Embedding Computational Thinking into Authentic Technology Practice

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ABSTRACT

There is recognition internationally about the need for digital technologies within the curriculum. Computational thinking is a critical component of this and is defined as an approach to problem-solving, designing computer systems, and understanding related human behaviours, while drawing on fundamental ideas of computing. Therefore, it is critical that all students acquire computational thinking skills. Technology practice is most successful when embedded within authentic contexts, thus this paper presents a study that facilitated the learning of two concepts of computational thinking: sequencing and orientation within culturally embedded technology practice. The study's vision is to teach mainstream Māori learners from low socio-economic backgrounds concepts of computational thinking within authentic cultural contexts. The research design drew on Māori values and practice that situates learning within authentic Māori contexts. Kaupapa Māori pedagogies were used in our design-based intervention programme to achieve the research goal. The focus of the project was to improve digital technologies learning outcomes to ensure Māori tamariki (children) see themselves as comfortably situated in a digital world.

Key Words: digital technologies, computational thinking, authentic technological practice indigenous knowledge.

1. INTRODUCTION

Digital technologies have facilitated developing a context-rich teaching and learning environment that increases learners' participation in quality authentically situated technology education (Turnbull, 2002). The progress of society in various fields (economic, educational, industrial, and social) today is strongly coupled to the integration of digital technologies (Caballero-Gonzalez et al., 2019), among which computer thinking is being recognized as important and foundation skills. Research suggests that teachers need to be better equipped to teach digital technologies to ensure their students' capabilities and dispositions are such that they are well placed for a future in high-tech industries and rapidly changing work conditions (Falloon, 2015). This has led to an increasing interest in developing computational thinking at the primary school level before students are 10 years old (Bell et al., 2014). The study reports the development of computational thinking skills for young New Zealand's indigenous Māori (New Zealand's Indigenous people) students situated within authentic cultural practice and context.

2. LITERATURE REVIEW

2.1. Digital Technology and Computational Thinking

Computational thinking assists learners in understanding of problems and determining the correct tools and methods for solving problems (Mohaghegh & McCauley, 2016; Zeng et al., 2023). Brennan and Resnick (2012) identify three dimensions of computational thinking: 1) computational concepts such as sequencing, iteration, loops, and parallelism, 2) computational practices such as testing and debugging, reusing or remixing others' work, and abstracting and modularising, 3) computational perspectives, that is learners seeing themselves as more than consumers but rather participants who express and question themselves and connect with others. Zeng et al. (2023) found the above framework appropriate for children.

Studies in the last few years suggest many teachers undergo considerable professional development to understand and effectively teach computational thinking and highlight the needs to prepare teachers in junior classrooms irrespective of the resources provided to them (Bell et al., 2014; Bell & Duncan, 2015; Duncan et al., 2017; Geldreich et al., 2018; Yadav et al., 2016). Bell and Roberts (2016) report teachers with little or no experience teaching computational thinking-related topics have identified unexpected opportunities for integrating computational thinking with other subjects such as maths or into the activities that enhance the development of collaborative skills among students. Therefore, reluctant teachers may be convinced to add computational thinking to an already crowded curriculum if they can see multiple connections and benefits for their students.

2.2. Working with Māori learners and technology

Learners need to see their cultural practices in the learning (Tiakiwai & Tiakiwai, 2010). Teachers' beliefs about culturally responsive teaching, attitudes toward computational thinking, and STEM practices were flexible and differed in different contexts. According to Leonard et al. (2018) using culture as a hook to engage underserved students to learn essential computational thinking skills is virtually unresearched.

Axell (2020) Kaupapa Māori (perceiving the world from a Māori perspective and normalising Māori values, behaviours, and understandings) is underpinned by the implementation of Māori processes and understandings within a Māori philosophical framework (Hargraves, 2020; Hoskins & Jones, 2017 . In terms of computational thinking in Kaupapa Māori, Mohaghegh and McCauley (2016) state that there is little research on the development of Māori students. There are, however, documented links between cultural identity and technological artefacts. In in her study of indigenous technologies of the Sami people in North Sweden Axell (2020) found that technology assisted the development of children's cultural identify, especially when they understood the role their cultural artefacts play within their culture and society. This was assisted by comparing the old with the new, for example a lávvu (mobile home similar to Native American tipi) with a caravan, shoe hay with socks and sinew threads with dental floss. The message was that although some knowledge is old, it remains important and relevant today and that new and old technologies are often used side by side. Rice et al. (2016) also identifed the links between using technologies (social media) with strong cultural identity and community and family connections in indigenous Australian communities.

