A Pedagogical Framework for Embedding Computational Thinking in Authentic Technology Practice

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Abstract

Computational thinking is an aspect of digital technologies in the New Zealand Curriculum that teaches children to approach problems systematically, using logical and analytical reasoning. This paper presents a study undertaken in a small-town primary school in New Zealand with a high population of Māori students. The study drew on four aspects from Kotsopoulos et al.'s framework of pedagogical experiences: unplugged, tinkering, making, remixing to investigate pedagogical strategies that facilitate the successful embedding of computational thinking within authentic technological practice. The research aimed to identify learning pedagogies that support young learners in their understanding of computational thinking through designing and developing digital technologies. The qualitative methodologies were informed by the three pedagogical principles from Bishop and Berryman to guide the research design and frame learning support for students. Key themes that emerged from the data included the values of local context, self-autonomy, classroom organisation, use of physical and digital manipulatives. Finally, the paper presents a model for the pedagogical delivery of computational thinking when embedded in technological practice in primary schools, drawing from and adding to Kotsopoulos and colleague's pedagogical framework. The most significant modification situates the existing model within authentic technology practice, providing context for learning. The model shows an adjustment from 'Making' to 'Designing and Making', thus strengthening the position of digital technologies within the Technology learning area. The model also signals that authentic technological within a primary classroom practice is heavily impacted by 'the pragmatics of delivery' through a range of pedagogical and organisational strategies developed to ensure the needs of all students are met and to support them through their learning journey in computational thinking. The last significant modification of Kotsopoulos and colleagues' model is the removal of 'remixing' because the primary aged students in this study did not reach the level of sophistication required for remixing. The aim of the framework is to assist teachers and teacher educators to design and develop successful teaching and learning strategies for implementing computational thinking into authentic technology practice in primary schools.

Keywords: computational thinking, digital technologies, technology education, pedagogical strategies, primary, authentic technology practice

1. Introduction

Computational thinking (CT) is an essential aspect of the New Zealand Curriculum (Ministry of Education, 2017a), designed to teach children how to approach problems systematically through logical and analytical reasoning. It prepares students to be creators of digital outcomes, with applications not only in computer science and mathematics but across the full spectrum of STEM disciplines (Li et al., 2020; Yadav et al., 2016). CT incorporates various skills such as algorithmic thinking, abstraction, decomposition, sequencing, pattern recognition, and logical reasoning. These skills are vital in both technology-related fields and everyday life. Introducing computational thinking at an early age is an effective way to equip children with the skills they need to succeed in an increasingly technology-driven world. Yet, anecdotal evidence suggests that for young learners, particularly those between the ages of five to eight years of age, the development of CT skills is most successful when embedded within meaningful, authentic contexts. The importance of authentic contexts in technology education is well documented (Fox-

Turnbull, 2003; Fox-Turnbull et al., 2023; Hill, 2017; Snape & Fox-Turnbull, 2013). Such contexts help children connect with the learning material, utilising their prior knowledge, cultural experiences, and personal interests. In New Zealand, technology education has long emphasized that students should learn in contexts that are relevant to them (Fox-Turnbull, 2003).

However, current teaching resources (e.g. digital tools) and practices often focus on decontextualized skill-building, failing to connect abstract concepts to real-world scenarios that resonate with students (Fox-Turnbull, 2019). While elements of local culture—such as traditional stories or culturally appropriate language—are sometimes incorporated, these practices often fall short in demonstrating how computational thinking can help address challenges in students' local communities. As a result, children may struggle to see the relevance of what they are learning. To bridge this gap, there is a pressing need for approaches that go beyond simply presenting cultural content and instead integrate computational thinking in ways that connect directly to students' lived experiences.

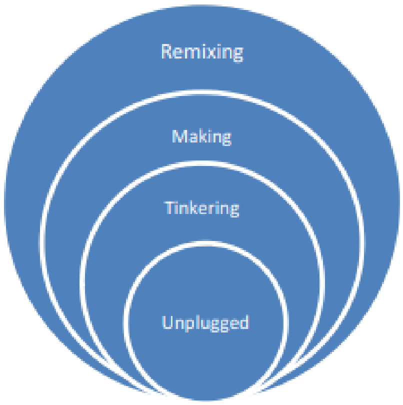
To address this gap, this research investigates how young learners can develop computational thinking skills within authentic and culturally relevant contexts. It aligns with the New Zealand Curriculum's emphasis on Mātaiahikā, which connects learning to local environments, communities, and cultures, and encourages schools to tailor their learning programs by drawing from their unique, local contexts. We adopt a community-based model that facilitates collaboration between teachers and students to co-create learning activities that reflect the community's needs and interests. This model fosters trust and ownership of the learning experience, with students more invested in their learning (Berryman et al., 2016).

