Available online at JECE (Journal of Early Childhood Education)
Website: http://journal.uinjkt.ac.id/index.php/jece
Permalink/DOI: http://dx.doi.org/10.15408/jece.v7i1.46568
JECE, 7 (1), Juni 2025, 22-35

EXPERT CONSENSUS ON COMPUTATIONAL THINKING LEARNING SEQUENCES FOR KINDERGARTEN USING FUZZY DELPHI METHOD

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Abstract

This study aims to develop a structured and developmentally appropriate sequence for teaching Computational Thinking (CT), specifically designed for kindergarten. In response to the increasing importance of 21st-century skills and the global push to integrate CT into early childhood education, this research addresses the gap in pedagogical strategies suitable for young learners. The Fuzzy Delphi Method was employed, involving 12 experts in early childhood education, CT, and curriculum development. The expert panel evaluated six core elements of CT: logical reasoning, abstraction, decomposition, pattern recognition, algorithm design, and evaluation. The results showed a high level of consensus (≥90.91%) with threshold values ranging from 0.101 to 0.197 and fuzzy values between 0.509 and 0.564, indicating strong agreement on the relevance and feasibility of implementing CT in kindergartens. These elements were contextualized through screen-free, interactive, and play-based activities tailored to young children's cognitive characteristics. This study contributes to early childhood education by offering a CT learning sequence grounded in empirical data and contemporary educational theory. It also addresses contextual challenges in Indonesia, such as limited digital infrastructure, by proposing cost-effective and culturally relevant pedagogical strategies. The findings demonstrate that early exposure to CT can foster foundational skills in logical thinking, creativity, and problem-solving—essential for lifelong learning. The study highlights the need for policy support, teacher training, and curriculum development to effectively integrate CT into early childhood education.

Keywords: computational thinking; 21st century skills; curriculum design

Abstrak

Penelitian ini bertujuan mengembangkan urutan pembelajaran Computational Thinking (CT) yang terstruktur dan sesuai perkembangan anak, khusus untuk taman kanak-kanak. Seiring pentingnya keterampilan abad ke-21 dan dorongan global untuk mengintegrasikan CT dalam pendidikan usia dini, penelitian ini menjawab kesenjangan dalam strategi pedagogis yang sesuai. Metode Fuzzy Delphi digunakan dalam penelitian ini, yang melibatkan 12 pakar pendidikan anak usia dini, CT, dan kurikulum. Panel ahli mengevaluasi enam elemen inti CT: penalaran logis, abstraksi, dekomposisi, pengenalan pola, desain algoritma, dan evaluasi. Hasil menunjukkan tingkat konsensus tinggi (≥90,91%) dengan ambang batas 0,101–0,197 dan nilai fuzzy 0,509–0,564, menandakan kesepakatan kuat terhadap relevansi dan kelayakan penerapan CT di TK. Elemen-elemen ini dikontekstualisasikan dengan kegiatan tanpa layar, interaktif, dan berbasis permainan, sesuai dengan karakteristik kognitif anak usia dini. Studi ini berkontribusi pada pendidikan anak usia dini dengan menawarkan urutan pembelajaran CT berdasarkan data empiris dan teori pendidikan kontemporer. Penelitian ini juga merespons tantangan seperti keterbatasan infrastruktur digital di Indonesia dengan strategi pedagogis yang murah dan relevan secara budaya. Hasil menunjukkan bahwa pengenalan CT sejak dini dapat menumbuhkan kemampuan berpikir logis, kreativitas, dan pemecahan masalah, yang penting untuk pembelajaran sepanjang hayat. Studi ini menekankan pentingnya dukungan kebijakan, pelatihan guru, dan pengembangan kurikulum untuk integrasi CT yang efektif dalam pendidikan anak usia dini.

Kata kunci*: computational thinking; keterampilan abad ke-21; rancangan kurikulum*

Introduction

In the context of the 21st century's increasingly complex and technology-saturated environment, the capacity to think critically, solve problems systematically, and adapt to dynamic situations has emerged as a vital competency. One cognitive framework that encapsulates these abilities is Computational Thinking (CT). Initially rooted in computer science and programming disciplines, CT has evolved into a broader, interdisciplinary cognitive approach that supports analytical reasoning, abstraction, decomposition, and algorithmic thinking (Wing, 2006). As such, it is now widely recognized as a transferable skill set applicable not only in computing but also across various domains including mathematics, science, literacy, and everyday life decision-making processes Shute et al. (2017).

