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An exploration of teachers' perspectives on computational thinking in mathematics learning

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Abstract. The integration of Computational Thinking (CT) into mathematics learning has become a key demand in 21st-century education, as it plays an important role in developing logical, creative, and systematic thinking skills. However, in the context of Indonesian education, implementing CT still faces various challenges, particularly regarding teachers' understanding and readiness to integrate it into the learning process. This study aims to explore teachers' perspectives on CT-based mathematics learning, including their understanding, perceived relevance, readiness, and the challenges they face in its implementation at the junior high school level. This study offers a novel contribution by explicitly distinguishing between teachers' conceptual understanding of CT and their pedagogical readiness to implement CT in mathematics learning, a gap that has been insufficiently explored in previous studies. The study employed a qualitative approach with an exploratory design. The research population consisted of junior high school mathematics teachers in Singaraja City, Indonesia. Eight teachers were selected as research participants using purposive sampling based on criteria such as teaching experience, involvement in CT-related or technology-based learning, and willingness to participate in the study. Data were collected through semi-structured interviews, classroom observations, and analysis of learning documents, then analyzed inductively through the stages of data reduction, data presentation, and conclusion drawing. The results showed that the teachers' perspectives on CT-based mathematics learning are conceptually positive but still limited in practice. CT is considered relevant and potentially effective in strengthening mathematical thinking skills; however, its implementation requires systematic support. Based on these findings, the study recommends providing continuous, practice-oriented professional development programs for teachers, developing CT-based mathematics teaching resources, and stronger policy support to facilitate the effective integration of CT into junior high school mathematics learning. The study's implications highlight the importance of strategies to strengthen teachers' capacity.

Introduction

Twenty-first-century education has undergone a fundamental transformation in line with the development of digital technology, globalization, and increasingly complex socio-economic dynamics (Purnadewi & Widana, 2023). In this context, education can no longer be viewed merely as a process of transferring knowledge from teachers to students, but rather as an effort to develop thinking, adaptability, and innovation skills. The 21st-century competencies, often referred to as the 4Cs (critical thinking, creativity, collaboration, and communication), have become the main pillars students must master to compete in the global era (Thornhill-Miller et al., 2023; Voogt et al., 2015). Thus, the education system must shift from an orientation focused solely on memorization and content mastery toward developing higher-order thinking skills. Mathematics, as a core subject, plays a strategic role in this transformation, as it not only teaches numerical skills but also shapes logical, systematic, and critical thinking patterns (Apriliana et al., 2019; Mingjing & Yidi, 2022). In many developed countries, integrating 21st-century skills into mathematics curricula has become a top priority to prepare a generation that is technologically literate, innovative, and adaptable to changing times. However, in many developing countries, including Indonesia, this transformation still faces various structural and cultural challenges, including limitations in curriculum, teacher competencies, and available resources (Masjudin et al., 2024; OECD, 2024).

Mathematics plays an important role not only in developing logical reasoning but also in supporting problem-solving skills that are highly needed in the 21st century (Hartawan, Suharta, et al., 2024; Lee et al., 2023; Szabo et al., 2020). Mathematics learning should not only focus on problem-solving procedures but also encourage students to formulate problems, choose strategies, and evaluate solutions (Vessonen et al., 2025; Zhang et al., 2024; Sumandya et al., 2025). Unfortunately, mathematics teaching practices in schools still tend to emphasize routine problem-solving with mechanical steps. This condition affects students' critical and creative thinking skills, as shown in various international studies such as PISA, which places Indonesian students below the average in mathematical problem-solving abilities (OECD, 2023). In fact, these skills are crucial for addressing the complex challenges of the real world, where solutions are rarely single and require adaptive thinking (English, 2023). Thus, a new paradigm in mathematics education is needed, one that not only emphasizes content mastery but also integrates higher-order thinking skills, including CT skills. (Markandan et al., 2022; Ye et al., 2023). The concept of CT is relevant because it provides a systematic framework that helps students break down problems, recognize patterns, and design solutions more efficiently (Büscher, 2025; Ye et al., 2023).