There is a need to promote technology and computer science to Māori students and for Māori to be trained as developers and creators of technology and digital solutions, rather than just users and consumers of existing technologies. The above studies suggest that one way to do this is to current past indigenous technologies with future ideas, artefacts and processes. It is of critical importance to include computational thinking in the curriculum that is particularly accessible to groups of people who are technology consumers but are not traditionally pictured as employed in the fields of computer science and technology, such as Māori, minority ethnic groups, and women.

2.3. Methodology and Methods

Qualitative methodology underpinned by theoretical concepts of Kaupapa Māori (Hoskins & Jones, 2017) and Constructionism (Papert & Harel, 1991) guided this study. Within a constructionist paradigm, meaning is constructed by people as they engage with the world they interpret, which facilitates sense-making of the same reality in different ways (Crotty, 1998). Kaupapa Māori enabled the rethink of academic conventions by including cultural expression, values, and ethics, and aims to achieve higher academic standards for Māori (Hoskins & Jones, 2017). It promotes Māori-centered approaches in terms of questions, methods, motivations (Stewart, 2021). This research was implemented using a Māori perspective with an aim of increasing learning outcomes for Māori (Hoskins & Jones, 2017; Stewart, 2021). The research question was "How can teaching computational thinking and understanding of technology be enhanced by planning and implementing culturally authentic activities with young Māori learners?

In total twelve students and two teachers participated in the study (Table 1). Ethical consent was obtained through the participating university. Purposeful sampling was used to identify a school with a high Māori roll in a low socioeconomic area. Access to the school was through the principal, with two teachers of students in Years 1-3 (5-7 years old) agreeing to participate in the study. All children in the class of 35 participated in the planned learning. Information letters and consent forms were sent to the parents. Data was gathered only from children who, along with their parents, consented to participate (n=12). Participants were guaranteed confidentiality; however, anonymity was not guaranteed as data included photos and videos of students in their school uniforms. The results reported in this paper drew on focus group interviews with students, observations, and videos of students at work, teacher planning, and student work samples.

Table 1
Study Participants

Teacher Pseudonym	Ethnicity	Sex	Years teaching	Years at this school
Whaea* M (WM)	Māori	F	7	5
Whaea O (WO)	Pakeha**	F	10 months at start of study	1
Student Pseudonym		**Sex**	**Age**	**School year**
Peta	Māori	M	6	2
Colin	Māori/Pakeha	M	7	3
Ahere	Māori	F	7	3
Ihaka	Māori	M	7	3
Bobby	Pacifica	M	5	1
Gerald	Pakeha	M	6	2
Sua	Pacifica	M	5	1
Danny	Māori	F	6	2
Ana	Māori	F	5	1
Kali	Māori	F	6	3
Ihu	Māori	M	6	6
Hanna	Pakeha	F	5	1

** Term used for respected females- literally means mother, aunty. Often used in schools with high proportion of Māori students*
*** Term used in New Zealand for non-Māori, usually of European descent*

Students engaged in constructing their learning through a set of scaffolded activities to teach them the concepts of sequencing and orientation in relation to programming a simple robot -Bee-Bots (Figure 1), with the long-term aim for the students designing an App to assist newcomers to navigate their way around their school. The lead researcher and the teachers co-constructed a unit of work (Appendix 1) which the teachers implemented. The research team assisted implementation when needed. Each teaching session was video recorded. Focus group interviews (Appendix 2) with the students occurred before and after the unit.

Figure 1.
Bee-bot® in action in the classroom

Data was analysed using thematic analysis aiming to understand the students' learning in computational thinking within authentic technology-related contexts. The researchers coded and recoded the data to identify key themes with the aim to understand meaningful reality as suggested by Crotty (1998).

3. FINDINGS

Students in the study learned computational thinking concepts from a te Ao Māori (Māori world view) perspective. Two key themes were identified: culturally informed pedagogy and student engagement that demonstrated a developing understanding of the computational thinking concepts.