There is a growing consensus among educators and researchers that the development of CT should begin early in a learner's educational journey. Early childhood represents a critical period for cognitive development, during which children naturally engage in pattern recognition, sequencing, and logical reasoning—behaviors that closely align with CT principles. Recent scholarship supports the integration of CT within early childhood education (ECE) to leverage these developmental opportunities and establish foundational thinking skills that promote long-term academic and cognitive outcomes (Bers, 2020; Lye & Koh, 2024; Resnick, 2017)

Despite these promising perspectives, the implementation of CT in early childhood education remains limited in many educational systems, particularly in developing contexts such as Indonesia. The current early childhood curriculum in Indonesia emphasizes moral values, creativity, and basic academic readiness but lacks explicit references to CT (Handayani & Kusumah, 2021). Several factors contribute to this gap, including limited awareness among educators, insufficient pedagogical tools, and the absence of formal training in CT instruction (Sari & Wibowo, 2023). Moreover, prevailing misconceptions often associate CT exclusively with screen-based or coding activities, overlooking its broader cognitive potential. These challenges highlight the urgent need to reframe CT as a foundational mode of thought rather than a purely technical competency, and to explore developmentally appropriate, culturally contextualized pathways for its integration into ECE.

In response to these needs, this study proposes the development of a structured and sequenced CT learning design tailored specifically for kindergarten in the Indonesian educational context. The learning design is informed by contemporary cognitive development theories (Piaget, 1972; Vygotsky, 1978) and grounded in culturally relevant, screen-free, and resource-sensitive pedagogical strategies. The aim is to offer a practical, sustainable framework that empowers teachers to embed CT in daily classroom practice. Through expert agreement and iterative refinement using the fuzzy Delphi method, this research contributes both a tangible instructional strategies and a theoretical foundation to support the broader inclusion of CT in early childhood education in Indonesia.

Moreover, most existing CT programs and teaching models are designed for older students in primary or secondary school, and often involve screen-based activities. While these approaches have proven effective in certain contexts, they are not developmentally appropriate for children in kindergarten who learn best through hands-on, sensory, and social experiences. Young children require learning methods that are concrete, visual, and grounded in physical activity. Therefore, there is an urgent need for CT learning models that are not only age-appropriate but also compatible with the ways in which young children naturally learn and explore their world.

This study aims to address that gap by developing a sequenced learning design for CT that is tailored to the cognitive and developmental needs of kindergarten children. Unlike one-off activities or general teaching suggestions, a structured sequence offers a coherent, step-by-step progression that builds CT skills in a scaffolded manner. This is especially important in early childhood education, where consistency and repetition are key to internalizing new concepts. The proposed learning sequence includes engaging, screen-free activities such as story-based problem-solving, physical games that simulate algorithms, pattern-based art, and group exercises that encourage logical reasoning.

Several studies have highlighted the potential of unplugged CT activities in early childhood. Bers (2021), for instance, emphasizes that CT for young learners should not begin with coding but with cognitive strategies that can be taught through developmentally appropriate methods. Similarly, Resnick (2017) advocates for CT activities embedded in meaningful play and project-based experiences. In Indonesia, (Handayani & Kusumah, 2021) successfully used storytelling-based CT activities with kindergarten students and found that these helped improve focus, logical order, and sequencing skills. In another study, Sari & Wibowo (2023) implemented a series of logic games and sequencing tasks with TK students in Central Java, reporting improved ability to anticipate steps and understand consequences.

In spite of these promising efforts, there is still no standard or validated learning sequence for teaching CT at the kindergarten level in Indonesia. The national early childhood curriculum emphasizes moral development, creativity, and basic academic readiness but does not yet include CT as a formal learning objective. As a result, many educators are unsure of how to introduce CT or where to begin. A well-designed learning sequence would help bridge that gap by offering a roadmap that teachers can follow and adapt to their classroom realities.

The develop of such a sequence is not without its challenges. It must be rooted in educational psychology, aligned with the stages of cognitive development identified by theorists such as Piaget and Vygotsky, and tested in real classroom settings to ensure feasibility and effectiveness. Additionally, the activities must reflect cultural relevance and linguistic accessibility for young Indonesian learners. The design must also consider the limited infrastructure of many kindergarten institutions, especially those in rural or underserved areas. For this reason, the learning sequences proposed in this research emphasizes low-cost, screen-free learning activities that can be delivered using everyday materials.