CT was first widely introduced by Wing (2006) as a 21st-century foundational skill. CT is not merely a technical skill in computer programming; it also encompasses a systematic thinking process for solving problems. (Li et al., 2020; Weintrop et al., 2016; Wing, 2017). The main components of CT include decomposition, pattern recognition, abstraction, and algorithmic thinking (Wing, 2017). This thinking framework provides a foundation for students to develop cross-disciplinary problem-solving skills. In the context of global education, CT is considered a bridge between technological skills and broader critical thinking abilities (Grover & Pea, 2018). Many countries, such as the United States, the United Kingdom, and Singapore, have incorporated CT into their national curricula as part of a strategy to prepare young generations for the challenges of the digital era. (CT4EDU, n.d.; Education, 2013; Singapore, 2021).

Various studies have shown that the use of CT in education, particularly in mathematics and science, has a positive impact on students' higher-order thinking skills. (Orton et al., 2016) developed a framework for integrating CT into STEM, comprising four dimensions: data modeling practices, systems thinking, algorithmic thinking, and representation and simulation. Their study found that students who engaged in CT-based learning showed significant improvements in analytical skills and problem-solving creativity. Furthermore, research by Suarsana et al. (2025) emphasized that CT can enhance the connection between mathematics learning and the real world through simulations, data exploration, and technology-based activities. Similar findings were also reported by Angeli and Giannakos (2019), who emphasize the need for a clear CT curriculum framework so that teachers can implement it consistently. In other words, integrating CT into mathematics learning not only enriches students' learning experiences but also expands the role of mathematics from a purely procedural subject to a means of developing more adaptive, reflective, and creative thinking skills. This highlights that CT holds a strategic position in strengthening the relevance of mathematics education to the competency demands of the 21st century.

The integration of CT into mathematics learning holds great potential, as both are grounded in logical, systematic, and analytical thinking. Traditionally, mathematics has taught students how to construct deductive arguments, identify patterns, and formulate solutions based on consistent rules. CT reinforces these processes by providing a more explicit approach through decomposition, abstraction, pattern recognition, and algorithms (Wing, 2017). For example, when solving a system of linear equations with two variables, students can apply CT strategies by breaking the problem into smaller steps, recognizing patterns in the coefficients, abstracting essential information, and then designing a systematic solution algorithm, such as the substitution or elimination method. In this way, CT not only enriches problem-solving strategies but also teaches students how to approach problems in a structured manner. This aligns with the view of Li et al. (2020) and Wang et al. (2022) that CT is not merely about technical programming skills but rather about a mindset that supports learning across disciplines. Therefore, integrating CT into mathematics learning can help students develop higher-order thinking skills such as critical thinking, problem-solving, and creativity in finding alternative solutions.

Although the potential of integrating CT into education has been widely recognized, its implementation in various countries still faces several challenges. One of the main challenges is teachers' limited understanding of CT and how to integrate it into their teaching practices (Hartawan, Putri, et al., 2024). Grover & Pea (2018). It is often said that many teachers consider CT identical to computer programming, but in reality, its scope is much broader and can be applied without advanced technological tools. Another challenge arises from curricula that have not explicitly positioned CT as a core competency, leaving teachers without clear guidance on how to design learning activities. Additionally, limited resources and infrastructure, such as internet access, digital devices, and educational software, also become hindering factors, particularly in developing countries. Angeli & Giannakos (2019) emphasize that, without a consistent curriculum framework and adequate professional support, the integration of CT often remains at the level of discourse or limited experimentation. In some developed countries, this challenge has been addressed by organizing intensive training programs for teachers and providing easily accessible digital learning resource banks (Bocconi et al., 2016; Kong et al., 2022; Juniantari et al., 2025). However, in countries with limited infrastructure, CT integration is still not operating optimally.

