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Exploring Teachers' Self-Perceived Understanding and Reported Implementation of Computational Thinking in Early Childhood Education

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Abstract

Computational thinking (CT) has emerged as an important competency in contemporary education, including early childhood education (ECE). This study aimed to explore teachers' self-reported understanding and reported implementation of CT in ECE and to identify the challenges encountered in its implementation. An online survey with a convergent mixed-methods design was employed, in which quantitative and qualitative data were collected concurrently through the same online questionnaire and analyzed separately before being integrated during interpretation. Because both strands came from a single self-report instrument, integration was narrative and does not constitute triangulation. The study involved 97 ECE teachers in Java and Yogyakarta. Quantitative data were collected through closed-ended questionnaire items addressing teachers' understanding and reported implementation of CT, while qualitative data were obtained from open-ended questionnaire responses (OQR) concerning teachers' classroom practices and implementation challenges. Quantitative data were analyzed using descriptive statistics and Pearson correlation, while qualitative data were analyzed using deductive content analysis based on predefined CT indicators. On the item concerning the concept of CT in ECE, 43.30% of teachers reported understanding it, 35.05% reported moderate understanding, 13.40% reported not understanding it, and 8.25% reported a very high level of understanding. Self-reported understanding and reported implementation were positively correlated ($r = .632$, $p < .001$, $n = 95$). Teachers reported implementing CT through activities such as classification, pattern recognition, sequencing, prediction, and simple problem-solving, as well as through play-based strategies, STEAM-based learning, and the use of unplugged media. The most frequently reported challenges were limited learning media (52.1%), a lack of concrete implementation guidelines (47.9%), and limited time and readiness (38.5%); fewer teachers reported difficulty understanding the CT concept (16.7%) or integrating it into play (13.5%). The integrated findings indicate that teachers reported varying levels of understanding and described implementing CT through classroom practices that varied in depth and scope, while continued support is needed to strengthen conceptual understanding and the use of appropriate strategies and learning media. Future research should focus on developing contextually appropriate models, methods, and learning media to support CT implementation in early childhood education.

Keywords: *Computational thinking, teacher perceptions, children*

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INTRODUCTION

Computational thinking (CT) has increasingly been recognized as an important competency in contemporary education, including early childhood education(Bati, 2022; Mulyati, 2023). CT was popularised by Wing (2006) as a set of problem-solving skills drawn from computer science, and definitions and component lists have since varied across the literature (Grover & Pea, 2013; Shute et al., 2017). In this study, CT is conceptualized as a way of thinking that involves four core components: decomposition, pattern recognition, abstraction, and algorithmic thinking (Nurhopipah et al., 2021; Yang et al., 2022). These four components constitute the conceptual foundation for examining teachers' understanding of CT. In early childhood education, however, CT is not necessarily expressed through formal computational tasks or digital technologies. Instead, its development can be supported through developmentally appropriate learning activities, including sequencing, classification or grouping, pattern recognition, prediction, and simple problem-solving through play. In this study, these activities are treated as observable manifestations or pedagogical practices through which CT may be implemented, rather than as additional CT components. The implementation of CT is also considered in relation to teachers' use of play-based strategies, STEAM-based learning, unplugged media, and other learning media that support children's engagement with CT-related thinking. This conceptual distinction is maintained throughout the study to differentiate the core components of CT from the classroom activities and pedagogical strategies used to implement them in early childhood education(Yuliana et al., 2024).

This global positioning of CT is reflected in a growing body of international research situating it within early childhood education (ECE), ranging from technology-based interventions such as robot programming (Nurhopipah et al., 2021; Yang et al., 2022) to developmentally appropriate, unplugged approaches (Bati, 2022). More broadly, developments in educational technology have reshaped expectations of what schools should deliver, extending their role beyond the transmission of knowledge toward the cultivation of higher-order thinking skills needed to face future challenges (Hartono et al., 2025). In Indonesia, this international momentum is echoed in national education policy that emphasizes digital literacy and 21st-century competencies as part of the response to the Fourth Industrial In Indonesia, this international momentum is reflected in national education policies emphasizing digital literacy and 21st-century competencies as part of the response to the Industrial Revolution 4.0, as outlined in the Regulation of the Minister of Education, Culture, Research, and Technology Number 12 of 2024 concerning the Curriculum for Early Childhood Education, Basic Education, and Secondary Education, as amended by the Regulation of the Minister of Basic and Secondary Education Number 13 of 2025, and CT has begun to be incorporated into curriculum development and teacher training initiatives (Bati, 2022; Mulyati, 2023). However, implementation at the school level continues to face challenges, particularly regarding teachers' understanding and readiness to apply CT in practice (Alam et al., 2025). Early robotics and tinkering curricula, for example, have shown that young children can engage with CT-related ideas (Bers et al., 2014).

Despite this momentum, research that directly examines how teachers understand and enact CT rather than its effects on children as end users remains limited, particularly in the Indonesian early childhood context. International studies have investigated ECE teachers' preconceptions and self-efficacy regarding CT (Avci & Deniz, 2022). Indonesian theoretical reviews likewise

