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# Incorporating unplugged computational thinking teaching into preschool theme-based curriculum

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**ABSTRACT**

This research aims to investigate the effective integration of unplugged computational thinking (CT) into a project-based curriculum for preschool educators, emphasizing the interplay between thematic content and computational skills. The study also seeks to assess the impact of this curriculum on the CT abilities of young learners, contributing valuable insights to the intersection of early childhood education (ECE) and CT pedagogy. The case study methodology was employed. Purposive sampling was utilized to select a case that would yield rich and relevant data. The research involved a single class comprising 15 children aged 5-6 years old. The result reveals that unplugged CT teaching can be effectively incorporated into a theme-based curriculum project within the ECE framework. This integration significantly enhances children's CT abilities. In delivering CT instruction, teachers are advised to provide stimulating materials, employ guided questioning strategies, and engage children in hands-on activities to optimize the learning experience. The findings demonstrate that children exhibit commendable CT performance following the CT teaching. This research contributes to the emerging field of early childhood CT education by providing practical insights into the successful integration of unplugged CT activities into theme-based preschool curricula.

**Keywords:** unplugged computational thinking, early childhood computational thinking teaching, early STEM education, STEAM curriculum

## INTRODUCTION

In the contemporary society characterized by technological advancements, the lives of young children are intricately intertwined with various technological products, rendering computer science an indispensable component of both learning and future career trajectories. Internationally, there is a growing emphasis on computer science education for young learners, encompassing STEM education and programming. Computational thinking (CT) has emerged as a central focus in global educational development (Manches & Plowman, 2017). Wing (2006) defines CT as the ability to solve problems using computer science approaches in real-world situations. Recognized as an essential skill in the 21st century, CT has become a key focus in curriculum reforms in several countries, including the United States, United Kingdom, China, Taiwan, and Singapore (Saxena et al., 2020).

Despite the predominant focus on CT research and curriculum development for primary education and beyond, the feasibility and implementation of CT education in early childhood education (ECE) remain underexplored (Hsu & Ching, 2023; Shute et al., 2017). Current initiatives in Taiwan for CT promotion in ECE are sporadic, prompting this study to systematically explore the strategies for implementing CT in preschools and evaluating the outcomes of CT initiatives.

The primary objective of this research is to explore how preschool educators can effectively integrate unplugged CT into a theme-based curriculum, emphasizing the synergies between thematic content and computational skills. Additionally, the study seeks to investigate the impact of this curriculum on the CT abilities of young learners. Based on this research goal, the research questions are:

1. How can an unplugged CT curriculum be effectively implemented in preschool settings?
2. What are the effects of implementing the unplugged CT curriculum on children's CT abilities?

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## LITERATURE REVIEW

### CT in ECE

Wing (2006) defined CT as the systematic approach of employing systematic design to solve problems through the lens of computer science. This skill is considered essential for addressing real-world problems in daily life (Buitrago-Flórez et al., 2021; Grover & Pea, 2013). Angeli et al. (2016) proposed five elements: abstraction, generalization, decomposition, algorithms, and debugging as the major components of CT. According to Andrian and Hikmawan (2021), the process of CT involves four distinct steps:

(1) decomposition, wherein complex problems are disassembled into comprehensible components,

(2) pattern recognition, entailing the identification and interpretation of consistent structures or regularities within data,

(3) abstraction, which encompasses the recognition of similarities and the summarization of key points among problems, and

(4) algorithm design, involving the formulation of systematic steps to solve a given problem.

This study utilizes these four CT components of decomposition, pattern recognition, abstraction, and algorithm design as the basis for planning the CT curriculum.

### Unplugged CT Activities

In current CT research, curricula can be broadly categorized into "plug" and "unplugged" courses. "Plug" courses, prevalent in ECE, involve integrating robots or computers. Children engage in block coding to program robots, benefiting cognitive, social, and motor development, as well as problem-solving skills (Bers et al., 2019, 2022). Conversely, "unplugged" CT courses offer examples without computers. Activities include poker card games, binary number games, coding games with "if/then" conditions, teaching algorithms with LEGO, and introducing coding concepts through a hacker invasion game (Saxena et al., 2020). The unplugged CT activities provide engaging and hands-on learning experiences to deepen children's understanding of computational concept (Kirçali & Özdener, 2023; Lin et al., 2023).

