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COMPUTATIONAL THINKING IN ELEMENTARY SCHOOL: ANALYSIS OF TEACHER READINESS AND IMPLEMENTATION STRATEGY IN THE INDONESIAN CONTEXT

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ABSTRACT

Computational thinking (CT) has been recognized globally as a fundamental 21st-century competency essential for elementary students. However, research analyzing teacher readiness and implementation experiences in the Indonesian context remains limited. This research aims to analyze how teachers with different expertise levels understand, implement, and perceive computational thinking instruction at grades 3-4 in Indonesian elementary schools. This study adopted a qualitative phenomenological content analysis approach with 12 semi-structured interview questions administered to three elementary school teachers with varying expertise levels (expert, intermediate, novice). Teachers were selected using purposive sampling from elementary schools in Bandung. The interview data were analyzed systematically using ATLAS.ti 24 software, generating 36 individual codes across five major themes: conceptual understanding, teaching strategies, implementation challenges, perception of effectiveness, and professional development needs. The findings reveal significant expertise stratification among teachers, with distinct patterns of CT understanding and implementation approaches. All three teachers demonstrated genuine commitment to student learning and acknowledged that professional development training alone is insufficient without institutional support. Expert teachers showed comprehensive understanding, intermediate teachers demonstrated practical adaptation, and novice teachers showed foundational approaches with positive agency. This research provides evidence-based insights into teacher readiness essential for formulating systemic recommendations. Successful CT implementation requires differentiated professional development, structured mentoring systems, institutional support mechanisms, and long-term policy commitments.

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INTRODUCTION

Digital transformation in education has become an unavoidable imperative in the Industry 4.0 era, particularly as Indonesia continues to strive to improve the quality of learning for future generations who will live and work in an increasingly digitally connected world (Selwyn, 2021; Enriquez, 2021). Computational thinking (CT) has been globally recognized as one of the fundamental 21st-century competencies that students need to master from an early age, not merely as a technical skill but as a systematic and universal way of thinking (Wing, 2020; Angeli & Valanides, 2020). Leading international organizations including UNESCO (2021), the International Society for Technology in Education (ISTE, 2017), and the National Council of Teachers of Mathematics (NCTM, 2020) consistently incorporate CT in their elementary education curricula, recognizing its profound potential in developing critical thinking skills, problem-solving abilities, and creativity at a young age—a period crucial for establishing cognitive foundations (Korkmaz et al., 2021; Grover & Pea, 2021). Global surveys indicate that more than 60 countries have incorporated computational thinking into their national curriculum standards, reflecting an international commitment to computational literacy as a vital component of modern education.

In Indonesia, the integration of computational thinking in learning has begun to be promoted enthusiastically through various government and non-government initiatives, including the viral Hour of Code program, STEM initiatives adapted to local contexts, and the revised Independent Curriculum that increasingly considers digital literacy as a strategic priority (Ahmad & Farley, 2020; Papadakis et al., 2021). However, beneath this optimism, recent research reveals that CT adoption at the elementary school level still faces significant barriers that remain unresolved. Extensive research by Balanskat and Punie (2021) involving 2,500 teachers across 28 countries reveals a crucial insight: teacher competency and self-efficacy are the most significant factors influencing successful CT implementation, even more important than advanced technology and infrastructure availability. Indonesian research, such as Heriyanto and Supratman (2023), identifies infrastructure barriers as a primary factor, while Sudarma et al. (2022) emphasize the importance of structured professional training.

Although global literature has clearly identified the importance of teacher readiness in CT implementation, research specifically analyzing teacher perspectives in the Indonesian context remains very limited. The majority of CT studies in Indonesia focus on student learning outcomes or technology evaluation rather than on the authentic experiences and deep perspectives of implementing teachers (Tjhin et al., 2023). While Indonesian research identifies infrastructure barriers, there remains an absence of in-depth qualitative research that holistically explores how teachers with different expertise levels understand, adapt, and implement CT in authentic classroom practice (Cahyadi et al., 2021).