In terms of research methodology, this study employs a fuzzy delphi method that focus to develop the learning sequences of computational thinking. It is designed based on literature review and expert consensus. Through this approach, the research not only offers a product (the CT learning sequence) but also contributes to the theoretical discourse on early CT education in Indonesia.

The contribution of this research is twofold. First, it fills a practical need by providing a usable learning sequences that supports the integration of CT into kindergarten education. This strategies can empower teachers, enhance classroom instruction, and promote children's cognitive growth. Second, it contributes to the academic field by offering a contextualized understanding of how CT can be introduced in early childhood within the Indonesian education system. The study provides empirical evidence to support the inclusion of CT in future curriculum revisions and teacher training programs.

Finally, this research is driven by the belief that early exposure to structured CT learning experiences can have long-term benefits for children. CT is not just about computing; it is about developing a way of thinking that is analytical, creative, and resilient. As Rahman (2019) asserts, "problem-solving skill is the most crucial ability demanded by our society and the vital element to enhance students' comprehending knowledge and prepare them to survive future challenges in life." By equipping young children with these skills early, we are helping to prepare them not only for academic success but also for the uncertainties and complexities of the future.

In conclusion, this study proposes a structured, developmentally appropriate Computational Thinking learning sequence for kindergarten students in Indonesia. By doing so, it seeks to promote CT as a component of early education, support teachers with practical guidance, and contribute to a more inclusive and future-ready learning environment for young Indonesian children.

Method

This research employs the Fuzzy Delphi Method (FDM) to obtain consensus from experts regarding the appropriate Computational Thinking (CT) learning sequence for kindergarten. Fuzzy Delphi Method is a modified version of the traditional Delphi Method, a structured communication technique aimed at achieving consensus among specialists in a specific field. The selection of this method was predicated on its capacity to systematically integrate expert opinions and to take into account the element of uncertainty in the decision-making process.

The objective of this research is to develop a CT learning sequence that is relevant and appropriate for application at the kindergarten level. This will be achieved by considering aspects of children's cognitive development and appropriate pedagogical principles.

The data collection techniques employed in this study entailed the administration of questionnaires, which were meticulously prepared based on the findings of a comprehensive literature review. This review focused on CT components in the context of early childhood education. The questionnaire is structured in the form of a fuzzy Likert scale and consists of a number of items that represent the stages of CT learning.

The research instrument employed is a questionnaire that has undergone a rigorous validation process by experts prior to its dissemination. A total of 12 experts in the field of early childhood education, computational thinking, and curriculum development from several university in Indonesia participated as an expert panel in this study.

Table 1. The Construct of Computational Thinking Learning Sequences

No	Components
1	Logical reasoning The rocess of making predictions, analysing information and checking information based on prior knowledge.
2	Abstract The process of sorting out information, ignoring less important things in order to focus on the main idea.
3	Decomposition The process of breaking down a large/complicated problem into smaller, more detailed and simpler parts.
4	Pattern recognition The process of recognising similarities and differences in patterns to help children make predictions
5	Alogarithms The process of organising steps or rules to solve a problem
6	Evaluation The process of reviewing whether the steps/problem-solving process (algorithm) that has been carried out is in accordance with the objectives.

The construct of computational thinking elements consisting of six main elements, namely logical reasoning, abstraction, decomposition, pattern recognition, algorithms, and evaluation, which were formulated based on the results of the previous literature review, were then given to experts for review through a validation process using the Fuzzy Delphi Method.