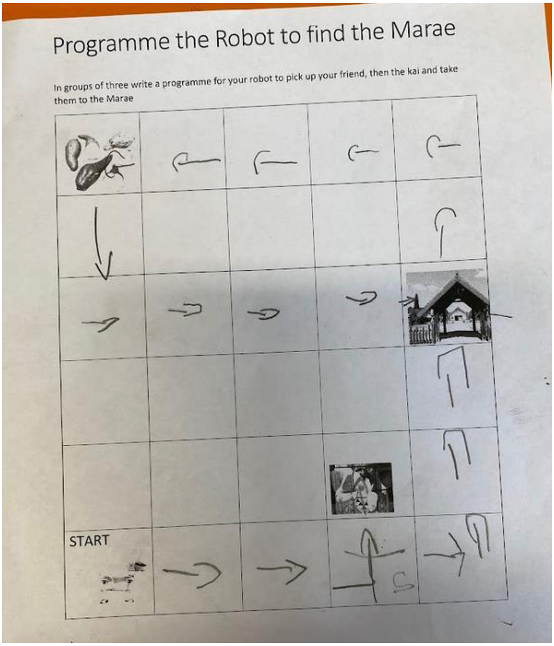
3.1. Culturally Informed Pedagogy

Culturally informed pedagogy is reflected in four aspects: learning context, use of te reo Māori (Māori language), relationship building and ownership of learning. First, as illustrated below, the teachers set up a context relevant to the students' lived experience and their whānau using story-telling, daily routines and role-plays.

> WM: WO and I were talking tonight, there's the disco and we have lots of new tamariki[children] who have come to our school and some of their whānau probably don't know where the hall is, they probably don't know where to park their car…they might get lost. We have lots of gates.

Examples are that students were taught the importance of sequencing through engagement with a Māori legend, 'How Maui slowed the Sun', WO reminds students the story of Māui taming Tama-nui-te-Rā sun) and shows them the cards and how they need to be organised into the correct order of events' (observation notes 2 November). One activity required the students with their dog to navigate to the marae meeting a friend and gathering kumara (sweet potato) on the way by placing forward, back, left and right arrows on the template provided (Figure 2).

Figure 2.
Peta, Kaihautu and Bobby's programme to take the dog to the marae, collecting a friend and kai (food) in the way



Other examples include role-plays that are related to the students' everyday lives to illustrate sequencing such as going to toilets shown below.

> WO: You imagine if you were a computer or a robot right. So I am a robot and WM is going to tell me what to do and I am going to do it.
>
> WM: Sit down, stand up, turn around, take two steps maui [left], and three steps matou [right].
>
> *WO follows the instructions in order*

Student: You have to tell the directions

WO: Yeah, so from the start, what happens first and then next. So sequencing for going to the wharepaku [toilet], what do you do first?

Student: Open the door

WO: Then we…

Student: Lock the door

WO: Then we…

Student: Pull our pants down…….

Second, use of te reo Māori was frequent and natural, constantly inserted as a part of everyday classroom dialogue as demonstrated by Whaea O (Miss O), with English words added by the writer as she gives instructions for one of the activities.

WO Yeah otherwise it gets pakaru [broken] and then just doesn't work properly.

WO: Your job is to figure out, some of you are going straight to the marae [communal meeting house]. Some of you need to start here, we all start at the same place. Then we need to go pick up our friends. Then we need to go and get the kai [food] and then we need to go to the marae. You need to figure out how many steps forward you need to take to get to your friend, then you are going to have to turn left or right to get to the kai.

Third, strong relationships were developed and established between older and younger students and between students and teachers. Tuakana/Tēina teaching (tuakana -older & more capable) and tēina (younger peers) is key to Te Ae Māori [Māori word view]. The extract from researcher observation notes demonstrates this.

Students are directed to read the packs and use the pictures as clues to put the story in the right order. Tuakana have been put in charge as leaders of each group.

The teacher in the classroom developed very strong relationships with their students. The classroom climate was one where failure was accepted and respected and then turned into opportunities for learning as evidenced by researcher observation notes, "Groups who were unsuccessful were shown which part of their sequence was incorrect and were sent away happily to reconfigure and test again" (observation notes 24 November).

The fourth pedagogical strategy related to students' ownership and co-construction of their own learning. Initially using the template illustrated in Figure 2.

WO: Who knows what this might be? Ahere?

Ahere It might be a map.

WO: That’s right, it is a map. What can you see on the map?