This research is important because it provides deep insights into CT implementation realities at the Indonesian elementary school level from the perspective of teachers at the heart of learning practice—a perspective essential for informing culturally appropriate and evidence-based educational policy (Mishra & Koehler, 2020). This research identifies clear patterns of expertise stratification that can be used for designing differentiated professional development programs tailored to the needs and readiness of teachers at different levels (Voogt et al., 2021; Koehler et al., 2021). Furthermore, this research provides a deep understanding of teacher agency and resilience in facing real barriers, insights that are valuable and can serve as a foundation for peer mentoring initiatives and sustainable communities of practice (Darling-Hammond et al., 2023; Guzey et al., 2020). Finally, this research offers comprehensive and realistic recommendations that balance aspirations for best practices with a deep understanding of field realities and constraints, ensuring that recommendations are truly implementable and contextually sensitive (Fullan, 2021).

This research is designed to fill this critical gap by analyzing how teachers with different expertise levels (expert, intermediate, novice) understand, implement, and perceive computational thinking instruction at the elementary school level in the Indonesian context, providing evidence-based insights for formulating targeted, systemic interventions (Darling-Hammond et al., 2023).

The guiding research questions are: (1) How do teachers with different expertise levels understand the concept of computational thinking and its pedagogical purpose at grades 3-4; (2) What teaching strategies and methods do these teachers use, and how do they adapt to infrastructure and competency limitations; (3) What specific challenges are faced at each expertise level, and how do teachers proactively address these challenges; (4) How do teachers perceive CT learning effectiveness and what deeply motivates them in teaching CT; and (5) What are teacher professional needs and what systemic recommendations are needed to support more effective and sustainable CT implementation in Indonesian elementary schools (Selwyn & Macleod, 2020).

The broader roadmap of this research is to contribute to the development of comprehensive CT implementation frameworks that are not only aspirational but also grounded in an authentic understanding of field realities. By systematically documenting and analyzing how teachers at different expertise levels navigate CT implementation challenges, this research aims to transform isolated training initiatives into coherent systemic approaches that recognize and support the diverse pathways and paces of teacher professional development (Fullan, 2021). This research seeks to shift the conversation about CT adoption in Indonesian elementary schools from a deficit-focused perspective (what teachers lack) to an asset-based perspective (what teachers can do and achieve with appropriate support), contributing to more sustainable and contextually responsive educational transformation (Darling-Hammond et al., 2023).

METHOD

This research adopts a qualitative design with a phenomenological content analysis approach to deeply explore teacher experiences and perspectives in implementing computational thinking learning (Braun & Clarke, 2019; Patton, 2021). The phenomenological approach enables in-depth exploration of teacher perspectives within their own contexts (Moustakas, 2019; van Manen, 2020). Data were collected through in-depth semi-structured interviews with three elementary school teachers teaching CT at grades 3-4, using an instrument comprised of 12 open-ended questions systematically designed to explore five main themes: conceptual understanding of CT, teaching strategies and methods, implementation challenges and barriers, perception of learning effectiveness, and teacher competency and professional development needs (Rubin & Rubin, 2021; DeJonckheere & Vaughn, 2020). Teachers were selected using purposive sampling based on different expertise levels and identified as: Teacher 1 (expert with comprehensive CT experience of at least 5 years) from one of elementary schools in Bandung, Teacher 2 (intermediate with foundational understanding and 2-4 years of experience) from one of elementary schools in Bandung, and Teacher 3 (novice with limited understanding and less than 2 years of experience) from one of elementary schools in Bandung, ensuring representation of a broad spectrum of CT implementation in the field (Tondeur et al., 2021).