### How to Teach Unplugged CT in Early Childhood Settings

Most research in CT aligns with a constructivist theory, serving as its foundational framework (e.g., Strawhacker & Bers, 2019). Rooted in Piaget's constructivist theory, this approach posits that young children actively construct knowledge through interactions with objects and actions. Additionally, this study embraces the Vygotskian socio-cultural perspective, where teachers and capable peers provide scaffolding for children's learning (Daniels, 2002), fostering intrinsic development within the zone of proximal development (Rehmat et al., 2020). We provide stimulating materials and guide, hands-on activities in this study to construct children's collaborative CT knowledge. Furthermore, the core principle of our CT activities emphasizes nurturing children's problem-solving abilities (Hsing et al., 2017). The curriculum focuses on identifying potential opportunities or concepts related to CT within a theme-based project. Thus, this study implements a CT curriculum within a theme-based framework, with CT activities emerging from problem-solving opportunities encountered during the learning process of a theme-based project. The primary method employed in this study to facilitate children's CT learning was a questioning strategy. Numerous studies have indicated that teacher questioning plays a pivotal role in promoting dialogic interaction and cultivating students' ownership of learning (Chin, 2007; Kawalkar & Vijapurkar, 2013). Therefore, this study adopts questioning strategies as the principal guiding method to enhance children's CT learning.

### Assessing CT Abilities for Young Children

CT assessment provides valuable insights into the effectiveness of curricula (Clarke-Midura et al., 2021). However, a notable gap exists in validated CT assessment tools with the majority designed for older children (Tang et al., 2020). Validating CT abilities in young learners presents a unique challenge, as discussed by researchers such as Grover and Pea (2013), who highlight the complexities of assessing CT skills in early childhood. Previous CT assessment tools have encompassed rubrics, interviews, project-oriented coding systems, and programming evaluations (Bers, 2010; Tang et al., 2020). However, some of these methods are time-consuming, unsuitable for classroom use, and largely inappropriate for preschoolers (Relkin et al., 2020). Therefore, this study advocates for the utilization of common assessment tools for young children, such as the "children's work portfolio" and "CT tasks". The "children's work portfolio" involves collecting and analyzing children's work that reflects CT abilities. CT tasks entail designing age-appropriate computational tasks, such as puzzles, games, or hands-on activities, to directly assess children's application of CT components. These assessment methods aim to comprehensively evaluate preschoolers' CT abilities, providing valuable insights into their cognitive development in the realm of CT.

## METHOD

### Case Study

The primary research methodology employed in this study was the case study method, chosen for its ability to provide a comprehensive understanding of the phenomenon under investigation (Sjoberg et al., 2020). Purposive sampling was employed to select a case that would yield rich and relevant data from the study participants (Creswell & Poth, 2017). The chosen case was a preschool classroom devoid of prior experience in CT teaching but with a noteworthy history of high-quality theme-based teaching. The research unfolded in the collaborative formation of a research team consisting of the teachers and the researcher.

This team worked together to explore the implementation of CT teaching within their classroom setting. Discussions and joint design of teaching strategies were integral to the collaborative effort. The process of CT teaching development involved iterative cycles of practice and reflection, leading to continuous enhancements in the application of CT teaching methodologies. The collective efforts of the research team resulted in tangible improvements over time, demonstrating the efficacy of the collaborative approach in fostering successful CT teaching practices.

### Participants

This research was conducted at an H preschool in Pingtung County, Taiwan, chosen for its high quality and positive reputation for theme-based teaching in the region. The study involved a single class consisting of 15 children aged 5-6 years old. The participating teacher had over 10 years of teaching experience but lacked specific experience in teaching a CT curriculum. Written informed consent was obtained from both the teachers and the parents of the participating children. Before implementing CT teaching, the researcher provided the teacher with foundational knowledge of CT teaching through a 3-hour workshop. During the workshop, the researcher introduced theories, curriculum planning, and teaching strategies related to CT. Additionally, the researcher visited the class every week, observed the teacher's instruction, and engaged in discussions to enhance and improve her CT teaching competences.