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report that misconceptions and limited conceptual knowledge continue to hinder classroom implementation (Bati, 2022; Mulyati, 2023). Yet most existing Indonesian empirical studies remain narrow in scope. Many are research-and-development projects situated within a single institution or district, such as a CT learning-strategy model developed across 36 ECE units in Kudus (Yuliantina, 2025) or a STEAM-based unplugged-coding programme at a single institution (Insani, 2025). Other studies examine CT outcomes in children rather than teachers' own knowledge and classroom practice (Angeli & Giannakos, 2020; Faizatul Fitriyah et al., 2023); these studies explicitly note that many cases in Indonesia still lack a clear picture of the activities teachers can use to stimulate CT in young children. This underscores that teachers' knowledge and practice not only children's learning outcomes warrant closer empirical attention. Existing research has provided valuable insights into teachers' understanding and implementation of computational thinking (CT) in education. However, limited attention has been given to examining teachers' CT understanding alongside their classroom implementation within the context of early childhood education, particularly across institutions. This study addresses this gap by combining quantitative data on teachers' self-reported understanding of CT and its implementation with qualitative evidence from open-ended questionnaire responses concerning their classroom practices and implementation challenges. By drawing on data from ECE teachers in Java and Yogyakarta, the study provides empirical evidence on how teachers understand and implement CT within the Indonesian early childhood education context. It also contributes to the teacher-cognition perspective by examining the relationship between teachers' knowledge and practice in the specific context of CT in early childhood education(Chen, 2024; Roehrig & Kruse, 2005)

Teachers play a crucial role in implementing educational innovations in schools. Teachers' knowledge and understanding will determine how new learning concepts are integrated into play-based activities. In the case of computational thinking, teachers are not only required to understand the basic concepts of computational thinking but also to design learning activities that encourage students to develop these skills. If teachers do not yet possess sufficient knowledge, the implementation will remain theoretical and not be maximized (Farman et al., 2025).

In the context of early childhood education, the development of thinking skills is a key foundation for cognitive development; therefore, introducing computational thinking at an early age is essential to support cognitive development. Integrating computational thinking into the early childhood education curriculum can serve as a strategy to enhance the quality of learning and prepare children to face the challenges of the 21st century. (Yuliantina, 2025)

However, in reality, the implementation of computational thinking in early childhood education still faces various challenges. One of the challenges is teachers' limited understanding of the concept of computational thinking. Many teachers still hold the misconception that computational thinking is synonymous with coding activities and the use of digital technology, leading them to view its implementation as difficult and ill-suited to the characteristics of young children (Insani, 2025). This indicates a gap between the competency requirements of the 21st century and teachers' readiness to implement computational thinking-based learning. In addition, limited research and professional development for teachers are also factors contributing to the low level of implementation in early childhood education.

This gap is especially consequential given that CT does not require sophisticated technology to be introduced in early childhood settings. Unplugged approaches allow children

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to engage with CT concepts sequencing, simple problem-solving, and pattern recognition through everyday play, without reliance on digital devices life (Octalia & Ardiansyah, 2021; Yuliana et al., 2024) and are considered developmentally more appropriate for children at the concrete-preoperational stage than technology-based methods (Bati, 2022). If teachers hold a narrow or technology-centric understanding of CT, however, this low-cost, developmentally appropriate pathway risks being underused or misapplied in practice reinforcing the need to first establish an accurate, evidence-based picture of teachers' actual knowledge and classroom implementation before designing interventions or training programs. This is consistent with Piaget's constructivist account of young children as learners who construct knowledge through concrete, hands-on experience (Erawati & Adnyana, 2024; Mandar & Sihono, 2025).

Therefore, improving teachers' competence in understanding and implementing computational thinking is of utmost importance. Teachers serve as facilitators who determine the success of learning, so their level of knowledge will influence the quality of computational thinking implementation in the classroom (Djatmika, 2023). Based on the above discussion, a study is needed to analyze early childhood education teachers' level of understanding of computational thinking and how it is implemented in the classroom. This analysis is important to assess the extent to which teachers are prepared to implement computational thinking in the learning process, as well as to identify the challenges they face in the field.

Theoretical Framework

This study draws on two bodies of theory. First, teacher cognition research holds that what teachers know and believe shapes how they plan and enact instruction (Ertmer, 2005; Roehrig & Kruse, 2005; Chen, 2024); teachers' self-reported understanding of CT is therefore examined in relation to their reported implementation. Second, diffusion of innovations theory (Rogers, 2003) describes how a new idea such as CT is gradually adopted by practitioners and why support is needed in the early stages of adoption. Experiential learning theory (Kolb, 1984) is used only as a cautious lens for interpreting why practice-based activities may be reported more readily than abstract concepts. Because understanding is measured by self-rating rather than by a knowledge test, it is treated throughout as teachers' perceived understanding, not as demonstrated knowledge.

The purpose of this study is to explore teachers' self-reported understanding of computational thinking, to examine its reported implementation in early childhood education, to test the association between the two, and to identify the challenges teachers report. This study is expected to provide a comprehensive overview of the actual conditions in the field, while the findings are intended to serve as a reference for early childhood education administrators and policymakers in designing teacher training and professional development programs. Consequently, early childhood education will become more adaptable to the changing times, particularly in addressing 21st-century challenges, thereby enabling children to develop their thinking skills optimally from an early age.

The study addresses four research questions: (RQ1) What is the level of ECE teachers' self-reported understanding of CT? (RQ2) To what extent, and through which practices, do teachers report implementing CT? (RQ3) Is teachers' self-reported understanding associated with their reported implementation? (RQ4) What challenges do teachers report when implementing CT?

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METHODS

This study employed an online survey with a convergent (concurrent) mixed-methods design, in which closed-ended and open-ended items were included in a single questionnaire, to describe ECE teachers' self-reported understanding and reported implementation of CT. This design was selected over sequential explanatory or exploratory designs because the research aim was not to explain or explore one data type using the other in sequence, but rather to collect quantitative and qualitative data simultaneously and compare them (Creswell et al., 2006). Because both strands come from one source (a single questionnaire) and both are self-reports, the design is better characterised as an open-ended survey with narrative integration than as full mixed-methods triangulation: the qualitative responses elaborate the quantitative results but do not independently validate them or make them more objective. The quantitative approach was used to identify general trends in teachers' understanding, while the qualitative approach aimed to explore implementation practices and the challenges faced in the field.