The collected data were analyzed systematically using ATLAS.ti 24 software, an integrated platform for qualitative data analysis enabling robust coding, memoing, and network visualization (Friese, 2023; Silver & Woolf, 2020). The analysis process followed systematic qualitative coding procedures, utilizing open coding approaches to identify meaningful units and concepts in each teacher's responses (Saldaña, 2021; Creswell & Creswell, 2021). Each response from each teacher was assigned a specific code of a maximum of three words capturing the essence of the statement, generating a total of 36 individual codes (12 questions

× 3 informants). Subsequently, axial coding was performed to establish relationships among codes, and thematic clustering identified cohesive patterns and critical divergences among the three informants at various expertise levels (Khandkar, 2020; Bazeley, 2021). The ATLAS.ti 24 framework facilitated the creation of code hierarchies, quotation assignments, memos for analytical notes, and network diagrams for visualizing complex cross-thematic patterns (Schreier, 2021; Konopásek & Krejčí, 2020).

Trustworthiness of this qualitative research was established through multiple strategies: (1) thick description to ensure vivid and detailed representation of data and findings (Lincoln & Guba, 2021; Merriam & Tisdell, 2021), (2) prolonged engagement and persistent observation with data to achieve depth of understanding (Guba & Lincoln, 2020), (3) peer debriefing with other researchers to clarify assumptions and triangulate interpretations (Smith & McGannon, 2021), and (4) member checking where preliminary findings were confirmed back with informants to verify accuracy and relevance (Harper & Cole, 2021). Research ethics were maintained by ensuring informed consent from all participants, confidentiality through the use of pseudonyms (Teacher 1, 2, 3), anonymity of institutional affiliation, and full transparency in reporting methodology and limitations (Bryman, 2021). This research obtained ethical clearance from the institutional review board (IRB) and followed ethical guidelines for human subjects research.

Figure 1. Qualitative research flow of phenomenological content analysis

RESULTS AND DISCUSSION

Results

Qualitative data from 12 interview questions with three teachers of different expertise levels (expert, intermediate, novice) were analyzed systematically using ATLAS.ti 24. The analysis generated 36 individual codes distributed across five major themes: conceptual understanding of CT (Q1-Q2), teaching strategies and methods (Q3-Q5), challenges and barriers (Q6-Q8), perception of effectiveness (Q9-Q10), and professional needs (Q11-Q12). Below are the research findings structured according to research themes:

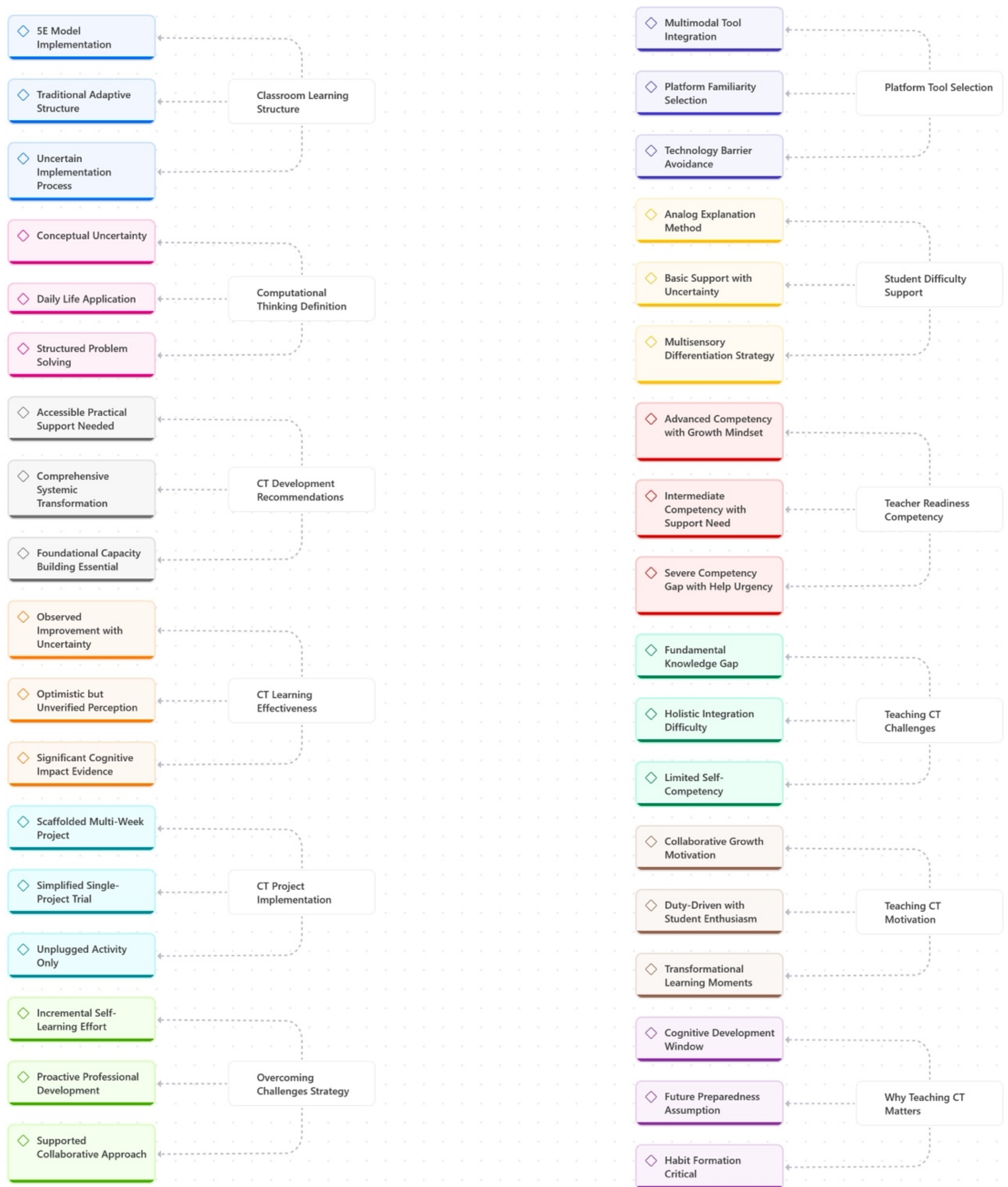

Figure 2. Distribution of 36 research codes from ATLAS.ti 24 based on 12 instrument questions × 3 informants with expertise level categories and coding frequency

Theme 1: Conceptual Understanding of Computational Thinking (Q1-Q2)

Analysis of question Q1 ("How do you understand computational thinking?") and Q2 ("Why is it important to teach CT at grades 3-4?") revealed significant differences in conceptualization and pedagogical understanding among the three teachers. In Q1, Teacher 1 generated the code "Structured Problem Solving," showing a comprehensive understanding of CT as a universal framework, while Teacher 2 generated "Daily Life Application," and Teacher 3 generated "Conceptual Uncertainty." In Q2, the expertise stratification pattern became clearer with Teacher 1 coding "Cognitive Development Window" (explicit reference to Piaget), Teacher 2 "Habit Formation Critical," and Teacher 3 "Future Preparedness Assumption" (with caveat of uncertainty).

Theme 2: Teaching Strategies and Methods (Q3-Q5)

Questions Q3 ("What tools/platforms do you use?"), Q4 ("How is your learning structure?"), and Q5 ("Tell about the CT project you implemented?") generated patterns consistent with the expertise level. In Q3, Teacher 1 was coded "Multimodal Tool Integration" (ScratchJr, Code.org, Blockly, unplugged), Teacher 2 "Platform Familiarity Selection" (Code.org, ScratchJr), and Teacher 3 "Technology Barrier Avoidance" (PowerPoint, Paint, mostly unplugged). In Q4, learning structure varied: Teacher 1 "5E Model Implementation" (85 minutes), Teacher 2 "Traditional Adaptive Structure" (45-50 minutes), and Teacher 3 "Uncertain Implementation Process" (50 minutes traditional). On Q5, project complexity ranged from "Scaffolded Multi-Week Project" (Teacher 1) to "Unplugged Activity Only" (Teacher 3).