Multiple students: A marae, kumara, kete [basket]

WO: Your job is to figure out [where you want to do and what you want to do], some of you are going straight to the marae. Some of you need to start here. ……. You need to figure out how many steps forward you need to take to get to your friend, then you are going to have to turn left or right to get to the kai. You might want to draw how you are going to get there.

After completing this task, the students were given the option of writing code for a Bee-bot to navigate their pathway, selecting their own starting point (Figure 3). To scaffold learning for those who found coding Bee-bot difficult, some students began by writing and practicing their coding using a ‘teddy bear’ manipulative (Figure 4).

Figure 3.
Programme their own journey to the Mara

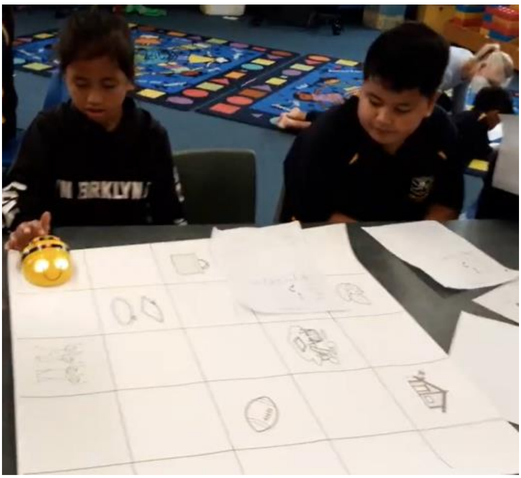
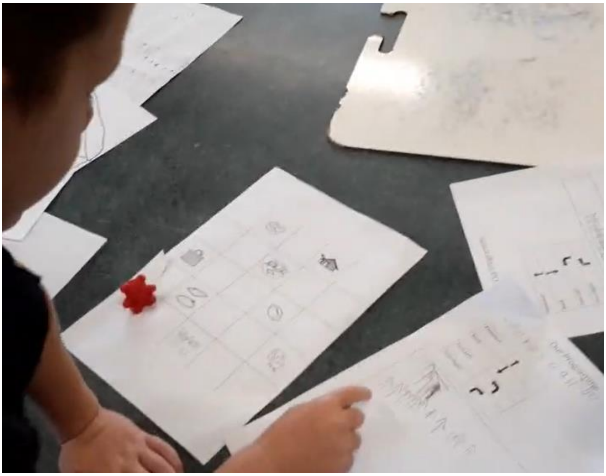


Figure 4.
Programme their own journey to the Marae with Teddy manipulative



Next the students walked around the school and drew pictures of significant school landmarks and then placed them on their own blank map. "Students create their own maps that mirror the locations of the class's big map. The locations have been chosen and designed by the students based on real locations in the school" (Observation notes 21 November 2022). Students then wrote code to 'navigate' around the school.

> WO: You can start anywhere, I might want to start over here, ……. Or maybe my main entrance, the office, my office might be over here. [points to different spaces on the map while talking].

3.2. Student Engagement and Emerging Understanding of Computational Thinking and Coding

Sequencing and orientation to the two concepts of computational thinking specifically taught in the unit. The extract below showed that most children could identify left and right. "Almost all of the students raised their left hand, a few realised their mistake and changed" (observation notes 3 November). Some tēina needed prompts, for example letters on their hands as Bobby mentions below.

> WM: It's like they were a computer, and you were inputting directions

> WO: Yeah, you guys were computers, and I was giving you information and you were following my instructions.

Bobby: The reason I was there was because of the letters

WM: Oh, the letters, but what about when we took the letters away, you still knew

Students clearly understood what the term sequencing meant.

WO: Who knows what sequencing means? What does sequencing mean? If I say you going to put this in, you are going to sequence these pictures in…?

Student: Order!

Student: I remember what order is, you put them in the right order.

Students appeared to gain an understanding of map layout in relation to their school, incorporating orientation and sequencing relevant coding in context.

WO: So, what do you think we need to make it look like a map?

Student: We need pictures on it. ……..

WO: What kind of map is going to be of?

Student: The school

WO: Oh, so what does it need on there? It needs…

Student: The office……

WO: Someone is going to choose because the office is the front of the school, isn't it? So, if I was a manuhiri, a visitor, I would start at the office, because I have to sign in. [Kali is then invited to stick a picture representing the office on the 5x5 grid map. She places the picture of the office on the lowest left-side corner of the grid]

WO: OK, so do you think that's a good place to put the office?