Participants

The participants consisted of 97 early childhood education (ECE) teachers from approximately 76 ECE institutions across Central Java, West Java, and Yogyakarta. Data were collected via an online survey, with the questionnaire link distributed through HIMPAUDI chapter heads and WhatsApp groups. Participants were recruited using a non-probability voluntary sampling technique, based on willingness to participate and the following eligibility criteria: teaching Group A or Group B and having at least one year of teaching experience. The participants taught Group A or Group B classes in kindergartens and playgroups, spanning both public and private institutions of the 97 respondents, 31 (32.0%) taught Group A (ages 4–5 years) and 66 (68.0%) taught Group B (ages 5–6 years). The responses represented approximately 76 different institutions.

Research Instrument

The research instrument consisted of a structured questionnaire distributed via Google Forms, comprising three sections: (1) respondents' demographic profiles, (2) Likert-scale questions to measure understanding of CT concepts (decomposition, pattern recognition, abstraction, and algorithmic thinking) and the reported implementation of CT (including sequencing, problem solving through play, pattern recognition/grouping/prediction, play-based strategies, STEAM-based learning, and unplugged and other learning media), and (3) open-ended questions to explore teaching practices, challenges, and needs for media development. The Likert-scale section consisted of 11 items: three understanding items rated on a four-point scale, with response categories ranging from "Very well understood" to "Not understood at all": "Very well understood," "Understood," "Moderately understood," and "Not understood at all." The eight implementation items were rated on a five-point frequency scale: "Very often" (5), "Often" (4), "Sometimes" (3), "Rarely" (2), and "Never" (1). The three understanding items were scored from 4 ("Very well understood") to 1 ("Not understood at all"). Because the two sets of items use different response formats, their means are not compared with each other. In Table 6 the two lowest categories ("Rarely" and "Never") are combined for display. The items assessed teachers' understanding of CT concepts, perceptions of non-digital CT, CT components, and the reported implementation of CT (Table 1). Scores were calculated by summing the item scores within each indicator and converting the results into percentages for

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descriptive analysis. Mean scores of the understanding items were interpreted using the criteria in Table 3.

Table 1. Research Instruments

Variable	Indicator	Data Format
Teachers' Understanding of CT	The Concept of CT in ECE	Likert scale
	Perception of non-digital CT	Likert scale
	CT Components (decomposition, pattern recognition, abstraction, algorithmic thinking)	Likert scale
Implementation of CT in Institutions	Institutional implementation; classroom activities (sequencing, problem solving, pattern recognition/grouping/prediction); strategies and media (play, STEAM, unplugged media)	Likert scale
Implementation Practices	Types of CT activities implemented	Content Analysis
Barriers to Implementation	Challenges teachers face in implementing CT	Content Analysis

The research instrument was developed based on the operational definition of computational thinking provided by the Computer Science Teachers Association and the International Society for Technology in Education (CSTA & ISTE, 2011), while being adapted to the four-component conceptualization employed in this study. As the CSTA/ISTE definition encompasses a broader scope including problem formulation, data organization and analysis, and generalization the instrument items cover only a portion of these elements. Content validity was established through expert assessments conducted by media and subject matter experts in their respective fields.

Data Collection

Data collection was conducted concurrently during a single period, from December 2025 to January 2026. All 97 respondents submitted the online questionnaire independently through Google Forms without researcher intervention. The questionnaire consisted of closed-ended items for the quantitative component and open-ended questions for the qualitative component. The open-ended questions asked teachers to describe their experiences, classroom practices, and challenges related to the implementation of computational thinking (CT). Accordingly, the qualitative dataset consisted of respondents' written responses to the open-ended questionnaire questions. These responses were coded as Open-ended Questionnaire Responses (OQR) and used to provide qualitative insights into teachers' CT practices and implementation challenges. Both quantitative and qualitative data were collected concurrently through the same questionnaire, analyzed separately using their respective analytical procedures, and subsequently integrated during the interpretation stage. Four implementation items had one or two missing responses (two respondents in total), so item means and percentages use all available responses (n = 95–97), whereas Cronbach's alpha and the correlation use the 95 respondents with complete data. The challenges item was answered by 96 respondents and the open-ended item on classroom activities by 93.

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Data Analysis

Quantitative data were analyzed using descriptive statistics, including frequencies and percentages, to describe the distribution of teachers' understanding and implementation of computational thinking (CT). Pearson correlation analysis was also conducted to examine the relationship between teachers' understanding and implementation of CT. Because the understanding and implementation items use different response formats, each composite score was computed as the mean of its items on the original response scale (four-point for understanding, five-point for implementation); Pearson's r is unaffected by linear rescaling, but the raw means of the two constructs are not compared with each other. Correlation strength was interpreted following Schober et al. (2018). Qualitative data from the Open-ended Questionnaire Responses (OQR) were analyzed using deductive content analysis. The coding framework was derived from the predefined CT indicators used in the questionnaire, including teachers' understanding of CT concepts and components, reported classroom practices, pedagogical strategies, and the use of learning media. This directed (deductive) approach (Hsieh & Shannon, 2005) is partly circular, because the open-ended questions and the coding categories derive from the same indicators as the closed-ended items; it therefore describes how teachers talk about those indicators and cannot identify categories beyond them (see Limitations).