In Indonesia, the adoption of CT in mathematics education faces more complex challenges. Most mathematics teachers are still oriented towards conventional methods that focus on procedural mastery and exam preparation, rather than the development of higher-order thinking skills (Rosadi et al., 2025). On the other hand, teachers' limited digital literacy makes it difficult for them to use technology-based learning resources, which have the potential to enhance students' CT skills (Liu et al., 2024; Nouri et al., 2020; Tondeur et al., 2023). This situation is further exacerbated by infrastructure constraints, especially in rural schools that lack stable internet access and adequate digital devices. As a result, many teachers still rely on textbooks as the primary learning resource, even though conventional textbooks often do not explicitly facilitate the development of computational thinking skills (Graves et al., 2021; Timotheou et al., 2023). Various studies show that the use of innovative learning resources, such as digital simulations, interactive apps, problem-based projects, and educational games, can significantly enhance students' CT skills (Gundersen, 2025; Noordin, 2025). However, such practices are still rarely found in mathematics learning in Indonesia. The gap between the theoretical potential of CT and its implementation in practice highlights the need for more in-depth research to understand how teachers interpret, design, and implement CT-based mathematics learning in line with local contexts and limitations. Therefore, this research is crucial for comprehensively exploring teachers' perspectives on CT-based mathematics learning, providing an empirical foundation for the development of policies, training, and more contextual learning resources in the future.

Although previous studies have extensively examined the integration of Computational Thinking (CT) in mathematics education, most of them have focused on the development of instructional models, learning materials, or the measurement of students' learning outcomes and higher-order thinking skills (Angeli & Giannakos, 2019; Markandan et al., 2022; Suarsana et al., 2025). These studies generally report positive impacts of CT on students' problem-solving and analytical abilities. However, relatively little attention has been paid to teachers as the primary agents of CT implementation, particularly regarding how they conceptualize CT and how this understanding translates into pedagogical readiness in real classroom practice. Furthermore, existing research often treats teachers' CT competence as a unified construct, without clearly distinguishing between conceptual understanding (what teachers know about CT) and pedagogical readiness (how teachers operationalize CT in mathematics instruction). As a result, the reasons why positive teacher perceptions of CT do not consistently lead to effective classroom implementation remain underexplored, especially in developing country contexts such as Indonesia.

Therefore, the novelty of this study lies in its explicit focus on examining the conceptual–pedagogical gap in teachers' perspectives on CT-based mathematics learning. By systematically differentiating teachers' conceptual understanding, perceived relevance, readiness, and implementation challenges, this study extends previous research by providing a more nuanced explanation of why CT integration often remains at a conceptual level rather than being fully embedded in mathematics teaching practice. This perspective has not been sufficiently highlighted in prior studies, particularly within the Indonesian junior high school context.

The urgency of research on teachers' perspectives on CT-based mathematics learning stems from the need to bridge the gap between theory and practice in the field. Several studies have shown that CT plays a crucial role in enhancing students' critical thinking, problem-solving, and creativity skills. However, most of these studies focus on developing learning models or teaching materials, while understanding and exploring teachers' views, who are the primary implementers of learning, has been rarely explored, particularly in the Indonesian context, which has its own characteristics and challenges. More importantly, few studies have empirically examined how teachers' conceptual understanding of CT aligns or fails to align with their pedagogical readiness to implement CT in mathematics classrooms. The Indonesian education context shows significant variation in school infrastructure, teacher readiness, and the availability of technology-based learning resources. If research focuses solely on developing teaching materials or curricula without considering the realities of classroom implementation, CT integration will be difficult to sustain and may not align with teachers' actual needs on the ground. Therefore, exploring teachers' perspectives is crucial to understanding how they interpret, perceive, and apply CT principles in mathematics learning. This study not only provides empirical insight into teachers' readiness and challenges but also offers strategic contributions to the development of professional training, educational policies, and the design of more contextual, CT-oriented mathematics learning.

Based on the above background, the main problem addressed in this study is the gap between teachers' positive perceptions of Computational Thinking and their limited ability to implement CT explicitly in mathematics learning practices. Although CT is widely recognized as relevant to mathematics education and 21st-century skills development, there is insufficient empirical evidence on how teachers conceptualize CT, how they perceive its relevance, and the challenges that hinder its classroom implementation in the Indonesian junior high school context.