While valuable for teaching programming concepts, digital tools often reinforce a top-down, structured approach to problem-solving, not aligning with the cultural learning styles of diverse communities. This paper explores a more bottom-up, "tinkering" approach—one that encourages exploration, experimentation, and creative problem-solving, aligning with indigenous learning traditions and providing a holistic way of engaging with technology (Bell & Reinsfield, 2012).

2. Research Design

Given the recent developments in digital technologies and CT curriculum it is vitally important for teachers to equip themselves with the appropriate and accurate content and pedagogical knowledge and skills so they can teach effectively (Rehmat et al., 2020). Quality instruction with appropriate pedagogical approaches is more effective at increasing student achievement in computational thinking than tools, programmes and environments (Kandemir et al., 2021). This study employed a range of pedagogical strategies designed to maximize student engagement and learning outcomes. These strategies were drawn from existing frameworks of pedagogical experiences, including unplugged activities, tinkering, making, and remixing (Kotsopoulos et al., 2017) (Figure 1). Unplugged activities, which involve teaching CT concepts without the use of computers or devices are particularly effective in fostering foundational understanding and engaging a wide range of learners, including neurodiverse students (Hermans & Aivaloglou, 2017). Tinkering, which involves the hands-on exploration and modification of existing technologies or code, encourages curiosity and experimentation, allowing students to explore computational concepts in a low-stakes, iterative environment. The making process, where students design and develop their own digital outcomes, helps them apply computational thinking to solve real-world problems. Finally, remixing, which involves adapting or repurposing existing digital artifacts in creative ways, pushes students to apply their CT skills at a higher level of complexity (Kotsopoulos et al., 2017).

Figure 1: Four Pedagogical Experiences (Kotsopoulos et al., 2017, p. 159)



By employing these strategies in the classroom, the study sought to create a more authentic and culturally responsive learning environment, where computational thinking was not taught as an isolated set of skills, but integrated meaningfully into students' lives. This research aims to offer valuable insights into how young children can develop computational thinking within contexts that reflect their cultural identities and local communities. Through this work, we hope to contribute to a broader understanding of how CT can be taught effectively and meaningfully in primary education and attempt to answer the following research question: What learning pedagogies support young learners in developing their computational thinking to understand, design and develop digital technologies within their cultural context?

3. Methodology and Methods

Valuing students' cultural funds of knowledge and bringing this understanding and knowledge into the classroom has the potential to enhance students' engagement and achievement (González et al., 2005). With a focus on teaching computational thinking in a meaningful culturally situated context as intended in The New Zealand Curriculum (NZC) (Ministry of Education, 2017c) this study encompassed skills-based lessons within culturally authentic contexts relevant to students' current and possible future lives (Hennessy, 1993).

Three pedagogical principles from Bishop and Berryman (2006) informed this qualitative research design. The co-constructed learning sequences and processes were characterised by:

- being embedded in students' local environment (school and local small town).
- encouraged innovation and creativity among students, who will be to be creative in learning by deploying individual culture experiences.
- interactivity, with students developing new knowledge through dialogue with peers and teachers, teacher feedback and guidance, and interaction with a digital tool, Kete.

The team investigated pedagogies that led to successful student learning in digital technology. It drew on findings from previous study which investigated sequencing and orientation aspects of computational thinking using Beebot® robots, with 35 Year 0-3 students, which highlighted the success of using te reo Māori, a Tuakana/Teina teaching approach and merging lived experiences as Māori with technology education (Fox-Turnbull W. et al., 2024).

The University of Waikato Division of Education ethics committee gave approval. Participation was voluntary and consent was gained by the school principal, participant teachers, students and their parents. Confidentiality was guaranteed however anonymity was not due to the limited number of schools which fit the description within the region. Methods used in the study included initial and final semi-structured interviews with teachers, initial interviews with 10 consented students and researcher observations of teaching and learning with related photographs.