A The unit of analysis was each response to the open-ended item on classroom activities, and one response could be assigned to more than one category. Of the 97 respondents, 93 answered this item. Using the CT indicators in the questionnaire as the coding frame, responses were assigned to six activity categories: (1) blocks, puzzles, and construction (arranging blocks, Lego, puzzles, or mazes; n = 30, 32.3%; e.g., "Menyusun balok" [stacking blocks]); (2) grouping or sorting (grouping objects by color, shape, size, or type; n = 27, 29.0%; e.g., "Mengelompokkan benda berdasarkan warna bentuk" [grouping objects by color and shape]); (3) patterns and threading (making color or shape patterns, including threading beads; n = 24, 25.8%; e.g., "Meronce dengan pola warna tertentu" [threading beads in a given color pattern]); (4) ordering or sequencing (ordering objects, numbers, or steps of a routine; n = 21, 22.6%; e.g., "Mengurutkan benda dari kecil ke besar" [ordering objects from small to large]); (5) role-play (n = 4, 4.3%; e.g., "Bermain peran" [role-playing]); and (6) digital media (video, educational games, laptop; n = 7, 7.5%). Altogether, 74 responses (79.6%) fitted at least one category, 12 responses (12.9%) mentioned only grouping or sorting, and 19 responses (20.4%) fitted none, including empty answers ("-", "Ya") and everyday activities not linked to the CT indicators (e.g., tooth brushing, cooking). Two responses described instruction-following games. The codebook, with category definitions and example segments, is provided in [Supplementary Table __]. The excerpts reported in the Results were selected as illustrative examples of different response types: OQR 1 explicitly maps one activity onto all four CT components, OQR 2 and OQR 8 represent the grouping responses, which were among the most frequent, and OQR 10 is one of the two instruction-following games.

The qualitative analysis involved coding, categorization, data reduction, and interpretation to identify recurring patterns of CT implementation and the challenges reported by teachers. Coding was conducted manually by two researchers. The two coders independently reviewed and categorized the relevant OQR excerpts, and discrepancies were resolved through discussion and consensus. No formal intercoder reliability coefficient was calculated. The quantitative and

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qualitative findings were subsequently integrated during the interpretation stage to compare the reported patterns in the quantitative data with the qualitative evidence from teachers' responses.

Data Integration

Data analysis was conducted separately according to the type of data and subsequently integrated during the interpretation phase. Integration was achieved by connecting qualitative themes and selected Open-ended Questionnaire Responses (OQR), such as OQR 1, OQR 2, OQR 8, and OQR 10, with the quantitative findings for the corresponding indicators. The qualitative responses were used to elaborate and contextualize the quantitative results by illustrating teachers' reported classroom practices, strategies, and challenges related to CT implementation. This process enabled the identification of areas of convergence and divergence between the two datasets. In particular, the integrated findings indicated that relatively positive levels of teachers' reported understanding and implementation were accompanied by qualitative evidence showing that CT-related classroom practices varied in their depth, scope, and use of developmentally appropriate strategies and media. Integration was narrative only: no joint display was constructed, and the selected excerpts illustrate rather than test the quantitative findings (Fetters et al., 2013).

Data Validity

Integrating the two strands does not by itself establish validity, because both come from the same self-report questionnaire and share its biases (Podsakoff et al., 2003). Quantitative quality evidence consists of expert content validation and Cronbach's alpha per construct (see Research Instrument). Quantitative findings on teachers' understanding and reported implementation of CT were complemented by qualitative evidence from the open-ended questionnaire responses (OQR), allowing the quantitative results to be interpreted in greater depth and context. The two datasets were collected concurrently through the same questionnaire, analyzed separately, and subsequently compared and integrated during the interpretation stage. For the qualitative component, trustworthiness was supported through an audit trail documenting the coding and categorization process. The coded OQR excerpts were systematically linked to the predefined CT indicators, and the coding and categorization were reviewed by two researchers. Any discrepancies were discussed and resolved through consensus. This process provided a transparent basis for interpreting the qualitative findings and their relationship to the quantitative results.

Ethical Considerations

Participation was voluntary. Respondents completed an online questionnaire via Google Forms and were asked to provide their names and institutional affiliations; this information was kept confidential, was not used in the analysis, and was not reported in this article, nor did the excerpts presented in the Results section contain personally identifiable information. Before beginning the questionnaire, respondents read a statement explaining the study's purpose and the use of their responses, and indicated their willingness to participate by proceeding to complete the form. This study was exempt from formal ethical review under (institutional regulations) because it involved a voluntary survey with minimal risk targeting adult professionals.

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RESULT AND DISCUSSION

Teachers' understanding of CT

Based on the closed-ended questionnaire data, teachers demonstrated varying levels of self-reported understanding of computational thinking (CT) in the context of early childhood education. The distribution of teachers' self-reported understanding of CT is presented in Table 2. Qualitative evidence from the open-ended questionnaire responses (OQR) was used to provide additional context regarding teachers' understanding and reported implementation of CT in classroom practices.

Table 2. Teachers' Self-Reported Understanding of Computational Thinking

CT Understanding Indicator	Very Well Understood (%)	Understood (%)	Moderately Understood (%)	Not Understood (%)	Mean	Interpretation
Understanding the concept of computational thinking in early childhood education	8.25	43.30	35.05	13.40	2.46	Fair
Understanding that computational thinking is not always related to computers or digital devices	12.40	41.20	36.10	10.30	2.56	High
Understanding the core components of CT (decomposition, pattern recognition, abstraction, and algorithmic thinking)	19.60	46.40	29.90	4.10	2.81	High

The results of the analysis show that only 8.25% of teachers fall into the "**Very Well Understood**" category, while 43.30% fall into the "understood" category, 35.05% fall into the "moderately understoodd" category, and 13.4% not understood the concept of CT. These findings indicate that although most teachers have a basic understanding, conceptual depth regarding CT remains uneven. This pattern may indicate that abstract concepts such as CT have not yet been fully internalised by some teachers; however, because understanding was self-assessed rather than tested, this interpretation remains tentative.