Accordingly, this study aims to explore teachers' perspectives on CT-based mathematics learning by addressing the following research objectives: (1) to examine teachers' conceptual understanding of Computational Thinking; (2) to analyze teachers' perceptions of the relevance of CT in mathematics learning; (3) to investigate teachers' readiness to implement CT-based mathematics instruction; and (4) to identify the pedagogical, institutional, and contextual challenges faced by teachers in integrating CT into classroom practice. By achieving these objectives, the study is expected to contribute both theoretically and practically to the development of more effective CT integration strategies in mathematics education.

Method

Research Method and Design

This study uses aqualitative approach with an exploratory research design. This design was selected because the study aimed to gain an in-depth understanding of teachers' perspectives on the implementation of CT in mathematics learning, including their understanding of the CT concept, perceptions of its relevance, and the experiences and challenges they face. An exploratory design is appropriate because it allows the researcher to gain a comprehensive understanding of a relatively new phenomenon that has not been extensively studied, particularly among middle school mathematics teachers (Kooloos et al., 2023).

Participants, Research Subjects, and Informants

The research subjects consisted of junior secondary school mathematics teachers. These teachers also served as key informants, providing rich, contextual insights into CT-based mathematics learning practices. A total of eight teachers participated in the study, which was considered sufficient to achieve data saturation, as no new themes emerged in the later stages of data collection.

Sampling Technique and Sample Selection Criteria

Participants were selected using purposive sampling, which allows researchers to intentionally select individuals who possess relevant experience and knowledge related to the research focus. The selection criteria were (1) Active mathematics teachers at junior secondary schools, (2) A minimum of one year of teaching experience, (3) Prior exposure to CT-related learning, STEM education, or technology-based instruction, and (4) Willingness to participate voluntarily in the study.

When additional relevant informants were identified, snowball sampling was used to enrich the data. The sampling process was terminated once data saturation was achieved.

Research Location, Duration, and Trustworthiness

The research was conducted in Singaraja City, Buleleng Regency, Bali Province. This location was chosen for the presence of schools that have implemented technology-based or innovative learning practices aligned with CT principles. The research was carried out over three months, including preparation, data collection, and analysis. To ensure the trustworthiness of the research findings, several strategies were employed: (1) Source triangulation, by comparing interview, observation, and document data; (2) Technique triangulation, by using multiple data collection methods, and Member checking, by confirming key findings with participants to ensure accuracy and credibility.

Research Procedures

The research procedures were conducted in the following stages:

Image 1. Research Procedures Diagram

These stages are visually summarized in a research procedure diagram (Image 1), which illustrates the iterative and reflective nature of the qualitative research process.

Data Collection Techniques and Research Instruments

The primary instrument of the research is the researcher themselves (human instrument), who plays a role in determining the focus, selecting informants, collecting data, analyzing, and interpreting the research findings. The supporting instruments include: 1) A semi-structured interview guide, containing questions related to teachers' understanding of CT, their experiences with learning resources, and how they integrate them; 2) An observation sheet, to record teacher and student activities that reflect CT aspects such as decomposition, pattern recognition, abstraction, and algorithmic thinking; and 3) A document analysis sheet, to examine the learning resources used or developed by the teachers. The research instruments are presented below.

Table 1. Aspects and Interview Indicators

Aspects to Be Explored	Interview Indicators
Understanding of CT	The teacher can explain the general meaning of CT.
	The teacher understands the connection between CT and mathematics learning.
	The teacher is familiar with CT components, including decomposition, pattern recognition, abstraction, and algorithmic thinking.
Perception of the Relevance of CT in Mathematics Learning	The teacher views CT as an essential 21st-century skill.
	The teacher understands the benefits of CT in enhancing students' logical thinking and problem-solving skills.

Aspects to Be Explored	Interview Indicators
	The teacher assesses that CT can enrich mathematics learning strategies.
Experience in Implementing CT in the Classroom	The teacher has experience integrating CT elements into mathematics learning.
	The teacher mentions examples of learning activities that reflect CT.
	The teacher explains the challenges faced in implementing CT.
Teacher Readiness and Competence	The teacher feels confident in implementing CT-based learning.
	The teacher has pedagogical and technological knowledge to support the implementation of CT.
	Teachers assess the need for specialized training to gain a deeper understanding of CT.
Need for Support and Learning Resources	Teachers need guidance, example materials, or training related to CT
	Teachers identify learning resources that support the integration of CT.
	Teachers provide feedback on the development of CT-based mathematics learning resources