The process of data analysis was systematically conducted. The viewpoints of the experts were meticulously scrutinized through the utilization of Microsoft Excel software, as espoused by Jamil et al. (2017; Jamil & Noh, 2020) . The Fuzzy Delphi technique requires strict adherence to two fundamental prerequisites, namely the Triangular Fuzzy Number and the Defuzzification Process. The Triangular Fuzzy Number has two imperative conditions, wherein the value of Threshold (d) should be less than or equal to 0.2. The attainment of expert consensus is achieved when the resulting value is equal to or less than 0.2 (Chen, 2000; Cheng & Lin, 2002). The subsequent formula is employed:

$$d(\tilde{m},\tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

The second requirement for the Triangular Fuzzy Number is to incorporate a level of expert consensus. According to the conventional Delphi technique, a consensus of over 75% among experts is deemed acceptable Click or tap here to enter text.. On the other hand, the Defuzzification Process involves deducing the fuzzy (A) score value by considering the α-cut value of 0.5 Click or tap here to enter text.. In the event that the fuzzy score value (A) is equal to or greater than 0.5, the measurement is accepted,

whereas a value below 0.5 implies the measurement is rejected. Evaluation of the fuzzy (A) score value was carried out using the following formula:
A= (1/3)*(m1 + m2 + m3)

Results and Discussion

The construct of computational thinking elements consisting of six main elements, namely logical reasoning, abstraction, decomposition, pattern recognition, algorithms, and evaluation, which were formulated based on the results of the previous literature review, were then given to experts for consensus process using the Fuzzy Delphi Method (FDM). The Fuzzy Delphi Method combines the traditional Delphi method with fuzzy logic to address uncertainty in expert judgment.

In its application, each element—such as logical reasoning, decomposition, abstraction, pattern, algorithm, and evaluation—is assessed using a linguistic scale (e.g., "very important"), which is then converted into fuzzy numbers in the form of Triangular Fuzzy Numbers (TFN). These values are averaged to obtain a group fuzzy score, then defuzzified using the Amax formula to produce a single value. Expert consensus is measured using the threshold value (d), and an element is considered accepted if Amax ≥ 0.5, d ≤ 0.2, and the agreement percentage is ≥ 75%. This approach ensures that each element is based on strong consensus and practical relevance in the context of kindergarten learning. The results of the expert agreement can be seen in the table 2.

Table 2 shows that all computational thinking components evaluated by the experts are considered relevant to kindergarten. These components help children build critical thinking and problem-solving skills that will be an important foundation in later learning. The high level of agreement confirms that these elements can be implemented with high effectiveness in early childhood learning environments.

Table 2. Experts' Agreement On Computational Thinking Learning Sequences

No	*Triangular Fuzzy Numbers*		*Fuzzy Evaluation Process*				Expert agreement
	Value of *Threshold*, d	Expert Agreement Percentage, %	m1	m2	m3	Skor *Fuzzy (A)*	
1	0,197	90,9%	0,327	0,509	0,709	0,515	ACCEPTED
2	0,176	90,9%	0,345	0,527	0,727	0,533	ACCEPTED
3	0,136	90,9%	0,345	0,545	0,745	0,545	ACCEPTED
4	0,136	90,91%	0,345	0,545	0,745	0,545	ACCEPTED
5	0,101	90,91%	0,364	0,564	0,764	0,564	ACCEPTED
6	0,177	90,91%	0,309	0,509	0,709	0,509	ACCEPTED

The components presented in the table have threshold values ranging from 0.101 to 0.197, indicating the level of accuracy and consistency of expert evaluation. All components have a high level of agreement (90.91%), which means experts agree that the components are relevant and important in supporting computational thinking learning. Component with Low Threshold Value (0.101): This component shows very strong agreement from the experts as a low threshold value indicates minimal uncertainty in their judgment. components with Higher Threshold Values (0.197): Despite the higher threshold value, the level of agreement is still high, indicating the element is still considered relevant even though it requires minor adjustments.

The first element, logical reasoning, in the context of early childhood education, refers to a child's ability to think in a structured and coherent manner, recognize simple cause-and-effect relationships, and make decisions based on concrete experiences. For instance, a child may understand that watering a plant daily will help it grow. This element recorded a threshold value of 0.197 and a fuzzy score of 0.515. Despite having the highest threshold value among the six elements, logical reasoning was still accepted due to its sufficiently high fuzzy score. The experts agreed that logical reasoning is a fundamental skill in shaping coherent thinking structures during early development.

The second element, decomposition, is defined as a child's ability to break down a complex task or problem into smaller, manageable steps. In early childhood learning, this can be fostered through activities such as completing puzzles, building with blocks, or understanding sequences in daily routines. This element achieved a threshold value of 0.176 and a fuzzy score of 0.533. These results reflect a high degree of expert agreement that teaching children to identify and manage component parts of a problem is essential for developing early analytical skills.