Regarding the second indicator, which pertains to the understanding that CT is not always synonymous with the use of digital devices, the results show that 12.4% of teachers **Very Well Understood**, 41.2% understood it, 36.1% have a moderatwly understood, and 10.3% still hold the misconception that CT is exclusively related to digital technology. This indicates a narrowing of the meaning of CT, which tends to be perceived as a technology-based skill, whereas conceptually, CT places greater emphasis on systematic, logical, and structured thinking processes.

Furthermore, regarding the indicators of understanding CT components which include decomposition, pattern recognition, abstraction, and algorithms relatively better results were

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obtained, with 19.6% of teachers having a **Well Understood**, 46.4% having an understood, 29.9% having a moderate understood, and only 4.10% not understood. These findings indicate that the operational aspects of CT are easier to understand than its conceptual aspects. This is consistent with experiential learning theory (Kolb, 1984), in which individuals tend to understand concepts more easily through direct practice rather than theoretical abstraction. Mean scores were interpreted using the criteria in Table 3.

Note. Category was determined based on the mean-interval classification shown in Table 3 below, following common practice in Likert-scale interpretation (interval width = range/number of categories = 3/4 = 0.75).

Table 3. Mean Interval Classification Criteria

Mean Interval	Category
1.00 – 1.75	Low (Tidak Paham)
1.76 – 2.50	Fair (Cukup Paham)
2.51 – 3.25	High (Paham)
3.26 – 4.00	Very High (Sangat Paham)

The results of the mean value calculations indicate that teachers' understanding of CT falls into the moderate to high category. Understanding of CT components (mean = 2.81) and the perception that CT is not always digital (mean = 2.56) fall into the high category, while understanding of basic CT concepts (mean = 2.46) falls into the fair category. Teachers therefore rated their understanding of the CT components higher than their understanding of the overall concept; this difference is within the same four-point scale, but it should be read with caution because the components item combines four concepts in one statement.

Statistical Relationship between Understanding and Implementation

To move beyond a purely descriptive account and provide statistical evidence for the relationship discussed in this study, descriptive statistics (mean and standard deviation) were calculated for all eleven Likert-scale indicators (n = 95–97 available cases), as shown in Table 4.

Table 4. Descriptive Statistics of All CT Indicators

Indicator	Mean	SD
Understanding the concept of CT	2.46	0.84
CT is not always related to digital devices	2.56	0.85
Understanding the core components of CT: decomposition, pattern recognition, abstraction, and algorithmic thinking	2.81	0.80
Institution has implemented CT-based learning	3.49	0.92
Teacher consciously designs sequencing activities	3.92	0.66
Children are invited to solve simple problems through play	4.05	0.63
Classroom activities train pattern recognition/grouping/prediction	4.09	0.58
Play used as the main strategy	3.92	0.69
STEAM-based learning implemented	3.59	0.74
Unplugged (non-digital) media used	3.61	0.76
Media used supports CT development	3.64	0.76

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Note. Understanding items (first three rows) were rated on a four-point scale; the response format of the implementation items is five-point ("Very often" to "Never"). Means are therefore not comparable across the two constructs. All means use available responses (n = 97 for seven items; n = 95–96 for the four items with missing responses). The mean for "Institution has implemented CT-based learning" (3.49) is on the five-point scale; Table 6 combines the two lowest categories for display, so a mean computed from its four displayed categories (2.53) is not comparable and is not used.

A composite understanding score (mean of the three understanding items) and a composite implementation score (mean of the eight implementation items) were computed for each respondent. Each composite was the mean of its items on the original scale (four-point for understanding, five-point for implementation), and the 95 respondents with complete data on all 11 items were included in the correlation analysis. A Pearson correlation analysis was then conducted to examine the relationship between the two composite scores, as reported in Table 5.

Table 5. Correlation between Understanding and Implementation of CT

Variables	Pearson r	p-value
Understanding of CT (composite) × Implementation of CT (composite), n = 95	0.632	< 0.001

The analysis reveals a positive, moderate-to-strong, and statistically significant correlation between teachers' understanding and their implementation of CT ($r = .632$, $p < .001$). This indicates that teachers who rated their understanding of CT higher also reported more implementation of it ($r^2 \approx .40$), a pattern consistent with teacher cognition research (Ertmer, 2005; Roehrig & Kruse, 2005). Because both variables are self-reports from the same questionnaire, the association may be inflated by common-method bias (Podsakoff et al., 2003) and says nothing about causal direction.

The Implementation of CT in Education

Data on the level of CT implementation in early childhood education institutions can be seen in Table 6. It shows that 9.3% of teachers reported implementing CT very often, 47.4% often, 29.9% sometimes, and 13.4% rarely or never. The mean on the original five-point scale is 3.49 (SD = 0.92). Table 6 combines "Rarely" (10.3%) and "Never" (3.1%) into one category. About 43.3% of respondents reported implementing CT only sometimes, rarely, or never, so reported implementation is not uniform across teachers.

Table 6. Teachers' Reported Implementation of CT in ECE Institutions

CT Implementation Indicator	Very Often (%)	Often (%)	Sometimes (%)	Rarely/Never (%)
Implementation of CT in ECE institutions	9.3	47.4	29.9	13.4

When these findings are considered in conjunction with those regarding understanding, the positive correlation reported above (Table 5) indicates that higher self-rated understanding goes together with higher reported implementation. The claim that teachers with limited understanding implement CT only partially and unsystematically is not tested directly here; it

is suggested only by the open-ended responses discussed below. Teacher cognition research (Ertmer, 2005; Roehrig & Kruse, 2005) offers one possible interpretation, but the cross-sectional self-report design cannot establish it.