Table 2. Observation Sheet

Aspects to Be Explored	Indicators
Teacher Activities in Learning	The teacher facilitates students in breaking down problems into smaller parts (decomposition)
	The teacher encourages students to recognize patterns (pattern recognition).
	The teacher helps students perform abstraction.
	The teacher guides the development of systematic steps (algorithmic thinking).
Student Activities in Learning	Students actively analyze problems and identify patterns.
	Students collaborate in problem-solving strategies.
	Students explain the logical reasoning behind their solution steps.
	Students use technology appropriately according to the context.
Learning Context	The material and activities are relevant to real-life situations.
	The media or learning resources support the exploration of CT.

Data Analysis Techniques and Criteria

Data analysis was conductedusing an inductive thematic analysis approach, comprising three main stages: 1) Data reduction, which involves selecting and simplifying data from interviews, observations, and documents; 2) Data presentation, presented in the form of narratives, tables, and thematic matrices that show the connections between CT elements and mathematics learning practices; and 3) Conclusion drawing and verification, through the interpretation of patterns and themes that emerge from the data. The analysis focused on identifying teachers' conceptual understanding of CT, pedagogical readiness, perceived relevance, and implementation challenges, and interpreting these in relation to existing theoretical frameworks and prior research findings.

Results and Discussion

Here are the key findings that the researcher successfully identified in this study, as follows:

Teacher's Understanding of the Concept of CT

In general, teachers understand CT as a systematic, logical, and structured way of thinking to solve problems. However, this understanding still varies. Most teachers associate CT with computers or other digital technologies, while only a few understand it as a thinking pattern that can be applied in various contexts, including mathematics. Teachers who have attended STEM education training demonstrate a more comprehensive understanding of CT. They recognize the four main components: decomposition, pattern recognition, abstraction, and algorithmic thinking, and are able to explain how these components relate to mathematical problem-solving activities. Below is a quote from a mathematics teacher interviewed in this study.

"*I think CT is not just about using computers, but how we think logically and step by step when solving problems*," (G6).

"*For me, CT is about thinking systematically, but the term is something I've only heard recently*," (G3).

This finding indicates that, although CT has not yet been fully conceptualized, teachers have intuitively applied CT principles in mathematics learning. The research results show that middle school mathematics teachers in Singaraja City are aware of the importance of CT in mathematics education, although their level of understanding varies. Most teachers understand CT as the ability to think logically, systematically, and in a structured manner when solving problems. This result aligns with the basic concept of CT as outlined by Wing (2006), which states that CT is "a way of thinking that involves formulating problems and solutions in such a way that they can be effectively executed by both humans and machines." In this context, the teachers' understanding, which emphasizes logical thinking and step-by-step problem-solving, indicates that the basic principles of CT have already been embedded in mathematics learning practices, even though they have not yet been explicitly articulated in terms of terminology. This aligns with the opinion of. (Shute et al., 2017), which emphasizes that CT is not only relevant to computer science but also serves as a cross-disciplinary framework that can be integrated into learning contexts, including mathematics.

However, this study extends previous research by revealing a conceptual gap in teachers' understanding of CT. While prior studies (e.g., Shute et al., 2017; Grover & Pea, 2018) primarily focus on defining CT conceptually, the present findings demonstrate that teachers' conceptual understanding does not automatically translate into pedagogical competence. Teachers tend to understand "what CT is" but struggle with "how CT should be operationalized" in mathematics instruction. This distinction constitutes a key novelty of this study.

Some teachers, especially those with experience in STEM education training, have reached a more reflective understanding of CT. They see CT not only as a systematic thinking process but also as a cognitive strategy for developing students' problem-solving and metacognitive abilities. This perspective aligns with the conceptual model (Brennan, K., & Resnick, 2012), which views CT as consisting of three main dimensions: computational concepts (thinking concepts such as iteration, algorithms, patterns), computational practices (the practices of designing, testing, and refining solutions), and computational perspectives (a reflective attitude towards how computational thinking is applied). Thus, it can be concluded that teachers' understanding of CT at the conceptual level has been established, but there is still a need to strengthen computational practices and perspectives. Teachers understand "what" CT is, but have not yet fully mastered "how" CT is systematically applied in mathematics learning.