The third element, abstraction, refers to the child's capacity to identify key information while disregarding non-essential details. For young learners, this can be seen when children group objects by color despite differences in shape or size, highlighting their focus on a relevant attribute. Abstraction promotes simplified processing of complex stimuli. This element received a threshold value of 0.136 and a fuzzy score of 0.545, indicating a strong consensus among experts that abstraction is a valuable component of early computational thinking instruction.

The fourth element, pattern recognition, pertains to a child's ability to identify regularities, repetitions, and similarities in objects, sounds, movements, or events. In the context of early childhood, this skill can be nurtured through activities such as sequencing colored beads, replicating rhythms, or following choreographed steps in songs and dances. This element recorded the same values as abstraction—a threshold of 0.136 and a fuzzy score of 0.545—demonstrating a similarly strong expert consensus on the importance of this element in supporting children's logical structuring abilities.

The fifth element, algorithm, is understood as the child's ability to follow a sequence of steps systematically to accomplish a specific goal. For example, making fruit juice involves sequential actions such as washing, cutting, blending, and pouring. Teaching this concept through routine and tangible activities helps children understand the impact of order on outcomes. Algorithm had the lowest threshold value (0.101) and the highest fuzzy score (0.564) among all elements, signaling the highest level of expert consensus and the strongest recommendation for its integration into early learning contexts.

The sixth element, evaluation, in early childhood learning refers to the child's ability to reflect on the outcomes of their actions, compare intended and actual results, and adjust strategies accordingly. A typical example is when a child builds a block tower that collapses and then attempts a different stacking method for greater stability. This element obtained a threshold value of 0.177 and a fuzzy score of 0.509. While it received the lowest fuzzy score among the elements, it still met the criteria for acceptance, indicating that experts recognized its importance in fostering early metacognitive and reflective skills.

All six computational thinking elements assessed in this study received strong expert endorsement as critical skills that can be cultivated meaningfully within early childhood education settings. The definitions of each element were adapted to the developmental characteristics of young children, ensuring relevance and feasibility. These elements can be embedded in playful, engaging activities that support the natural learning processes of young children. The outcomes of this expert consensus provide a robust conceptual and practical foundation for designing a structured, developmentally appropriate sequence of computational thinking instruction in early childhood education.

In addition to the above research results, this study also collected subjective thoughts and considerations of expert experts in commenting on and deepening the substance of computational thinking elements. The analysis of the open-ended responses showed that the experts paid special attention to the aspect of applying CT elements in the context of early childhood learning. There are three main themes that emerged from the experts' input, namely (1) strengthening the elements of creative thinking through patterns, (2) adjusting algorithms to the developmental stage of children, and (3) the importance of systematic integration between elements.

First, on the theme of strengthening pattern development, an expert, coded as ED in this report, said that pattern recognition activities should not only be directed at children's ability to recognize existing patterns, but also emphasize children's ability to build and create their own patterns. In his statement, ED stated that, “Children should not only be invited to recognize patterns, but also given the space to form patterns independently as a form of expression of creative thinking.” This suggests that in structuring the learning sequence for computational thinking, it is important to provide open-ended activities that allow flexible exploration of patterns.

Secondly, in relation to the algorithm element, EE made an important note about the need for an adaptive approach to early childhood characteristics. She emphasized that the development of learning algorithms should take into account children's cognitive and language development levels. According to him, “The design of algorithm activities should be concrete, systematic, yet flexible, and developmentally measurable.” From this statement, it can be understood that the steps in algorithmic activities need to be transformed into activities that are manipulative and easily understood by children.

Third, within the theme of integration and continuity of elements, EG provided a strategic view on the importance of structuring learning sequences that do not treat CT elements in isolation. She said, “Each element of computational thinking should be integrated in a learning sequence that complements and supports the development of analytical and reflective thinking skills in children.” This view emphasizes that the elements of CT need to be designed in the form of a continuous learning experience in order to promote full cognitive development.

From the overall feedback, it appears that experts not only agreed on the relevance of each element individually, but also encouraged attention to the context of implementation in the field. These inputs strengthen the previous quantitative results and become important references in developing an applicable, adaptive and comprehensive CT learning sequence for early childhood.