Responses to the open-ended questionnaire items (OQR) add context to the quantitative findings by giving concrete examples of how teachers describe implementing CT in the classroom. Of the 93 teachers who answered this item, the activities described most often were arranging blocks, puzzles, or similar materials (n = 30; 32.3%), grouping or sorting objects (n = 27; 29.0%), making patterns, for example by threading beads (n = 24; 25.8%), and ordering objects or steps (n = 21; 22.6%); role-playing was mentioned less often (n = 4; 4.3%). A response could mention more than one activity. The excerpts below were selected as illustrative examples of different response types (a multi-component response, grouping responses, and an instruction-following game) and do not represent all responses.

> "*bermain peran dengan permainan tokoku., adapun kegiatan untuk stimulasi dekomposisi biasanya terkait dengan mengenalkan macam2 jenis produk yang dijual di rak tokoku. abstraksi: anak mampu menyebutkan jenis produk. Nah untuk pola biasanya anak dapat mengelompokkan produk sesuai jenisnya, kalau untuk algoritma : anak mengurutkan ukuran besar kecil produk*" ["Role-playing with the 'my shop' game. For decomposition stimulation, the activity usually involves introducing the various types of products sold on the shop shelf. Abstraction: the child is able to name the product type. For pattern recognition, the child groups products by type, and for algorithm, the child sequences the products from largest to smallest."] **(OQR 1)**

This excerpt from OQR 1 shows a teacher labelling a single play activity with all four CT components (decomposition, abstraction, pattern recognition, and algorithmic thinking). The mapping is, however, open to debate: naming the types of products is closer to labelling or classification than to abstraction, and ordering products by size is a seriation task that does not necessarily involve designing an algorithm. The excerpt may therefore indicate familiarity with CT terminology rather than a deep understanding of the components, and, being a self-report, it cannot show that this practice actually occurs in the classroom.

However, 27 of 93 responses (29.0%) mentioned simple classification activities, and 12 (12.9%) mentioned nothing else, such as grouping objects by color, shape, or type. While these activities do reflect one component of CT pattern recognition they do not fully encompass the entire spectrum of CT skills.

> "*Mengenalkan Angka dengan benda yang menyesuaikan jumlah Angka beserta pengelompokan warna" ["*Introducing numbers using objects that match the quantity, along with grouping by color*"] (***OQR 2)**

> "*Mengelimpokan buah-buahan yang berkulit kasar dan berkulit kayu. Membedakan hewan berkaki dua atau berkaki empat*" ["Grouping fruits with rough skin versus woody skin; distinguishing animals with two legs from those with four legs"] **(OQR 8)**

This convergence, however, is only partial: the quantitative score for "understanding CT components" (mean = 2.81) is comparatively high, yet the qualitative excerpts show that, the activities that teachers described are often limited to pattern recognition (grouping) when they plan actual classroom activities. In other words, the survey captures teachers' self-rated

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understanding, while the open-ended responses suggest that the practices described do not always cover the full range of CT components. This is a difference between self-rated understanding and the breadth of described practice, not a measured gap between two comparable scores, because the two constructs were measured on different response formats and with different methods.

Two of the 93 responses described instructional games ("as the teacher says") that involve a sequence of commands.

> "*Permainan "kata Bu Guru" Anak Anak Mengikuti apa yg di ucapkan Guru/Intruksi, seperti Maju 1 Langkah Kedepan, Mundur 2 langkah Kebelakang, geser 1 langkah ke Kanan, geser 2 langkah ke kiri, ini Membantu mereka memahami Konsep Algoritma dan eksekusi*" ["The 'Teacher says' game, in which children follow what the teacher says or instructs such as 'step forward once,' 'step back twice,' 'shift one step to the right,' 'shift two steps to the left' helps them understand the concept of algorithm and execution."] (**OQR 10**)

This example involves following ordered instructions, which relates to the algorithmic and sequencing concepts that are central to CT. It relates to the sequencing item in Table 4 ("Teacher consciously designs sequencing activities", mean = 3.92). The game is a simple, developmentally appropriate sequencing activity: it shows that algorithmic ideas can be embedded in familiar play, but it should not be read as evidence of advanced or innovative practice.

Challenges in implementing CT

The research findings also identified various challenges faced by teachers in implementing CT, as shown in Figure 1. The challenges were measured with a multiple-response checklist item: respondents could select more than one of five fixed options and add other challenges in free text. The item was answered by 96 of the 97 respondents, so percentages are calculated on n = 96 and total more than 100%.

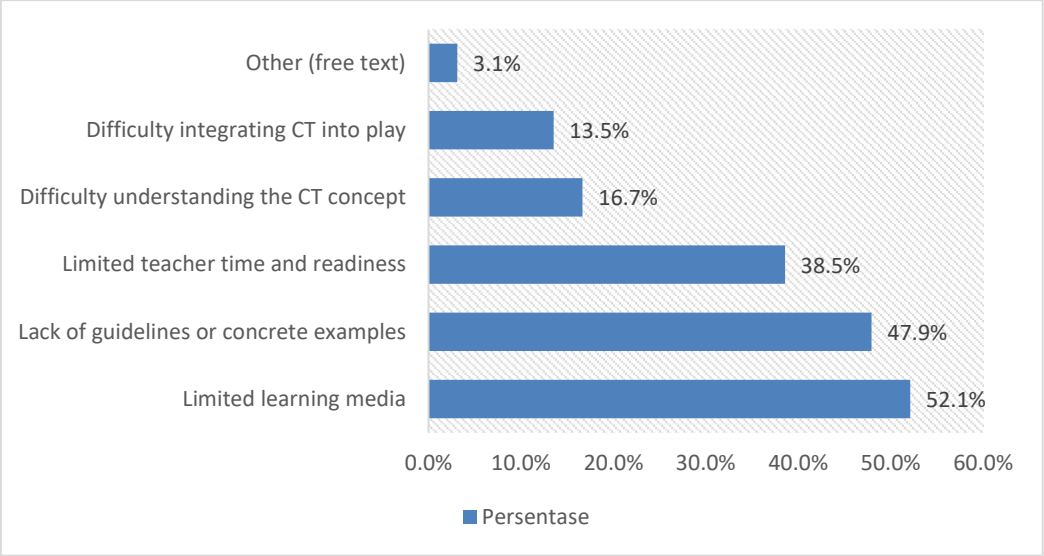

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Figure 1. Challenges in implementing CT reported by teachers (multiple responses allowed; percentage of respondents)

Note. Percentages are based on n = 96 respondents who answered the item and sum to 171.9% because respondents could select more than one challenge. "Other" comprises three free-text answers (limited digital skills, not all teachers understanding CT, and a large class taught by a single teacher).