Teachers' Perception of the Relevance of CT in Mathematics Learning

The interview results indicate that all teachers have a positive view of the relevance of CT in mathematics learning. They believe that CT aligns with the characteristics of mathematical thinking, which demands logic, order, and problem-solving abilities. Most teachers see CT not as a new concept but as a reinforcement of the thinking methods that have long been applied in mathematics education.

"*In my opinion, CT is very suitable to be applied in mathematics because it trains students to think logically and systematically*," (G3).

"*In mathematics, students often have to look for patterns or create steps to find formulas. That's already CT, actually*," (G5).

Teachers also view CT as relevant to the demands of 21st-century learning. They realize that students need more than just mastering concepts; they also need to think critically, creatively, and analytically when solving problems.

"*Nowadays, students need to learn how to think like a computer, not in terms of using a computer, but in how they can organize logical steps*," (G7).

"*If CT is developed in mathematics, students won't just memorize formulas, but they will be able to understand the thinking process behind those formulas*," (G1).

This perspective reflects the understanding that teachers view CT as a framework that helps students structure their mathematical thinking. Teachers who have attended STEM education training even assess that the application of CT can make learning more meaningful and contextual.

"*CT helps students understand why a formula works. They can think from the problem to the model, and then to the solution. It makes mathematics come alive*," (G6).

"*I think CT can make students more creative, especially if it's combined with projects or small experiments in class*," (G8).

However, some teachers also express challenges in implementing CT, particularly related to time, resources, and the lack of concrete teaching guidelines.

"*I agree that CT is important, but we need real examples of its implementation in teaching modules. Sometimes the theory is good, but the practice is difficult*," (G2).

"*The problem is the facilities. In urban schools, it might be possible, but in my school, the internet is sometimes unstable*," (G4).

The novelty of this study lies in categorizing teachers' perceptions into three distinct interpretative patterns:

CT as an Inherent Part of Mathematical Thinking. Teachers view CT as a continuation of mathematical thinking, particularly in problem-solving, pattern recognition, and the formulation of solution algorithms. This perspective aligns with the findings of (Weintrop et al., 2016), which state that CT has a strong overlap with mathematical thinking, as both are oriented toward pattern analysis, modeling, and the formulation of systematic procedures

CT as a Means of Strengthening 21st-Century Skills. Teachers regard CT as an essential tool for helping students think critically, logically, and adaptively about technology. This supports the findings of Markandan et al. (2022) and Timotheou et al. (2023), which emphasize that CT serves as a framework that strengthens higher-order thinking skills (HOTS) and digital literacy, particularly in mathematics and science (Pratama et al., 2024).

CT as an Ideal Concept That Is Still Difficult to Implement. Some teachers understand the relevance of CT but lack the pedagogical skills to implement it explicitly. This phenomenon is consistent with the findings of Liu (2023), Liu et al. (2024), and Ukkonen et al. (2024), who found that teachers' perceptions of CT are often positive, but its implementation remains low due to a lack of training and educational policy support.

From these three patterns, it appears that teachers' understanding of CT's relevance is in a transitional stage from conceptual to practical. Teachers have acknowledged the strategic value of CT, but its translation into classroom activities remains limited. This indicates a gap between awareness and action, as Liu (2023) also identifies, emphasizing that the successful implementation of CT requires structural support, including training, curriculum guidelines, and digital learning resources.

The results of this study reinforce the view of Wing (2006); Wing (2017) that CT is not merely a technical skill but a fundamental way of thinking that needs to be integrated across all disciplines, including mathematics. The teachers in this study have demonstrated an initial awareness of this, particularly in the context of problem-based learning. Furthermore, these findings align with the study by Brennan, K., & Resnick (2012), which highlights the importance of the computational perspectives dimension, namely, how individuals understand the world through the lens of CT. Several teachers in this study (e.g., G5, G6, and G8) demonstrated reflective awareness of CT's benefits for students, indicating the emergence of this perspective in the local context. On the other hand, this study's results confirm Angeli and Giannakos's (2019) finding that the integration of CT in the classroom largely depends on teachers' competencies and beliefs. Teachers with prior STEM training demonstrate greater readiness to understand the relevance of CT, while others still require guidance to connect CT more concretely with mathematics learning objectives. Overall, teachers' views on the relevance of CT in mathematics learning can be summarized into three main points: (1) CT is considered relevant because it strengthens mathematical and logical thinking skills; (2) teachers perceive CT as an important approach for developing 21st-century skills; and (3) the implementation of CT remains limited due to a lack of knowledge, training, and supporting facilities.