### CT Teaching Planning

Based on relevant literature, CT teaching was conducted by integrating CT activities into a theme-based project. The teaching content primarily focused on issues children encountered while "designing a toothbrush", the designated teaching theme. Teachers employed scaffolding questioning strategies to guide the children's CT activities. Additionally, a "toothbrush design CT learning center" was established in this study to facilitate individual or small-group experiments by the children. The CT teaching activities were child-centered and could be modified to align with the children's interests and curiosity during their exploration of CT activities. The entire CT curriculum spanned approximately 6 months and was regularly adjusted to meet the evolving interests and needs of the children in their exploration of CT.

### Data Collection

#### *CT implementation*

Data concerning CT curriculum development and processes were collected through research diaries, observations, interviews, and document reviews. The effects of CT teaching were also assessed through "CT task assessment." The researcher conducted weekly observations in H classrooms, focusing on CT teaching planning, children's learning responses, teachers' CT teaching strategies, and children's CT performance. Informal interviews with teachers followed each observation to capture their perspectives on teaching and observations of children's learning situations (Creswell & Poth, 2017). Each informal interview lasted approximately 10-15 minutes. In addition to face-to-face conversations, periodic online discussions were held through social media (i.e., LINE). Documents related to CT teaching plans, teaching aids, teaching assessment sheets, and teaching materials were also collected.

#### *Effect on children*

To evaluate the effectiveness of CT teaching, diversified, interactive, and activity-based tools were employed, aligning with recommendations for authentic assessments in ECE to understand children's abilities (Wortham & Hardin, 2015). In this study, collecting children's CT works served as one method to evaluate their CT performance. The examination of children's design work offered valuable insights into their creative problem-solving skills and CT processes (Bers, 2010).

Another method for evaluating children's CT abilities was through the "CT task assessment." In developing this tool tailored for preschoolers, tasks were designed to align with the unique cognitive developmental stages of preschoolers and the content of their CT activities, ensuring appropriateness and effectiveness in assessing their CT abilities.

The "CT task assessment" encompasses four components corresponding to the CV steps (i.e., decomposition, pattern recognition, abstraction, and algorithm design). Within each step, we devised manipulative CV tasks for children to engage with and respond to. The total number of tasks is 15. Examples of tasks and related questions are provided in **Figure 1**.

The development of the "CT task assessment" with expert validity and reliability involved several crucial stages. A comprehensive literature review identified key CT concepts and principles suitable for preschoolers. Drawing on age-appropriate CT curriculum content, an initial pool of CT tasks was generated. A panel of experts in CT and ECE rigorously reviewed and validated each task, incorporating iterative feedback to refine content validity. Following content validation, a pilot testing phase assessed initial reliability and gathered insights for refinements. Results from the pilot study were analyzed, tasks were adjusted as needed, and the final version of the "CT task assessment" underwent comprehensive reliability analysis, employing statistical methods such as Cronbach's alpha ($\alpha = 0.86$) to ensure consistency and accuracy. This meticulous process resulted in the "CT task assessment" attaining both expert validity and reliability, ensuring its efficacy as a robust instrument for evaluating preschoolers' CT skills.

### Data Analysis

In the development of CT teaching, the researcher conducted a thematic analysis following the method outlined by Creswell and Poth (2017), which encompassed transcribing, coding, categorizing, and establishing themes. The researcher scrutinized provisional claims through the analysis of various data sources, consistently reviewing data classification and the appropriateness of aforementioned claims. The process of proposition formation was iteratively conducted, and member checking of

