16%) demonstrated medium-level CT, with relatively strong abstraction but weak pattern recognition. Qualitative analysis of student essays confirmed these findings by illustrating distinct profiles: high-CT students integrated decomposition, algorithmic thinking, abstraction, and verification; medium-CT students displayed procedural fluency but incomplete reasoning; and low-CT students often presented conclusions without showing their processes.

These results highlight that while elementary learners possess foundational procedural skills in fractions, many struggle with higher-order CT processes such as generalization, verification, and justification. The findings underscore the importance of embedding CT explicitly into mathematics instruction, not only as technical procedures but as reflective practices that foster reasoning and communication.

Theoretically, this study extends CT research into the domain of fraction learning, demonstrating that CT can serve as a useful lens for analyzing mathematical thinking. Practically, it offers guidance for teachers and curriculum designers to strengthen CT development by emphasizing verification, using multiple representations, and integrating problem-based learning. By nurturing computational thinking from the early grades, educators can better prepare students for twenty-first-century learning demands. In this regard, the study contributes to advancing SDG 4 (Quality Education) by providing empirical evidence on how embedding computational thinking in elementary mathematics fosters equitable, high-quality learning opportunities.

References

Adorni, G., Piatti, A., Bumbacher, E., Negrini, L., Mondada, F., Assaf, D., & Mangili, F. (2024). FADE-CTP: A Framework for the Analysis and Design of Educational Computational Thinking Problems. arXiv preprint. https://arxiv.org/abs/2403.19475

Abidin, Z., Herman, T., & Wahyudin. (2023). The computational thinking in elementary school in the Indonesia new curriculum: A teacher's perspective. *Sekolah Dasar: Kajian Teori dan Praktik Pendidikan*, *32*(1), 1–14. https://doi.org/10.17977/um009v32i12023p001

Adiyastuti, N. N., Sutama, S., & Hidayati, Y. M. (2024). Computational thinking analysis in solving elementary school AKM numeracy problems. *Premiere Educandum: Jurnal Pendidikan Dasar dan Pembelajaran,* *14*(2), 121–137. https://doi.org/10.25273/pe.v14i2.21496

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). Computational thinking: What is it and how to integrate it into K-12 education? *Educational Technology & Society*, *19*(3), 47–57.

Assaf, D., Adorni, G., Lutz, E., Negrini, L., Mondada, F., & Mangili, F. (2024). The CTSkills App: Measuring Problem Decomposition Skills of Students in Computational Thinking. arXiv preprint. https://arxiv.org/abs/2411.14945

Bocconi, S., Chioccariello, A., & Earp, J. (2018). The Nordic approach to introducing computational thinking and programming in compulsory education. *European Schoolnet*.

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American Educational Research Association*. Vancouver, Canada.

Cajandig, A. J. S., & Ledesma, Z. C. (2025). The synergy between 21st-century skills and mathematical proficiency. *International Journal of Research and Innovation in Social Science*, *9*(1), 1371–1377. https://doi.org/10.47772/IJRISS.2025.9135

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). Thousand Oaks, CA: Sage.

Deringöl, Ö. (2019). Misconceptions of primary school students about the subject of fractions: Views of primary teachers and primary pre-service teachers. *International Journal of Evaluation and Research in Education,* *8*(1), 29–38. https://doi.org/10.11591/ijere.v8i1.16290

Fittriyanti, F., Zubainur, C. M., Anwar, A., & Novianti, N. (2020). Misconceptions of elementary school students about fractions. In *Proceedings of the 2nd International Conference on Elementary Education* (pp. 233–240). Bandung: Universitas Pendidikan Indonesia.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher, 42*(1), 38–43. https://doi.org/10.3102/0013189X12463051

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371–404). Charlotte, NC: Information Age.

Kong, S. C., & Abelson, H. (2019). Computational thinking education. Singapore: Springer.

Lamon, S. J. (2007). Rational numbers and proportional reasoning: Toward a theoretical framework for research. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 629–667). Charlotte, NC: Information Age.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159–174. https://doi.org/10.2307/2529310

Murjani, D., Kartini, N. H., & Elhawwa, T. (2022). Analysis of students' difficulties in understanding concepts and solving fraction problems in Class V of State Elementary School 5 Palangka. *International Journal of Universal Education, 1*(1), 27–36. https://doi.org/10.37304/ijue.v1i1.6921

OECD. (2019). *PISA 2018 results (Volume I): What students know and can do*. Paris: OECD Publishing. https://doi.org/10.1787/5f07c754-en

Priharvian, S. M., & Ibrahim, I. (2024). The students' computational thinking ability through problem-based learning in societal context. *Jurnal Didaktik Matematika, 11*(1), 33–47. https://doi.org/10.24815/jdm.v11i1.41034

Ratnasari, R. (2020). Students' errors and misconceptions about operations of fractions in an Indonesian primary school. *Southeast Asian Mathematics Education Journal, 10*(1), 1–12. https://doi.org/10.46517/seamej.v10i1.66

Rittle-Johnson, B., Schneider, M., & Star, J. R. (2015). Not a one-way street: Bidirectional relations between procedural and conceptual knowledge of mathematics. *Educational Psychology Review, 27*(4), 587–597. https://doi.org/10.1007/s10648-015-9302-x

Shute, V. J., Sun, C., & Clarke, J. A. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

Stephens, M., & Keqiang, R. X. (2014). Using a framework of 21st century competencies to examine changes between China's 2001 and 2011 mathematics curriculum standards for basic education. *Journal of Mathematics Education at Teachers College, 5*(2), 33–44.

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies, 20*(4), 715–728. https://doi.org/10.1007/s10639-015-9412-6

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*(1), 127–147. https://doi.org/10.1007/s10956-015-9581-5

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35.