Theme 3: Challenges and Barriers (Q6-Q8)

Analysis of Q6 ("What is your biggest challenge?"), Q7 ("How do you overcome it?"), and Q8 ("Do any students struggle?") revealed tiered challenges according to expertise level. Q6 produced three codes of different levels: Teacher 1 "Holistic Integration Difficulty" (advanced level), Teacher 2 "Limited Self-Competency" (intermediate level), and Teacher 3 "Fundamental Knowledge Gap" (novice level). However, on Q7, all teachers demonstrated positive agency with Teacher 1 "Proactive Professional Development," Teacher 2 "Incremental Self-Learning Effort," and Teacher 3 "Supported Collaborative Approach." Differentiation strategy on Q8 showed Teacher 1 using "Multisensory Differentiation Strategy," Teacher 2 "Analog Explanation Method," and Teacher 3 "Basic Support with Uncertainty," all with commitment to student support.

Theme 4: Perception of Effectiveness and Motivation (Q9-Q10)

On Q9 ("How effective is CT?") and Q10 ("What motivates you to teach CT?"), All three teachers reported positive perceptions despite different confidence levels. Q9 generated codes: Teacher 1 "Significant Cognitive Impact Evidence" (with systematic observation), Teacher 2 "Observed Improvement with Uncertainty" (caveat about causality), and Teacher 3 "Optimistic but Unverified Perception" (without concrete evidence). However, on Q10 all teachers expressed genuine motivation: Teacher 1 "Transformational Learning Moments" (student empowerment focus), Teacher 2 "Collaborative Growth Motivation" (mutual learning emphasis), and Teacher 3 "Duty-Driven with Student Enthusiasm" (will be linked to external factors). Notably, frustration and anxiety were acknowledged by all teachers, but did not diminish their commitment.

Theme 5: Professional Needs and Recommendations (Q11-Q12)

Analysis of Q11 ("Are you competent?") and Q12 ("What recommendations do you have?") revealed realistic self-awareness and a clear vision for improvement. On Q11, Teacher 1 was coded "Advanced Competency with Growth Mindset," Teacher 2 "Intermediate Competency with Support Need," and Teacher 3 "Severe Competency Gap with Help Urgency." Professional needs varied: Teacher 1 requested advanced training and research collaboration, Teacher 2 needed structured programs and mentoring, while Teacher 3 required comprehensive beginner support. On Q12, recommendations showed a progression from macro-level systemic transformation (Teacher 1: "Comprehensive Systemic Transformation") to foundational capacity building (Teacher 3: "Foundational Capacity Building Essential"), with Teacher 2 in the middle ("Accessible Practical Support Needed"). Crucially, all teachers acknowledged that professional development training alone is insufficient; institutional support, realistic timelines, and recognition systems are also essential.

Summary of Analysis Patterns

Overall ATLAS.ti 24 analysis identified three major patterns: (1) Expertise Stratification consistent across all themes, with Teacher 1 demonstrating comprehensive understanding and sophisticated implementation, Teacher 2 demonstrating practical adaptation with learning curve, and Teacher 3 demonstrating foundational challenges with positive agency; (2) Universal Resilience and Agency—all teachers demonstrated willingness to learn and commitment to student learning regardless of expertise level; and (3) Explicit Systemic Support Recognition—all teachers acknowledged that individual effort alone is insufficient without institutional support, policy enabling, and systemic changes. Frequency analysis showed that codes related to "uncertainty" and "support need" were more frequent in Teachers 2 and 3, while codes related to "integration" and "theory-grounding" were more frequent in Teacher 1, confirming the consistent expertise stratification pattern.