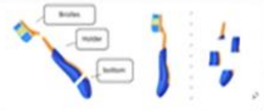
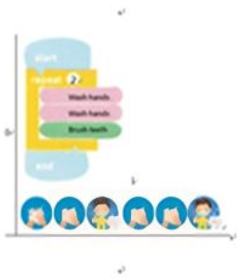
| Examples of the CT tasks | Task questions |
|---|---|
|  | **Decomposition:** (1) Can you name three parts of a toothbrush? (2) Which part of the toothbrush is missing? |
|  | Pattern recognition: (1) Pick a toothbrush with green and black colors; (2) Pick a toothbrush with dots |
|  | **Abstraction:** (1) Boolean value: (I) This toothbrush is red (true/ false?) (II) The bristles of this toothbrush are blue (true/false?); (2) data structure: (I) find "and"; (II) find "or"; (III) find "not" |
|  | **Algorithm design:** (1) data loop: (I) arrange the correct pattern; (II) Arrange the correct building blocks; (III) What to do when encountering tooth decay bacteria?(2) sorting (I) how to design a child friendly toothbrush; (3) design instruction: (I) help the teeth find the toothbrush (II) help the teeth find the toothpaste |

**Figure 1.** Example of the CT task assessment (Source: Authors' own elaboration)

transcriptions was performed to ensure the validity of data analysis, following the approach recommended by Yin (2015). Additionally, diverse data sources, including observations, interviews, and collected documents, were used for data triangulation. The reliability of the collected data was further validated through self-reflection and continual discussions and dialogue with the teacher.

To analyze the effects of CT teaching on children's CT abilities, the researcher utilized the percentage of correct responses in the "CT task assessment" to evaluate children's CT performance. The researcher initially analyzed the correctness rate of each task to identify the most challenging CT tasks for children. Subsequently, the researcher assessed the number of children who answered all tasks correctly.

## RESULT

### Origin of the CT Theme

The genesis of the CT themes under consideration can be traced back to the innate interests and daily life experiences of children, particularly stemming from their engagement with early childhood curriculum themes. In this study, the computational theme "toothbrush design" emanates from a curriculum centered around the preschool's crucial subject of healthcare, with a particular focus on dental hygiene in the theme "protect your teeth." In the course of this curriculum, children engage in dialogues surrounding their dental care practices, notably discussing the varied toothbrushes they employ in their daily routines. This discourse not only serves as a testament to the salience of children's lived experiences but also catalyzes a collective desire to innovate and design toothbrushes. Consequently, the origin of the CT themes is tied to the discussions and aspirations emerging from "how to design a toothbrush that is friendly for children."

### Activities of CT Curriculum

CT is a problem-solving approach that involves breaking down complex problems into smaller, manageable parts and solving them through the use of computational concepts, which include:

(1) Decomposition: Breaking down a problem into smaller, more manageable sub-problems;

(2) Pattern recognition: Identifying similarities or patterns within a problem to make it easier to solve;

(3) Abstraction: Focusing on the essential details while ignoring irrelevant information to create a simplified representation of the problem; and

(4) Algorithm design: Developing a step-by-step solution or set of instructions to solve the problem.

To help children solve the problem of designing a user-friendly toothbrush for young children, the design process of toothbrush was break into the following components, as shown in **Table 1**.

**Table 1.** CT activities of the toothbrush design

<table>
<tr><th>CT components</th><th>Design a toothbrush</th><th>Photo</th></tr>
<tr><td>Decomposition</td><td>Breaking down the overarching problem of designing a toothbrush into more manageable sub-problems. In this context, we started by identifying key elements of a toothbrush, such as brush hair, brush holder, and brush bottom. Each of these aspects can be treated as a distinct sub-problem, allowing for a more focused and systematic approach to the overall design challenge of a toothbrush.</td><td>
</td></tr>
<tr><td>Pattern recognition</td><td>Identifying commonalities or recurring features within the context of toothbrush design. By analyzing existing toothbrushes, children can discern patterns, functions, featured design in brush hair, brush holder, and brush bottom. For example, some toothbrushes are electronic, can stand, easy to hold, have cartoon appearance, etc. Recognizing these patterns provides a foundation for creative innovation of design.</td><td>
</td></tr>
<tr><td>Abstraction</td><td>Distilling the design challenge to its essential elements, filtering out irrelevant details. Identify the regular patterns, simplify them into symbols (Boolean values), or commands (and, or, not) o create a simplified representation. In the case of a toothbrush, abstraction might entail using simple symbols to focusing on fundamental aspects of designing a friendly toothbrush.<br>
</td><td>
</td></tr>
<tr><td>Algorithm design</td><td>Algorithm design is to develop a step-by-step solution or set of instructions to address each sub-problem. For instance, the handle design algorithm would delve into ergonomic principles, ensuring a comfortable grip for children. These step-by-step solutions collectively form the blueprint for the overall toothbrush design, providing a systematic guide for implementation.<br>
</td><td>
</td></tr>
</table>