3.1. Sample

This study took place in two primary classrooms in a small-town low decile school in New Zealand (NZ). The research was undertaken by two researchers with assistance from two summer scholars. The first researcher was a former primary teacher and current academic in technology education, the second a computer science lecturer. During the study, two teachers and their students co-constructed learning activities aimed at developing computational thinking. The first was Year 4 class with a first-year teacher, Whaea K, the second a Year 5-6 class, Whaea O. 'Whaea' is a Māori term for respected woman and often used in NZ primary schools. Teachers' names are pseudonyms. The goal was to create a learning space in which computational thinking was not an abstract set of skills, but an integral part of the students' everyday lives and cultural understanding (Berryman & Forde, 2017; Warren, 2018). Through this process, a co-authoring digital tool (Kete) is used to facilitate students' connection of CT concepts to their cultural knowledge and experiences, ensuring meaningful and contextually relevant learning.

3.2. Instrument

Researcher observation, teacher interviews, student focus group interviews and work samples were used to gather the research data. Thematic analysis was applied to elicit key themes as suggested by (Braun & Clarke, 2006). Representative quotes are presented in the findings. Rigour and consistency were ensured by one summer scholar completing initial coding, which was then cross-checked by the two researchers independently to identify the initial themes.

3.3. Procedure

The study compromised one-hour computational thinking (CT) lesson per day over five weeks during a school term. The students were introduced to key CT aspects with an aim of them developing a programme to assist the exploration of their local township. Resources used in the unit included the ByteEd 'Dino Steps' kits and 'Kete'- an app developed by the research team that enabled students to load maps and programme journeys through the map (Figure 2).

Figure 2: Kete app home page

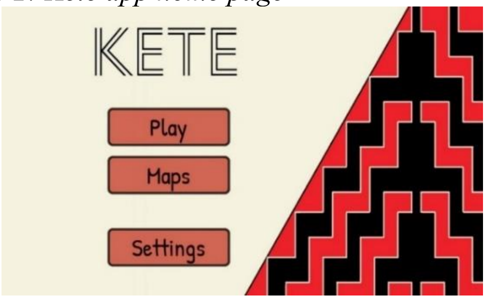


Figure 3: Kete page showing language selection

Central to Kete is the Poutama motif, an element in Māori culture. Poutama symbolises levels of learning and intellectual achievement. In Kete, Poutama is conceptualized as the framework for the game's progressive difficulty levels, mirroring the journey of gaining knowledge and skills. This cultural integration aimed to make Kete not only a tool for learning computational concepts but also a medium to connect with New Zealand's cultural heritage. In Kete students choose which language they use, English or Te reo Māori [Indigenous language of New Zealand] (Figure 3).

Kete features three distinct modes. *Free Play Mode* represents the foundational step in the Poutama, allowing players to explore and navigate freely, akin to the initial phase of learning where exploration and discovery are key. *Tour Mode* **r**eflects a higher step in the Poutama and introduces structured challenges, requiring players to visit locations in a specific sequence, thus promoting logical thinking and planning skills. Finally *Sequence Mode* is at the apex of the Poutama and engages players in advanced problem-solving. Students preload instructions for complex sequences, evidencing mastery of aspects of computational thinking.

4. Results

Key themes that emerged from the data related to successful pedagogical studies included the value of local context while undertaking authentic technology practice, student and classroom organisation, use of non-digital and digital activities and manipulatives.

Value of Local Context Embedded in Technology Practice

Contextualised learning motivated the students. The key purpose of the teaching unit was for the students to design and develop a tour of their school for newcomers on a tablet. To do this students' needed knowledge and skills in key aspects of computational thinking such as: abstraction, decomposition, pattern recognition, sequencing and debugging. Throughout their learning the students were able to see their world and culture and immersed in authentic technological practice. When this occurred student engagement flourished. When asked where she observed learner success Whaea O said "Applying their own context to their [programmes] and being able to create their own mix". The context used in this study included the students' school, historical sites in their hometown, and cultural practice (flax weaving patterns and carving patterns). Being Māori and local sites around their village were some of the more noticeable engagement areas and exemplified when the students were introduced to pattern recognition. When asked about the patterns they see one child stated they saw patterns "in the marae [tribal communal area]". See Figure 4 for an example of some of the patterns commonly seen in marae. The following extract from the researcher Observation explains this in more detail.

> The class were brought back together, and everyone had an opportunity to share their ideas. WO [teacher participant] focused on the student who said the marae and asked the students where they could find these patterns. The students said in the carvings and WO pointed out additional patterns in the tukutuku panels in the wharenui [meeting house on the marae] and a key feature they possessed was that the patterns repeated themselves (Researcher Observation p10).