The findings of this study, which employed the Fuzzy Delphi Method to develop a structured sequence for develop CT in kindergarten education, reveal a high level of expert consensus regarding the relevance and feasibility of six core CT components: logical reasoning, abstraction, decomposition, pattern recognition, algorithm design, and evaluation. These findings offer meaningful contributions to both theory and practice in early childhood pedagogy, particularly in integrating 21st-century skills into foundational learning environments.

One of the central theoretical frameworks supporting early CT integration is Wing (2006) conception of computational thinking as a fundamental skill akin to literacy and numeracy. Although Wing's original work dates back more than five years, her framework continues to be foundational and has been further elaborated in recent research. For example, Dagienė et al. (2024) emphasize that CT is not limited to programming but involves broader cognitive processes including abstraction, generalization, and automation. These processes align closely with the developmental trajectories of young learners when delivered through age-appropriate pedagogical approaches.

Bringing CT into early education aligns with Vygotsky's (1978) sociocultural theory, which posits that cognitive development is strongly influenced by social interaction and scaffolding within the Zone of Proximal Development (ZPD). Recent studies, such as those by Kotsopoulos et al. (2019), affirm that young children can engage meaningfully with CT concepts when supported through guided instruction, hands-on activities, and collaborative learning environments. These insights validate the study's focus on screen-free, activity-based CT sequences that leverage social learning contexts.

A crucial consideration in early childhood education is the developmental appropriateness of introducing complex skills. Piaget's (1972) theory, while foundational, has often been interpreted as discouraging early exposure to abstract reasoning. However, more recent work, such as that by Bers et al. (2022), argues that abstraction and algorithmic thinking can be introduced earlier than Piaget proposed, provided the activities are concrete and embodied. For example, young children can understand sequencing through storytelling or step-based physical games.

Additionally, Bruner's (1966) modes of representation—enactive, iconic, and symbolic—serve as an important guide in sequencing learning activities. Bruner's theory suggests that complex ideas can be taught at any age if the instruction is presented in a developmentally suitable format. For instance, logical reasoning can begin with sorting games (enactive), followed by using picture cards (iconic), and eventually involve symbolic representations like diagrams or simple flowcharts.

The high expert consensus on the six CT components resonates with findings in recent empirical studies. For instance, Kalelioğlu et al. (2016) demonstrated that incorporating CT activities into early education enhanced students' problem-solving and critical thinking abilities. Their study also emphasized the importance of repetition, scaffolding, and play-based learning—strategies which are integral to the learning sequence developed in this study.

Similarly, Click or tap here to enter text. noted that pattern recognition and decomposition are natural cognitive processes for young children and can be cultivated through structured play. Their research highlighted that children as young as five could successfully engage in tasks requiring them to identify patterns or break down larger tasks into smaller steps. These results align with the fuzzy evaluation in this study, where decomposition and pattern recognition received some of the highest fuzzy scores.

In terms of evaluation and reflective thinking, Relkin et al. (2021) argued that metacognitive skills, although more advanced, can be developed through simple reflective practices. For example, asking children to explain why they chose a certain step or what they would do differently encourages early forms of evaluation. This supports the inclusion of the evaluation component in the CT learning sequence, despite it having the lowest fuzzy score.

This study makes a unique contribution by contextualizing CT learning within the Indonesian early childhood education framework. Most prior CT research has been concentrated in Western contexts, often with access to advanced technological infrastructure. However, studies like those by Setiawan et al. (2025) and Handayani & Kusumah (2021) illustrate that CT can be effectively introduced in Indonesian kindergartens through local cultural narratives and traditional games. These culturally responsive practices not only support cognitive development but also affirm children's identities and enhance engagement.

Moreover, the emphasis on screen-free and low-cost activities aligns well with the infrastructure realities of many early education institutions in Indonesia, especially in rural areas. This design consideration is supported by studies like Pratama & Firmansyah R (2022), who highlighted the digital divide in early education and the importance of developing CT strategies that are equitable and accessible.

The integration of CT into early childhood education also supports broader educational goals such as those outlined in the Sustainable Development Goals (SDGs), particularly Goal 4: Quality Education. According to the UNESCO ICT Competency Framework for Teachers (2021), CT is a critical component of digital literacy and should be included in teacher training and curriculum design from the earliest levels of education. The structured learning sequence proposed in this study offers a practical roadmap for operationalizing these policy objectives.