The most frequently selected challenge was the limited availability of learning media (52.1%; 50 of 96), followed by a lack of guidelines or concrete examples for implementing CT in early childhood education (47.9%; 46) and limited teacher time and readiness (38.5%; 37).

In addition, 16.7% of teachers reported difficulty understanding the CT concept for young children, 13.5% reported difficulty integrating CT into play activities, and three teachers (3.1%) added other challenges in free text (limited digital skills, not all teachers understanding CT, and a large class taught by a single teacher). These findings indicate that the barriers to implementation are not only technical but also conceptual and pedagogical, and they may help explain why the correlation between self-rated understanding and reported implementation, although statistically significant, is moderate-to-strong ($r = .632$) rather than very strong: understanding accounts for about 40% of the variance ($r^2 \approx .40$), and barriers such as material availability and time constraints may limit implementation independently of understanding. This explanation is speculative because the barriers were not entered into the analysis.

Based on these findings, CT as a pedagogical innovation may still be at an early stage of adoption (Rogers, 2003); the self-report data cannot confirm this, but the reported barriers suggest that teachers need support in the form of training, practical guidance, and professional capacity building.

Discussion

The findings of this study indicate that teachers' self-reported understanding of CT in early childhood education falls within the moderate to high range. However, the open-ended responses suggest that the practices teachers described are narrower than the range of CT components they rated themselves as understanding, with some examples (12 of 93 responses) limited to grouping or sorting. Because understanding and implementation were measured on different response formats, no quantitative gap between the two is claimed; the correlation ($r = .632$, moderate-to-strong) indicates association, not a gap. Conceptually, CT is not only associated with digital technology but refers more to a structured problem-solving process involving decomposition, pattern recognition, abstraction, and algorithmic thinking (Juškevičienė et al., 2021; Oktaviani et al., 2025). Therefore, the tendency of some teachers to equate CT exclusively with the use of digital devices reflects a conceptual misconception that could potentially limit the full potential of its implementation in pedagogical practice.

The quantitative findings indicate that teachers rated their understanding of the components of CT (mean = 2.81) higher than their understanding of its underlying concept (mean = 2.46). This may suggest that teachers are more familiar with the procedural aspects of CT than with its underlying theoretical framework. This pattern is consistent with experiential learning theory (Kolb, 1984), which holds that learning is built from concrete experience and reflection before abstract conceptualisation . In this context, teachers have already been applying CT elements such as sorting, classifying, and sequencing without fully realizing that these elements are part

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of a broader computational framework (Avci & Deniz, 2022), a pattern that may be visible in the OQR 2 and OQR 8 excerpts above, where teachers described concrete CT-aligned activities without naming them in CT terms (OQR 1, in contrast, uses CT terms explicitly).

This helps explain why teachers appear to misunderstand or under-recognize CT at the conceptual level even when their classroom practice partially reflects it: understanding in this study was measured as self-assessed familiarity with the CT concept and terminology, not as tested knowledge, whereas the open-ended responses suggest that some teachers' competence may be tacit and embedded in practice rather than articulated as formal knowledge (Avci & Deniz, 2022) . This distinction between declarative and tacit/procedural knowledge is one possible explanation, which future studies should test with knowledge tests and classroom observation.

Although reported implementation was moderate to fairly high on the questionnaire (item means 3.49–4.09 on a five-point scale), the practices described in the open-ended responses were often basic. Many responses (51 of 93; 54.8%) describe basic play-based activities such as blocks, puzzles, threading, and role-playing, and 27 (29.0%) mention grouping objects by color, shape, or type. Although these activities align with pattern recognition, they do not fully capture the multidimensional nature of CT (Syafe'i et al., 2023). Meaningful learning occurs when students actively construct knowledge through engagement in authentic and exploratory activities (Rosa et al., 2025; Wahyuni & Antoro, 2025). From this perspective, the implementation of CT should extend beyond simple classification tasks to more complex problem-solving experiences that encourage children to think systematically and creatively (Angeli & Giannakos, 2020).

A few responses described structured sequencing games that involve step-by-step instructions, such as the "Teacher says" game (OQR 10); this is a simple activity rather than an advanced or innovative practice. Such activities relate to algorithmic thinking and sequencing, which are key components of CT (Lee & Junoh, 2019). This supports the idea that CT can be naturally integrated into a play-based learning environment, in line with the principles of early childhood education, which emphasize a developmentally appropriate and play-oriented pedagogical approach.

However, several challenges hinder the effective implementation of CT. The most frequently reported barriers were limited learning media, the absence of concrete implementation guidelines, and limited time and readiness, followed by difficulty understanding CT and difficulty integrating it into play. These findings align with several other research findings highlighting that the implementation of learning is also influenced by teachers' knowledge, beliefs, and experiences (Chen, 2024; Roehrig & Kruse, 2005). Teachers need to be systematically trained in how to design learning activities, how to teach, how to assess, and how to use technology to teach CT concepts in a more systematic way. (Angeli & Giannakos, 2020; Faizatul Fitriyah et al., 2023). Furthermore, the lack of systematic integration of CT into lesson planning indicates that CT is currently being implemented as an additional skill rather than as a core competency in early childhood education.