These findings indicate that Indonesian teachers are in the early stages of internalizing CT as a modern mathematics learning paradigm. With capacity strengthening through practical training and educational policy support, CT has the potential to become an essential foundation for developing students' mathematical literacy and CT in the digital era

Teacher Readiness and Challenges in Implementing CT in Mathematics Education

The research findings show that teachers are highly enthusiastic about integrating CT into mathematics learning. However, their readiness varies depending on their professional experience, pedagogical skills, and support from school facilities. Generally, teachers who are already familiar with project-based learning or STEM education are more ready than those who have not had similar experiences.

"*I feel ready to try applying CT, but I still need guidance. Sometimes I'm unsure where to start, whether from the problem, the model, or student activities*," (G6).
"*If there were concrete examples or practical training, I'm sure I could apply it. The problem so far is that the training has been mostly theoretical*," (G3).

Some teachers see CT as highly relevant and potentially applicable, but they face resource and time constraints. These limitations make it difficult for CT to become an explicit part of their lesson planning.

"*Teaching time is limited, especially with the curriculum targets we have to meet. It's hard to add new activities like CT*," (G4).
"*If the facilities supported it, like having computers and stable internet, it would be easier. But in my school, the resources aren't evenly distributed*," (G2).

Several teachers demonstrated conceptual readiness but were not fully prepared technically and pedagogically. They understood the value of CT in developing logical thinking and problem-solving skills, but struggled to convert it into concrete learning activities.

"*I understand the meaning of CT, but it's hard to translate it into teaching steps. Sometimes, I'm confused about choosing activities that can represent CT*," (G1).
"*We're actually ready, but we need practical training, not just theory. If we practice directly in the classroom, the results will be much more tangible*," (G8).

The teachers also highlighted the lack of support from school policies and the scarcity of contextual learning resources to integrate CT into mathematics content.

"*The teaching modules are flexible now, but there are no examples of CT implementation. If there were guidelines, it would be easier for us to adapt*" (G5). "*We need a teacher community to share practices. Sometimes other teachers have already implemented CT, but it's not documented*," (G7).

This study contributes new insights by demonstrating that teacher readiness to implement CT is multidimensional, encompassing conceptual understanding, pedagogical competence, institutional support, and resource availability. Teachers in this study frequently exhibit strong conceptual awareness of CT but remain pedagogically constrained in translating this understanding into concrete instructional practices. This distinction provides empirical evidence that positive attitudes and conceptual knowledge alone are insufficient to ensure effective CT integration in mathematics classrooms. From the interview results, it is evident that teachers have a strong enthusiasm for implementing CT, but they face several challenges, including limited pedagogical understanding, lack of training, and technology-related infrastructure constraints. Teachers' readiness is measured not only by their understanding of CT but also by their self-efficacy in applying it in the classroom. Teachers who are accustomed to using problem-based learning or project-based learning approaches demonstrate a higher level of readiness because these models share similar principles with CT, such as systematic thinking, collaboration, and exploration-based learning. However, the effective implementation of CT requires institutional support and policies. (Liu, 2023) which mentions that the integration of CT in schools requires three key elements: teacher competence, availability of learning resources, and a learning environment that supports exploration. In this study, teachers in Singaraja City show great potential in the first aspect but still require strengthening in the last two.