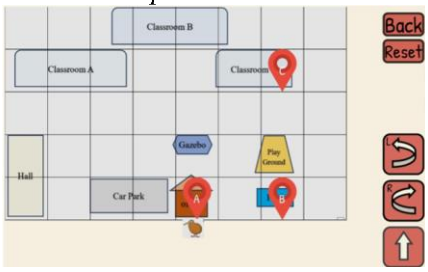
Figure 4: Tukutuku Pannels on either side of a Kowhaiwhai-patterned Carving

When teaching the concept of abstraction, the students were shown to maps from their local area. The first a google map of their village and the second one of their schools showing the different facilities. Researcher observations indicated student motivation and excitement. "Student were excited to identify different places they recognised such as the shops they frequented and streets they lived on" (Researcher Observation p7). When the students created their own map of their village Whaea K stated, "It was cool to have [them] create their own maps, and I definitely saw them thinking about their own community, putting in their own shops". Later students were then sent off in groups around their school to determine the important information and locations that would be needed for a school tour in Kete. Figures 5-6 show examples of the students' school maps in the Kete app, which so engaged the students.

Student engagement was evident at the post-unit focus group interview with the students when asked about how they see computing in their future. It is clear that students learned that they could become creators of digital technologies, not just users. "Make my own app and work on it properly and see if it's the right app to put in on the public" and "I want to make an app for little kids who don't know anything, and they can write a little code and learning everything" are two quotes that exemplify this.

Figure 5: Students with Kete app map of the school

Figure 6: One student's map of the school with their kiwi icon at point A



Classroom and student organisation

Whole Class and Group Work

Teachers employed a diverse range of organisational practices to meet the needs of their students. This was achieved by altering between whole class, group, and individual learning experiences. In the example below learning was introduced with a whole class session led by Whaea O. Within the whole class discussion Whaea O directed her students to discuss ideas with those around them before sharing their ideas with the whole class.

> We're thinking about our digital devices and the world, I want you now to turn to the person near you or next to you and think about what devices do you have at home and how do they help you. What are some digital devices do you have at your house and how do they help you turn and talk to your friends?

During the unit the students also worked in small, teacher-selected groups, for example when asked to identify about technology they might find at home.

> Students were then split into groups and given a task to complete. The students were presented with a blank cross section of a house and asked to identify different types of technology found in the home (Researcher Observation 6 Nov).

The unit continued with a range on unplugged activities through in 'Dino Steps'(ByteEd) the students worked in teacher-selected groups. The Dino Steps kits and programme involve the students putting together a prehistoric landscape jigsaw, then programming 'Explorer Ed' about a prehistoric landscape and through a range of challenges related to the dinosaur inhabitants. The students worked within their small groups developing their pattern recognition, algorithmic thinking, decomposition and debugging skills and understanding.

Working Autonomously

Later in the unit when the student each engaged in Kete to design a 'visitor guide for their school' they worked as individuals. They designed and developed their own programmed pathway around the school with kiwi icon in Kete. At her exit interview when asked about her highlights of the unit Whaea K said "I like how they could be so independent with the learning". Whaea O elaborated

> And they didn't wait on their mates….It's quite good to give them the independence where they can challenge themselves and go as far as they can go. [Test] their capabilities…

Seeing Themselves in the Classroom

The researchers observed that the students Māori culture was obviously reflected in their classroom. All the study's participants self-identifed as Māori. Te Reo Māori was evident in the classroom. The students were guided by Māori values, seen on the wall in their classroom.

Photographs of Māori elders significant to the region were displayed on the classroom walls. Many instructions given by the teachers were in Te Rei Māori.

Use of Non-digital Activities and Manipulatives

Physical manipulatives were used when students first learned coding. This assisted extension of their thinking and cemented different concepts. The manipulatives proved invaluable with students who did not have high levels of literacy and numeracy. In Dino Steps these included the jigsaw place map, Explorer Ed, dinosaurs, and the arrow cards for creating the code as seen in Figure 7. The manipulatives helped the students understand concepts such as sequence and notating code. Using manipulatives limited the barriers for the students.

> The visual, the visual application of it, like the dinosaurs, the creating the map, the challenges. They really liked the challenges and the resources like the step cards and the arrows. It was really good for them, clear, easy to use (Whaea O Exit Interview).

Non-digital manipulatives allowed the students to be creative and explore concepts at their own pace and ability. With teacher conferencing, students' thinking was extended, thus assisting the development of complexity in coding.