In synthesizing these components, designing a toothbrush becomes a comprehensive CT endeavor. Decomposition allows for a structured breakdown of the toothbrush design challenge; pattern recognition draws on knowledge and precedents of the existing toothbrushes; abstraction simplifies the complexities, and algorithm design provides the systematic steps to bring the conceptualized toothbrush to fruition. By applying these CT components, children can navigate the intricacies of toothbrush design with a strategic and methodical approach, ultimately yielding an innovative and children-centric design of toothbrush for young children.

### Scaffolding Strategies to Enhance CT Abilities

In fostering and enhancing CT abilities, teachers employ a multifaceted approach, intertwining various strategies to guide their learning journey. The following explains the details of the scaffolding strategies.

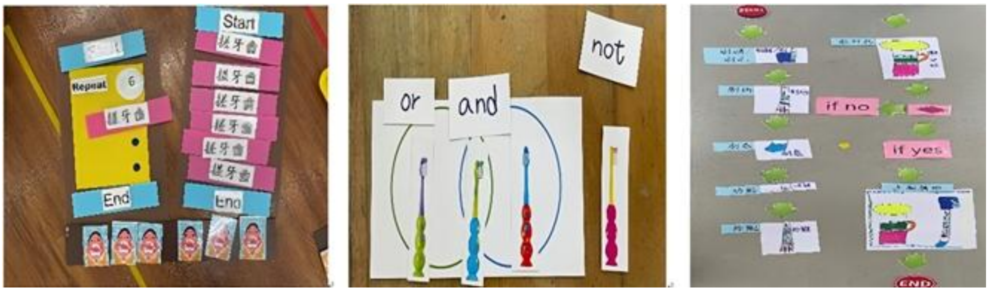



**Figure 2.** Examples of teaching aids and materials (Source: Field study)

**Table 2.** Guided questioning in CT activities

| CT components | Guided questions |
|---|---|
| Decomposition | ▪ What are the main components of a toothbrush? What are the different types of toothbrushes?<br>▪ What are the differences in bristle shapes? How about handle variations? And what about the bottom of the toothbrush? What about its overall appearance? |
| Pattern recognition | ▪ In terms of bristle shapes, what functionalities do different shapes serve? Which shapes are suitable for children?<br>▪ What are the various styles of toothbrush handles? Which styles are appropriate for toddlers to grasp?<br>▪ What are the different bottom designs of toothbrushes? Which designs allow the toothbrush to stand, and which ones require a cup for placement?<br>▪ What aspects make a toothbrush visually appealing? What are the characteristics of colors and what line designs are used? |
| Abstraction | ▪ How can the toothbrush design process be represented using flowcharts?<br>▪ Will you use abstract symbols like [*and/or/not*] to express communication in the design? For example, “I want circular bristles [*and*] a toothbrush that stands.”<br>▪ Will you use [*true/false*] to assess toothbrush conditions? For instance, “This toothbrush can stand? (*true/false*)” |
| Algorithm design | ▪ Will you give instructions to a robot to move to a destination? How do you command it to go [*forward/backward/left/right*] to avoid obstacles?<br>▪ How would you instruct it to brush teeth three times repeatedly? If it encounters a cavity bug, what additional instructions would you include? |

### *Provide stimulating materials*

Teachers providing inquisitive minds with the necessary materials to delve into pertinent questions, challenging them to develop problem-solving procedures independently. For example, teachers prepare teaching aids and materials in learning center to instill a sense of ownership in the learning process (**Figure 2**).

### *Guided inquiry-questioning*

Guided inquiry stands as a cornerstone, encouraging children to engage in systematic exploration. Diverse questioning approaches serve as crucial element in the guided inquiry. By posing questions that prompt critical thinking and reflection, teachers stimulate and encourage children to analyze problems and foster interactive discussions (**Table 2**).