These findings are consistent with research by Liu et al. (2024) and Stupurienė et al. (2024), which shows that, in general, teachers have a positive perception of CT, but its implementation is low due to a lack of ongoing training and structural support. Both studies emphasize that hands-on, contextual CT training is more effective at enhancing teachers' confidence than theory-based training. The study by Ukkonen et al. (2024) and Widana et al. (2024), also shows that many teachers understand the conceptual relevance of CT but are unable to integrate it into teaching modules and assessment activities. This is due to the lack of clear CT assessment models and limited guidance on lesson design that explicitly accommodates decomposition, pattern recognition, abstraction, and algorithmic thinking. In addition, Liu et al. (2024) found that teachers' readiness to implement CT is strongly influenced by professional experience and support from school policies. Teachers who receive hands-on training and have access to digital learning resources are better prepared than those in areas with limited infrastructure. These research findings are also in line with Angeli & Giannakos (2019), who emphasize that the successful integration of CT in primary and secondary education depends heavily on teachers' pedagogical content knowledge, particularly their ability to contextualize CT within subject matter. In this study, mathematics teachers in Singaraja have a solid foundational understanding but still require pedagogical scaffolding to translate CT into meaningful teaching practices.

Based on the above findings and discussion, this study offers several theoretical and practical implications for integrating CT into mathematics education. Theoretically, this study contributes to the CT literature by refining the understanding of teacher readiness through the lens of a conceptual–pedagogical gap. It extends existing CT frameworks by demonstrating that teacher cognition and teacher practice are not linearly related, particularly in mathematics education contexts. Practically, the findings underscore the need for practice-oriented professional development programs that emphasize classroom-level CT implementation, the development of CT-integrated mathematics teaching materials, and policy support that explicitly positions CT within curriculum guidelines. These implications provide actionable directions for teacher educators, curriculum developers, and policymakers.

In general, junior high school teachers demonstrate a high level of conceptual readiness but limited pedagogical readiness. They understand the potential of CT to strengthen mathematics learning but struggle to translate this into lesson design and implementation due to a lack of policy support, facilities, and practical training.

Conclusion

The results of this study reveal that teachers' perspectives on CT-based mathematics learning are fundamentally positive, yet remain at a conceptual level and are not yet fully implemented in teaching practice. Teachers view CT as a systematic, logical, and analytical approach to thinking that is relevant to helping students understand mathematical concepts more deeply and in context. For some teachers, CT is perceived as a way of thinking that can strengthen students' problem-solving and mathematical reasoning abilities, rather than merely as a technological or computer programming skill. Although teachers hold positive perceptions, most do not yet have a comprehensive understanding of how CT can be integrated into teaching and learning. CT components, such as pattern recognition and decomposition, are more easily recognized and applied, whereas abstraction and algorithmic thinking still rarely appear explicitly in classroom practice. These teacher perspectives indicate that CT is considered important and relevant, but still requires support through professional training, examples of best practices, and practical implementation guidelines tailored to the context of mathematics learning in junior high schools. Teachers' readiness to integrate CT largely depends on their professional experience, digital literacy, and support from school policies. Teachers who have participated in STEM-based training or innovative learning programs tend to have more reflective and open perspectives toward CT implementation, whereas those without such experience often view CT as a new concept that is difficult to apply.

Thus, teachers' perspectives on CT-based mathematics learning are conceptually positive but still limited in practice. Teachers recognize the relevance of CT in strengthening mathematics learning, yet they lack the adequate capacity and support to implement it systematically. Therefore, strategic efforts are needed through continuous professional development, the provision of contextual learning resources, and school policies that support pedagogical innovation, so that CT can be fully operationalized in mathematics learning in Indonesia.

Based on these findings, several recommendations can be proposed. First, continuous, practice-oriented professional development programs should be provided to strengthen teachers' pedagogical competence in integrating CT into mathematics instruction, with particular emphasis on classroom-level implementation of abstraction and algorithmic thinking. Second, curriculum developers and teacher education institutions are encouraged to design and disseminate CT-based mathematics teaching resources, including lesson plans, learning modules, and assessment instruments that explicitly incorporate CT components. Third, educational policymakers should provide institutional and policy support by explicitly positioning CT as an integral part of mathematics learning and by facilitating access to supportive infrastructure and professional learning communities. Finally, future research is recommended to examine the impact of teachers' CT readiness on student learning outcomes and to explore scalable models of CT integration across diverse educational contexts.

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