> Students were then sent back to their groups with the Dino Step kits and were instructed to create a sequence of instructions that repeated itself at least twice. They were told that the pattern could be as simple or as complex as they wanted, the only criteria… it needed to repeat itself twice (Researcher Observation 22 Nov).

Digital manipulatives and Gamification

Kete is designed to bridge the gap between traditional teaching methods and modern, interactive learning approaches. The shift from physical to digital manipulatives was assisted through the use of a common concepts of coding between Dino Steps and Kete. Both used a grid requiring students to write and debug algorithms for journeys through an environment, Dino Steps in the physical space and Kete digital. Researcher observation indicated the switch to abstract coding proved challenging at first. "This was one of the first times that students had to code without using manipulatives. Some students struggled to get started but with some teacher support, they began to get the concept" (Researcher Observation 21 Nov).

Kete facilitated a gradual increase in difficulty across its three game modes encouraging deeper engagement with computational concepts, promoting understanding and application of these skills. When asked about the advantages of using Kete Whaea O stated, "They can challenge themselves and go as far as they can go". An interesting finding this that when students were working on Kete debugging proved challenging. When an error occurred some students initially blamed the app "It didn't do what I told it to do" (frustrated student). However, the data suggests that those who were able to understand that the fault was not the app but their programme, were able to debug their programme and went on to become more proficient at coding. "Students who can debug effectively became more proficient at coding" (Observations, Researcher Journal).

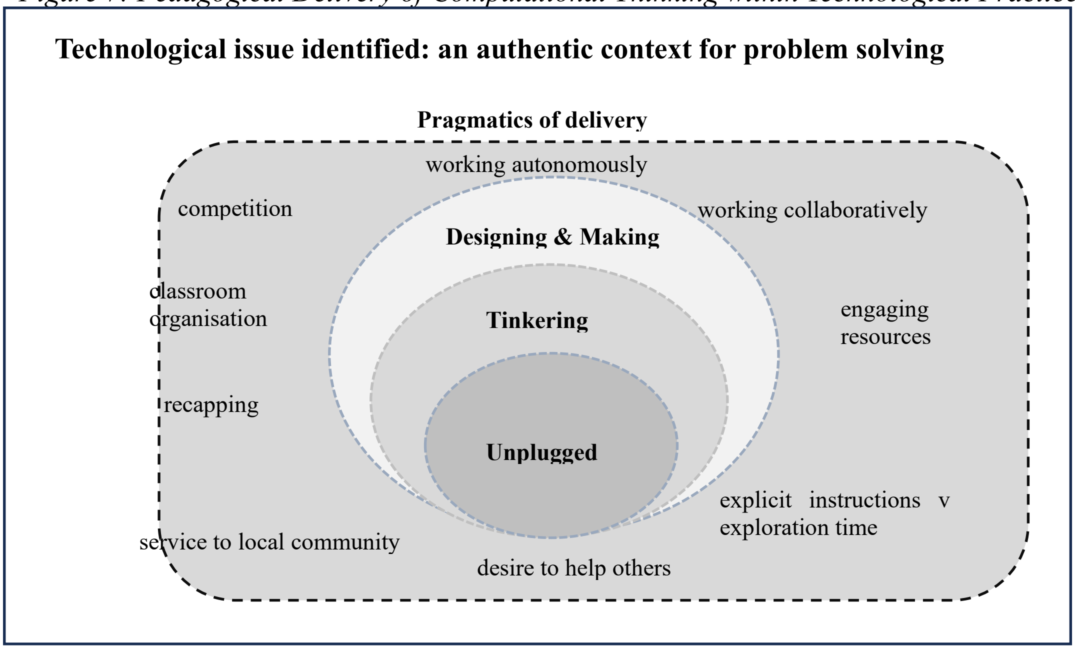
5. Discussion

Learning the concepts of computational thinking proved to be a challenging endeavour for both teachers and students involved in this study. During initial interviews, many teachers reported feeling underprepared to teach computational thinking, citing their limited understanding of the concepts themselves. This finding echoes the work of Rehmat et al. (2020) who observed that primary school teachers often struggle with computational thinking content knowledge. However, as the study progressed, teachers deepened their understanding and refined their pedagogical approaches. This growth led to increased confidence in delivering the content. Supporting this, Kandemir et al. (2021) and Yeni et al. (2021) found that enhancing teachers' content knowledge and pedagogical skills leads to improved student learning outcomes.