Through questioning strategies play a pivotal role in providing dynamic exchange among children and teachers, which not only refines their communication skills but also deepens their understanding of CT concepts.

### *Engage in hands-on activities*

Engaging in hands-on and stimulating activities plays a pivotal role in fostering children’s CT skills. By providing interactive experiences that involve problem-solving, logical reasoning, and algorithmic understanding, educators can effectively nurture the cognitive abilities required for CT. The hands-on activities conducted in this study aligned with specific CT concepts (**Figure 3**). For example, to reinforce “decomposition”, teachers utilized toothbrush puzzles where children identify different parts and discern missing components. For “pattern recognition”, “green/red jumping games” were employed to illustrate diverse patterns in toothbrush design, encompassing brush bristle, holder, and bottom. The concept of “abstraction” was conveyed through the use of hula hoops, helping children grasp the concepts of “and, or not” and used abstract symbols in their design ideas. Lastly, for “algorithm design”, “coding games” and “robot turtle” activities offer a practical approach to instruct children on providing directions to robots or computers, enabling them to reach destinations and navigate obstacles effectively during the journey.

Through hands-on activities that encourage exploration, experimentation, and collaboration, children not only develop a foundational understanding of programming concepts but also enhance their CT skills. The incorporation of tangible and interactive elements in educational settings lay the groundwork for future academic and professional success in the increasingly digital world.

## Evaluation of Learning

### *Children’s design of toothbrush*

The research findings demonstrate a promising and insightful glimpse into the CT abilities of young children through their design projects focused on creating innovative toothbrushes. The designed toothbrush’s photos are shown in **Figure 4**.

**Figure 3.** CT hands-on activities (Source: Field study)

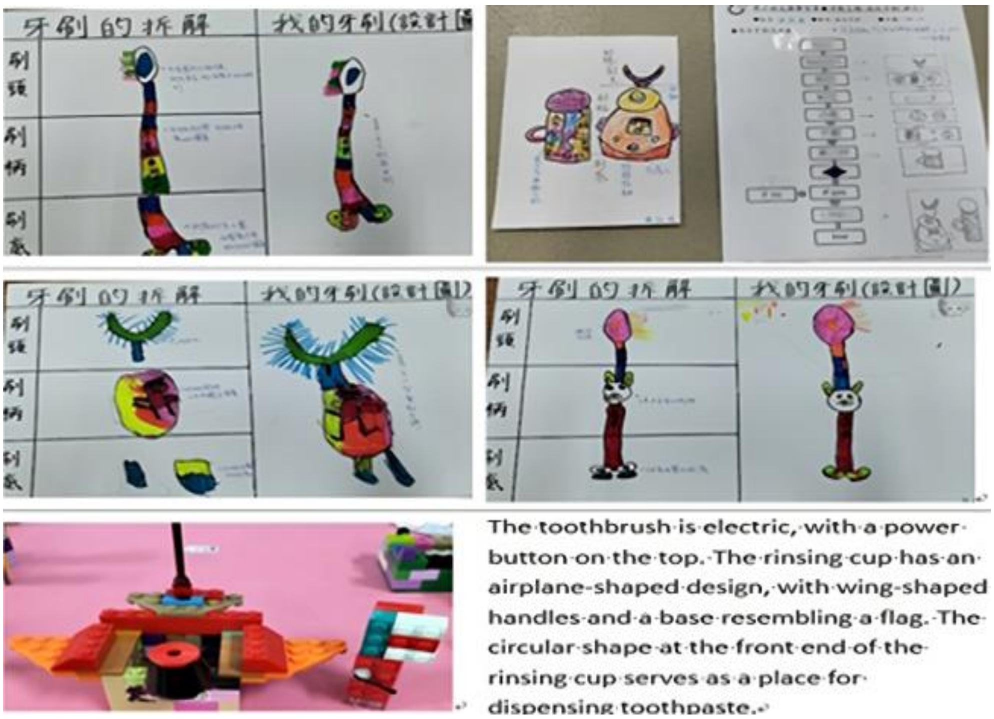



**Figure 4.** Children's CT designed blueprint and work (Source: Field study)

As evidenced by the photos of the children's work, it is apparent that the children successfully applied the CT skills acquired during the course to devise unique and imaginative solutions. Their designs not only showcase creativity but also reflect a solid understanding of key computational concepts such as problem decomposition, pattern recognition, abstraction, and algorithmic thinking. The diverse array of toothbrush designs reflects the individuality of each child's approach, indicating a positive development of their CT skills. This assessment not only highlights the effectiveness of the course in fostering CT but also underscores the potential for integrating such pedagogical strategies into ECE to nurture young minds with foundational skills for the digital age.