Furthermore, CT integration is in line with the Framework for 21st Century Learning developed by the Partnership for 21st Century Skills (P21). This framework includes critical thinking, communication, collaboration, and creativity (4Cs) as core competencies. CT naturally complements these skills, especially when introduced through interactive, group-based learning activities. Recent research by Lye & Koh (2024) also emphasizes the synergy between CT and 21st-century skills, highlighting how CT activities foster cross-disciplinary competencies.

The open-ended feedback from experts in this study provided critical insights into the nuances of implementing CT in early childhood classrooms. Three key themes emerged: creative pattern development, adaptive algorithm design, and integrated sequencing. First, encouraging children to create their own patterns—not just recognize them—nurtures creativity and deeper understanding. This is consistent with Resnick's (2017) advocacy for "tinkering" as a pathway to creativity in learning. Second, algorithm design should be adjusted to match developmental stages. Experts stressed the importance of making algorithmic steps concrete and manipulable, which is supported by the work of Bers et al. (2022), who recommend using storytelling and puppetry as methods to teach sequential logic. Third, an integrated approach to teaching CT—where all elements build upon each other—is essential for cognitive coherence. As Relkin et al. (2021) emphasizes, compartmentalizing skills can hinder holistic understanding. Instead, a seamless learning progression that connects logical reasoning, abstraction, and reflection supports deeper cognitive growth.

Despite strong support for the integration of CT in early education, ongoing challenges remain. One is the need for teacher training. As noted by Yadav & Chakraborty (2023), many early childhood educators lack sufficient understanding of CT and its pedagogical implications. This study's learning sequence could serve as the foundation for professional development programs aimed at enhancing teacher readiness.

Another area for further investigation is the longitudinal impact of early CT education. Long-term studies could assess how early exposure to CT influences academic achievement, problem-solving abilities, and adaptability in later education stages. Such evidence would provide a stronger empirical basis for curriculum reform.

Finally, the adaptability of CT frameworks across diverse linguistic and cultural contexts requires more exploration. What works in one cultural setting may not be as effective in another. Therefore, future research should continue to explore how CT principles can be culturally grounded, particularly in multilingual and multicultural settings like Indonesia.

The discussion affirms that integrating CT in kindergarten education is both theoretically sound and practically feasible when guided by developmental principles and cultural relevance. The study's high expert consensus supports the relevance of logical reasoning, abstraction, decomposition, pattern recognition, algorithm design, and evaluation for young learners. Grounded in current theories and supported by recent empirical research, the proposed learning sequence addresses both global educational trends and local implementation challenges. As such, it holds significant promise for transforming early childhood education in Indonesia and beyond by equipping children with essential cognitive tools for lifelong learning.

Conclusion

This study has successfully developed a structured and developmentally appropriate learning sequence for introducing Computational Thinking (CT) to kindergarten children in Indonesia. Through the application of the Fuzzy Delphi Method, consensus from 12 experts in early childhood education, computational thinking, and curriculum development confirmed the relevance, feasibility, and importance of six key CT components: logical reasoning, abstraction, decomposition, pattern recognition, algorithm design, and evaluation.

Each element received high levels of expert agreement (≥90.91%) and acceptable threshold values, demonstrating both theoretical soundness and practical applicability. The proposed CT learning sequence is tailored to align with children's cognitive stages and leverages developmentally appropriate practices, such as hands-on, screen-free, and play-based activities. These strategies are not only effective but also culturally and contextually suitable for the Indonesian educational environment, especially in settings with limited digital infrastructure.

The findings are supported by recent educational theories, including Vygotsky's sociocultural approach, Bruner's modes of representation, and Papert's constructionism, all of which advocate for early, guided engagement with complex concepts through concrete experiences. Moreover, the integration of CT aligns with global educational goals, including 21st-century skill development and the Sustainable Development Goals.

This study offers a novel contribution by developing a culturally contextualized, developmentally appropriate Computational Thinking (CT) learning sequence for Indonesian kindergarten students, through the Fuzzy Delphi Method. The implementation emphasizes screen-free, play-based activities that align with children's cognitive development and classroom realities, especially in low-resource settings. It provides teachers with practical, structured guidance to introduce CT effectively. The study recommends integrating CT into the national early childhood curriculum, enhancing teacher training, and encouraging policy support and further research on long-term impacts.

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