Discussions

Research findings reveal significant expertise stratification in CT learning at Indonesian elementary schools. The identified three-tier model—expert with comprehensive implementation, intermediate with adaptive practices, and novice with foundational approaches—is not merely descriptive but has important implications for teacher development and systemic support. This divergence aligns with research literature showing that teacher effectiveness in emerging educational approaches is strongly influenced by pedagogical content knowledge (PCK), self-efficacy, and access to professional development resources. Recent research by Balanskat and Punie (2021) in a multi-country study found that teacher competency and readiness are the most determinative factors in successful CT implementation. Heriyanto and Supratman (2023) demonstrate that barriers to CT implementation in Indonesia are multifaceted, yet positive teacher agency—as demonstrated by all three informants—is a powerful mitigating factor that can overcome institutional barriers.

Findings on expertise stratification in CT conceptual understanding reflect progressive deepening of understanding aligned with research on teacher learning trajectories. Expert teachers using theoretical frameworks such as cognitive development theory demonstrate that deep CT understanding is not merely knowing what CT is, but understanding why and how CT matters for cognitive development at specific ages. Conversely, novice teachers conflating CT with programming itself reflect findings from research literature that teachers new to emerging pedagogies often struggle with abstraction levels and general principles (Sudarma et al., 2022). This difference is crucial because extensive research evidence shows that teachers with deeper content knowledge produce better student learning outcomes. Intermediate teachers demonstrate what might be called "pragmatic accommodation"—making realistic adaptations given contextual constraints while still moving forward with implementation—an approach that is valuable and often overlooked (Guzey et al., 2020).

A notable pattern in findings is that all three teachers demonstrated positive agency in facing challenges with strategies appropriate to their expertise level. Expert teachers demonstrated characteristics of effective professional learners—active engagement, collaborative inquiry, and focus on continuous improvement (Darling-Hammond et al., 2023; Putnam & Borko, 2020). Intermediate teachers demonstrated incremental self-learning aligned with research on teacher learning in context (Bocconi et al., 2022; Ertmer & Ottenbruch, 2020). Novice teachers demonstrated awareness of limitations and actively sought supported collaborative approaches. Crucially, all three teachers showed resilience and commitment to student learning despite their challenges, underscoring that motivation and agency are powerful factors that can overcome institutional barriers.

Findings on CT learning effectiveness perception are particularly encouraging and supported by growing research evidence. That all teachers reported positive impact from CT instruction aligns with meta-analyses showing positive correlations between CT instruction and improvements in logical thinking and problem-solving skills (Lye & Koh, 2020). What is noteworthy is that expert reports systematic evidence, intermediate reports cautious observation, and novice reports optimistic belief—all of which are valid perspectives contributing to a healthier understanding. Evidence-based perspective from the expert teacher provides confidence, the cautious perspective from the intermediate promotes research-minded thinking, and the optimistic perspective from the novice demonstrates faith in CT's educational value.

Findings on teacher competency and stratified professional needs confirm what recent Indonesian research has found. Sudarma et al. (2022) found that significant training needs exist across teachers, but this research reveals that these needs are stratified by expertise level. What expert teachers need (advanced training, research collaboration) is fundamentally different from what novice teachers need (basic training, intensive coaching). This aligns with research on differentiated professional development (Darling-Hammond et al., 2023). Particularly significant is that all teachers acknowledged that training alone is insufficient—institutional support structures are essential. Bocconi et al. (2022) found the same conclusion: successful CT implementation requires not only teacher training but also structural support at the school level, including time allocation, administrative support, resources, and supportive organizational culture (Scherer et al., 2020).

For national and provincial policymakers: This research emphasizes the need for a comprehensive CT integration strategy that focuses not only on curriculum but also on systemic supports for teachers. Policy recommendations include: establishment of clear national standards for computational thinking competencies with differentiated standards for different expertise levels (Korkmaz et al., 2021); development of certification and credentialing systems recognizing and incentivizing teachers developing advanced CT competencies (Angeli & Valanides, 2020); allocation of adequate budgets for infrastructure investment, professional development, and creation of supportive structures such as learning communities and mentoring networks (Ahmad & Farley, 2020); integration of CT in preservice teacher education programs (Koehler et al., 2021); and long-term government commitment to ensure sustainable implementation (Fullan, 2021).