### *Children's performance of CT assessment*

Overall, children exhibited strong performance in the CT assessment. Specifically, in the CT tasks of "pattern recognition," "abstraction," and "design instruction," the correct answer rate was 100%. For the tasks related to "decomposition," "data loop," and "sorting," the correct answer rates exceeded 85%. Among the 15 questions, 60% of children answered all questions correctly, 27% made one mistake, and 7% made 2 or 3 mistakes. Therefore, children exhibited good performance in the CT assessment.

## CONCLUSION AND SUGGESTIONS

This study reveals that unplugged CT teaching can be effectively incorporated into a theme-based curriculum project within early childhood curriculum framework. When educators identify suitable opportunities or encounter challenges within the curriculum, they can initiate CT activities or themes, incorporating the components of CT (i.e., decomposition, pattern recognition, abstraction, and algorithm design). This integration serves to augment children's CT abilities. In delivering the CT teaching, teachers are advised to furnish stimulating materials, employ guided questioning strategies, and involve children in hands-on activities, thereby optimizing the learning experience. The findings indicate that children exhibit good CT performance after the CT teaching.

The findings of this study hold significant implications for illuminating the effective integration of CT activities into theme-based curriculum projects in early childhood settings. Prior to this study, there was a limited understanding of how such activities could be seamlessly incorporated into existing educational frameworks, thereby establishing a valuable contribution to the literature. In addition, the study's outcomes have noteworthy implications for practical solutions and interventions in the domain of CT teaching within ECE. By demonstrating the efficacy of integrating CT activities into theme-based projects, educators can adopt more diverse approached to enhance children's CT abilities. The emphasis on stimulating materials, guided questioning strategies, and hands-on activities provides actionable insights for educators seeking to optimize CT learning experiences in early childhood settings.

Despite the positive outcomes, it is crucial to acknowledge certain limitations encountered during the study. Potential constraints may include variations in teacher readiness to implement CT activities, differences in classroom dynamics, or resource limitations. These limitations should be considered when interpreting the study's results, recognizing that the generalizability of findings may be influenced by these contextual factors. Besides, the study's findings open avenues for future research directions and exploration within the field of early childhood CT education. Subsequent studies could delve deeper into the optimal frequency and duration of CT activities, explore variations in implementation across diverse cultural contexts, or investigate the longitudinal impact of integrating CT into ECE. Additionally, researchers may consider examining the scalability of these findings in larger educational settings to further validate and generalize the study's implications.

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**AI statement:** The authors stated that they used Claude (Anthropic) solely for English language proofreading and editing. All research design, data collection, analysis, interpretation, and manuscript writing were conducted entirely by the authors.

**Declaration of interest:** No conflict of interest is declared by the authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

## REFERENCES

Andrian, R., & Hikmawan, R. (2021). The importance of computational thinking to train structured thinking in problem solving. *Journal Online Informatika, 6*(1), 113-117. https://doi.org/10.15575/join.v6i1.677

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society, 19*(3), 47-57.

Bers, M. U. (2010). The TangibleK robotics program: Applied computational thinking for young children. *Early Childhood Research & Practice, 12*(2).

Bers, M. U., González-González, C., & Armas-Torres, M. B. (2019). Coding as a playground: Promoting positive learning experiences in childhood classrooms. *Computers & Education, 138*, 130-145. https://doi.org/10.1016/j.compedu.2019.04.013

Bers, M. U., Strawhacker, A., & Sullivan, A. (2022). *The state of the field of computational thinking in early childhood education*. IGI Global.