Another notable observation is that as students transitioned to digital environments, they were encouraged to "tinker"—explore freely without fear of failure. This phase, while challenging due to the absence of physical manipulatives, allowed students to experiment in a low-risk setting. For example, one challenge was understanding that the ‘kiwi icon’ (Figure 6) needed to be oriented in the direction of travel. With support from teachers and peers, students eventually grasped this through further tinkering. In addition, during this phase, students were only accountable to themselves, making the process less intimidating. Those who began to understand abstraction and debugging made notable progress, with some even actively debugging their code as they worked. While some students naturally grasped the need for debugging, others found it more difficult—particularly if they believed errors stemmed from the app rather than their own code. As their understanding deepened, students moved into the ‘making’ phase, where they were tasked with more complex and specific coding challenges (Kong et al., 2020).

Rehmat et al. (2020) emphasize the need for diverse pedagogical strategies to ensure all students are engaged and learning effectively. This study supported that notion, demonstrating how teachers adapted classroom organization to support engagement. Strategies included students working independently, in small groups, or as a whole class. Teachers frequently revisited prior learning and balanced explicit instruction with opportunities for exploration, self-directed learning, and friendly competition. Kandemir et al. (2021) also highlight the importance of varied instructional approaches in fostering computational thinking skills. To support teachers in developing strategies for teaching computational thinking, the model proposed by Kotsopoulos et al. (2017) served as a useful foundation. Insights from this study prompted modifications to the original model, as shown in Figure 7.

Figure 7: Pedagogical Delivery of Computational Thinking within Technological Practice



(Modified from Kotsopoulos et al., 2017, p. 159)

The most significant modification situates Kotsopoulos and colleagues’ model within authentic technology practice. The context gives purpose and guides all learning. The data in this study fund this as critical to engage and motivate the students. Another modification is a slight adjustment to ‘Making’ to ‘Designing and Making’. In this study an ‘issue or problem’ within an authentic context was identified for the students to solve by designing and developing a potential solution, then ‘making’ became ‘designing and making’. This is relevant because the New Zealand Curriculum positions digital technologies within the Technology learning area (Fox-Turnbull, 2019), therefore students develop their computational thinking skills with purpose, to enable them to become not just users but developers of digital technologies (Ministry of Education, 2017b).

The model also represents the study's findings that authentic technological within a primary classroom practice is heavily impacted by 'the pragmatics of delivery' a range of pedagogical strategies developed to ensure the needs of all students are met and to support them through their learning journey in computational thinking. The pragmatics of delivery in this study included strategies such as recapping previous learning, the giving of explicit instructions, giving students freedom to explore and engage with materials, using a range of unplugged and online resources, competition and giving students opportunity to make a difference. The last significant modification of Kotsopoulos and colleagues' model is the removal of 'remixing'. This has been excluded in Figure 7 because the primary aged students in this study did not reach the level of sophistication required for remixing.

6. Conclusion

This paper introduces a revised and expanded model for the pedagogical delivery of computational thinking, situated within authentic technological practice in primary school settings. Too often, computational concepts and skills are taught in isolation. This study emphasizes the vital role of local context, varied teaching strategies, and the use of both physical and digital tools in effectively developing computational thinking abilities among primary students. The findings highlight that when learning is connected to students' lived experiences—such as their community, cultural background, and familiar local settings—they become more engaged and motivated in their technological education. Embedding learning in authentic contexts enabled students to apply key computational thinking concepts like abstraction, decomposition, pattern recognition, sequencing, and debugging in meaningful, relevant ways. However, more research needed to investigate how the concept of abstraction can be taught effectively as it is an essential for debugging but remains an area of difficulty for students. The research further illustrates the value of diverse organizational strategies, including whole-class instruction, group collaboration, and independent tasks. These approaches allowed all students—regardless of their literacy or numeracy levels—to engage with and grasp computational thinking concepts.

Additionally, the study underscores the essential role of teacher development in delivering computational thinking effectively. As teachers grew more confident and knowledgeable, they adapted their instructional strategies to better support students, which led to improved learning outcomes. While challenges persisted, students' debugging and problem-solving abilities strengthened over time, demonstrating the impact of a hands-on, context-rich, and student-centered approach.

In summary, this research provides important insights into how computational thinking and technology can be successfully integrated into primary education. By continually evolving teaching practices and harnessing the power of local context and manipulatives, educators can nurture essential digital skills and better prepare students for the demands of an increasingly technology-driven world.

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