For school leaders and administrators: This research communicates that creating an enabling institutional environment is essential for successful CT implementation. Practical recommendations include: reducing teacher workload by providing dedicated time for CT planning and professional learning (Darling-Hammond et al., 2023; Tondeur et al., 2021); allocating adequate budgets for acquiring technology and software; facilitating creation of communities of practice (Heriyanto & Supratman, 2023); providing technical support for teachers (Tjhin et al., 2023); creating recognition systems acknowledging successful CT implementation (Munadi et al., 2020); and maintaining realistic expectations and timelines.

For teacher educators in preservice and in-service education: This research highlights the importance of differentiated professional development approaches. Recommendations include: developing tiered professional development programs catering to teachers with different expertise levels (Yadav et al., 2020); incorporating practical, hands-on experiences with CT tools (Grover & Pea, 2021); developing mentoring components pairing experienced with less experienced teachers (Lesseig et al., 2021); emphasizing development of pedagogical content knowledge (Mishra & Koehler, 2020); and creating ongoing learning communities (Doleck et al., 2020).

For individual teachers: Expertise development is a journey requiring continuous learning, collaboration, and a willingness to adapt. Recommendations include: seeking professional development opportunities (Park et al., 2021); engaging in collaborative learning with peers; experimenting with different pedagogical approaches (Nouri et al., 2020); remaining open to using both technology and unplugged activities; and advocating for needed support and resources (Maloney et al., 2021).

CONCLUSION

This qualitative research has analyzed computational thinking learning at elementary school grades 3-4 through the lens of three teachers with different expertise levels (expert, intermediate, novice) in Bandung schools. Using systematic phenomenological content analysis of 12 semi-structured interview questions, the research generated 36 individual codes, revealing significant expertise stratification yet also universal agency and resilience among all teachers in facing challenges. Research findings show that expert teachers demonstrate comprehensive CT understanding and integrated approach to teaching grounded in pedagogical theory, sophisticated use of multiple tools and strategies, and ability to mentor other teachers; intermediate teachers demonstrate practical CT understanding and teaching approaches adaptive to constraints, pragmatic use of familiar tools and strategies, and willingness to incrementally develop competency; and novice teachers demonstrate foundational CT understanding with significant conceptual gaps, beginning teaching approaches reliant on unplugged activities, limited technology use due to confidence and infrastructure barriers, yet demonstrated agency in seeking support and collaborative learning opportunities.

What is remarkable in the findings is that all three teachers, regardless of their expertise level, demonstrated a genuine commitment to student learning and a willingness to overcome challenges in teaching CT. This suggests that barriers to effective CT implementation in Indonesia are not motivational but structural and systemic—related to limited professional development opportunities, infrastructure constraints, and lack of institutional support systems. All teachers acknowledged that professional training alone is insufficient; institutional support at the school level, including time allocation, adequate resources, realistic timelines, and a collaborative approach, is essential for successful implementation. These findings provide a strong evidence basis for advocating comprehensive systemic approaches to CT implementation rather than isolated training initiatives.

The primary recommendation from this research is that successful CT implementation in Indonesian elementary schools requires a comprehensive systemic approach integrating: differentiated professional development programs catering to teachers with different expertise levels; structured mentoring systems pairing experienced with less experienced teachers; institutional support at the school level including time allocation, resources, and administrative backing; pedagogical flexibility encouraging both technology-based and unplugged approaches to CT teaching; and long-term commitment from policymakers, administrators, teacher educators, and teachers themselves to ensure CT implementation is sustainable and continually improved based on field evidence. Thoughtful implementation of these recommendations, with attention to local context and school and teacher readiness, can significantly enhance the quality of computational thinking education in Indonesian elementary schools. Future research directions include: longitudinal studies tracking teacher development in CT over time; comparative studies examining CT implementation across different regional and school contexts in Indonesia; studies on student learning outcomes in relation to teacher expertise level and professional development; and evaluations of the effectiveness of specific professional development interventions for developing teacher capacity in CT.

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