Buitrago-Flórez, F., Danies, G., Restrepo, S., & Hernández, C. (2021). Fostering 21st century competences through computational thinking and active learning: A mixed method study. *International Journal of Instruction, 14*(3), 737-754. https://doi.org/10.29333/iji.2021.14343a

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44*(6), 815-843. https://doi.org/10.1002/tea.20171

Clarke-Midura, J., Silvis, D., Shumway, J. F., Lee, V. R., & Kozlowski, J. S. (2021). Developing a kindergarten computational thinking assessment using evidence-centered design: The case of algorithmic thinking. *Computer Science Education, 31*(2), 117-140. https://doi.org/10.1080/08993408.2021.1877988

Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches*. SAGE.

Daniels, H. (2002). *Vygotsky and pedagogy*. Routledge. https://doi.org/10.4324/9780203469576

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

Hsing, M.-L., Yang, C.-P., Chiu, C.-H., Ko, H.-W., Tsai, M.-L., Chin, S.-C., Kuo-Li, T.-W., Chien, S.-C., & Lin, M.-J. (2017). *Xin kegang xiang shuo de shi: Youeryuan jiaobao huodong kecheng dagang de linian yu fazhan* [What the new curriculum wants to convey: The philosophy and development of the preschool education and care activity curriculum outline] (2nd ed.). Psychology.

Hsu, Y.-C., & Ching, Y.-H. (2023). Generative artificial intelligence in education, part one: The dynamic frontier. *TechTrends, 67*(4), 603-607. https://doi.org/10.1007/s11528-023-00863-9

Kawalkar, A., & Vijapurkar, J. (2013). Scaffolding science talk: The role of teachers' questions in the inquiry classroom. *International Journal of Science Education, 35*(12), 2004-2027. https://doi.org/10.1080/09500693.2011.604684

Kirçali, A. Ç., & Özdener, N. (2023). A comparison of plugged and unplugged tools in teaching algorithms at the K-12 level for computational thinking skills. *Technology, Knowledge and Learning, 28*(4), 1485-1513. https://doi.org/10.1007/s10758-021-09585-4

Lin, Y., Liao, H., Weng, S., & Dong, W. (2023). Comparing the effects of plugged-in and unplugged activities on computational thinking development in young children. *Education and Information Technologies, 29*, 9541-9574. https://doi.org/10.1007/s10639-023-12181-x

Manches, A., & Plowman, L. (2017). Computing education in children's early years: A call for debate. *British Journal of Educational Technology, 48*(1), 191-201. https://doi.org/10.1111/bjet.12355

Rehmat, A. P., Ehsan, H., & Cardella, M. E. (2020). Instructional strategies to promote computational thinking for young learners. *Journal of Digital Learning in Teacher Education, 36*(1), 46-62. https://doi.org/10.1080/21532974.2019.1693942

Relkin, E., de Ruiter, L., & Bers, M. U. (2020). TechCheck: Development and validation of an unplugged assessment of computational thinking in early childhood education. *Journal of Science Education and Technology, 29*, 482-498. https://doi.org/10.1007/s10956-020-09831-x

Saxena, A., Lo, C. K., Hew, K. F., & Wong, G. K. W. (2020). Designing unplugged and plugged activities to cultivate computational thinking: An exploratory study in early childhood education. *The Asia-Pacific Education Researcher, 29*(1), 55-66. https://doi.org/10.1007/s40299-019-00478-w

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

Sjoberg, G., Orum, A. M., & Feagin, J. R. (2020). *A case for the case study*. The University of North Carolina Press.

Strawhacker, A., & Bers, M. U. (2019). What they learn when they learn coding: Investigating cognitive domains and computer programming knowledge in young children. *Educational Technology Research and Development, 67*, 541-575. https://doi.org/10.1007/s11423-018-9622-x

Tang, X., Yin, Y., Lin, Q., Hadad, R., & Zhai, X. (2020). Assessing computational thinking: A systematic review of empirical studies. *Computers & Education, 148*, Article 103798. https://doi.org/10.1016/j.compedu.2019.103798

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35. https://doi.org/10.1145/1118178.1118215

Wortham, S., & Hardin, B. J. (2015). *Assessment in early childhood education* (7th ed.). Pearson.

Yin, R. K. (2015). *Qualitative research from start to finish*. Guilford Publications.