By narratively integrating the quantitative and qualitative data, this study suggests that self-reported understanding and reported implementation were relatively positive, whereas the practices described in open-ended responses were limited in scope and depth. Because both strands derive from the same self-report questionnaire, this pattern is suggestive rather than confirmatory, and actual classroom practice was not observed. This discrepancy may reflect a

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phenomenon commonly described in educational innovation, where knowledge acquisition does not automatically translate into effective practice. According to diffusion of innovations theory (Rogers, 2003), such conditions are characteristic of the early adoption phase, during which practitioners require ongoing support, professional development, and access to practical resources to fully implement new approaches (Sugiono, 2024).

Given these findings, improving the implementation of CT in early childhood education requires a comprehensive and systematic approach. This includes enhancing teachers' conceptual understanding, providing practical and contextually relevant training, developing clear pedagogical guidelines, and ensuring the availability of supportive learning materials.

CONCLUSION

Based on the findings, teachers reported varying levels of understanding of computational thinking (CT), with relatively stronger understanding of its core components, including decomposition, pattern recognition, abstraction, and algorithmic thinking. However, understanding of the fundamental meaning of CT was less consistent. Some teachers continued to associate CT primarily with the use of computers or digital devices, although CT fundamentally emphasizes ways of thinking that involve logical, systematic, and structured approaches to problem-solving. The qualitative findings further suggest that some teachers may already be engaging children in CT-related activities without explicitly identifying these practices as computational thinking. Thus, the findings point to a distinction between teachers' existing classroom practices and their explicit conceptual understanding of CT. This distinction is important because teachers may possess elements of practical or tacit knowledge related to CT while having limited awareness of the conceptual terminology used to describe these practices.

The implementation of CT in early childhood education institutions was reported through a variety of play-based activities, including sorting and grouping objects, role-playing, instructional games, pattern recognition, sequencing, and simple problem-solving. However, the reported implementation was not equally distributed across all CT components and appeared to emphasize activities related to pattern recognition, classification, and sequencing. This suggests that teachers' implementation of CT may be developing through familiar play-based practices rather than through an explicitly structured CT framework. The qualitative responses also indicate that unplugged and play-embedded activities are relatively accessible approaches for integrating CT because they can be incorporated into existing classroom routines without requiring sophisticated digital technologies. Nevertheless, the presence of such activities should not automatically be interpreted as evidence of comprehensive CT implementation, particularly when teachers do not explicitly connect the activities to the underlying CT concepts. Further support may therefore be needed to help teachers identify the CT dimensions embedded in familiar play-based practices and intentionally extend them across different CT components.

The findings further indicate that the challenges associated with CT implementation are not solely related to technology or infrastructure but also involve pedagogical and conceptual factors. Teachers most often reported limited learning resources and media, a lack of concrete implementation guidance, and limited time and readiness; less often they reported difficulty understanding the CT concept or integrating it into play. These conditions suggest that the implementation of CT in early childhood education requires sustained institutional and professional support. For teacher professional development, the findings imply that training

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may be strengthened by first helping teachers recognize and articulate CT-related practices that are already present in their classrooms, and subsequently connecting these practices to the broader conceptual framework of CT. Such an approach may allow teachers to develop conceptual understanding without treating CT as an entirely unfamiliar area of knowledge.

This study has several limitations. First, the findings are based primarily on teachers' self-reports rather than direct classroom observations or video-based evidence. Consequently, the reported implementation of CT may not fully represent teachers' actual classroom practices and may be influenced by self-reporting or social-desirability bias. Understanding was also measured by self-rating rather than by a knowledge test, so it reflects perceived rather than demonstrated knowledge, and both strands come from the same questionnaire, which may inflate their association through common-method bias (Podsakoff et al., 2003). Second, the sample was obtained from approximately 76 institutions using non-random sampling, which limits the extent to which the findings can be generalized to the broader population of early childhood education teachers in Indonesia. Third, the relationship between teachers' understanding and reported implementation was examined using correlational analysis; therefore, the findings should not be interpreted as evidence of a causal relationship. Fourth, although the qualitative responses were reviewed and coded by two researchers and discrepancies were resolved through discussion and consensus, no formal intercoder reliability coefficient was calculated. Accordingly, the qualitative findings should be interpreted as a systematically reviewed analysis rather than as evidence of statistically established coding reliability. Fifth, the deductive coding frame was derived from the same indicators as the closed-ended items, so the qualitative analysis is partly circular and could not identify categories beyond them, and the integration of the two strands was narrative, without a joint display. Sixth, the item on CT core components combined four concepts in one statement (double-barreled), so responses cannot be attributed to individual components, and understanding and implementation were measured on different response formats, so their means cannot be compared directly. Future studies could strengthen the evidence base through validated knowledge tests, direct classroom observation, video-based analysis, larger and more geographically diverse samples, and longitudinal or intervention-based research examining whether targeted professional development can improve both teachers' conceptual understanding and their CT-related classroom practices.

Overall, the findings indicate that supporting CT in early childhood education requires more than increasing teachers' conceptual understanding. It also requires an ecosystem that provides contextually relevant professional development, appropriate learning materials and media, and practical instructional guidance for integrating CT into play-based learning. The qualitative evidence from the open-ended questionnaire responses complements the quantitative findings by illustrating how teachers understand and enact CT-related practices within their classroom contexts. Rather than introducing CT solely as a new terminology or a technology-oriented concept, professional development may be more productive when it helps teachers recognize, name, and intentionally extend the CT-related practices that are already embedded in developmentally appropriate play activities. In this way, CT can be integrated more systematically into early childhood education while remaining consistent with the principles of play-based and developmentally appropriate pedagogy.

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