Multiple students: No

WO: Why not? What's next to the office?

Bobby: The car park

WO: Where's the car park going to go? Over here [indicates off the map]

Multiple students: No

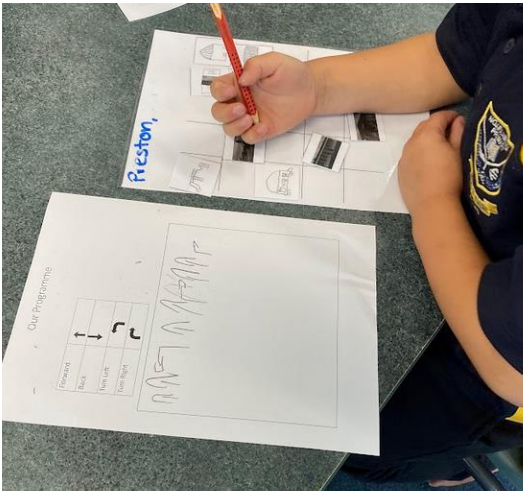
WO: [Indicates to the student to return to the grid map] Haere mai! (hello), so where would be a good place if we know…the office is in the…?

Student: Middle

WO: The office is in the middle. [Kali picks up the picture of the office and places it in the centre column and the lowest row of the grid]

Some of the students developed an understanding of the concept of a map and its use for navigation. This set them up for the necessity of sequencing the places to be visited in relation to the map (Figure 5) and therefore giving a foundation for the sequencing of a programme for navigation.

Figure 5.
Programme their own journey to the Marae around their school, having situated specific places.



Data suggests that by the end of the unit, that all students understood the concept of programming a robot (Bee-Bot) by giving it multiple sequenced instructions. The tuakana (older students) undertook self-correct debugging in relation to mapping a route. “After showing the kaiako his programme on paper, Ihaka entered his programme into the BeeBot and completed the task on his first attempt” [observation notes 24 November 2022].

Gerald is testing his programme on the map by using a manipulative and checking that each step in his programme works. After showing the kaiako, Gerald enters his

> programme into the BeeBot and signals it to start. ….. Gerald was able to complete the task on his first attempt. Ahere fails on her first attempt and then succeeds on her second attempt. Ihu succeeds on his second attempt. Peta was able to complete the task on his first attempt and Sua was able to complete the task on his first attempt. Two groups utilized the backward movement feature as part of their sequence [observation notes 24 November].

Some tēina (younger students) confused 'forward' with 'up', "One student, while entering his sequence into the Bee-Bot, had it facing right but input his sequence as if the bot was facing up". Others had difficulty transferring a three-dimensional journey on a map to the linear positioning of code on a page. For example, "Ihaka attempted to test his sequence, however, once the directions were off the map and in a sequenced line, he could not replicate his sequence on the map" [observation notes 15 November]. To assist with this the teachers introduced a manipulative (plastic teddy) which the students used to test their code one step at a time before entering the whole sequence into Bee-Bots.

> Without manipulatives, the students struggled to visualise the sequence working. It may be that the students perceived the left and right turn directions as turning a corner as opposed to a 90 ° rotation.

Another issue the students experienced was the assumption that the 'turn' command in Bee-Bot included a step forward. This was either corrected by the teachers and researchers working with the students or self-discovered. "[Researcher 3] clarifies this with Colin and explains that the turn does not include movement and that we stay still when we turn" [Observation Notes 14 November].

4. DISCUSSION

As the tauira (students) in this study were predominantly Māori, a te Ao Māori perspective involved them interacting with content that was based on Māori values and beliefs, using Māori learning practices and engaging with te reo Māori. The concepts of computation thinking were embedded in the students' cultural context in two ways: through the learning context and through the pedagogical strategies. With regards to context, kaiako (teachers) use a te Ao Māori focus as part of their Kaupapa (plan) to establish an authentic learning context for their tauira (students) where their cultural identity and everyday lives are reflected in their classroom activities. The context of tasks undertaken, and the purpose of the tasks were contextualised through the tauira's connection to their land and to their whanau. For example, a Māori legend was used in the introduction to the importance of sequencing, the sequencing objectives are the physical locations of their school and town, and the elements of home and whanau life are integrated into the lessons in storytelling. The final test programme requires students to direct Beebot to pick up 'Nan', get a kete [basket] and gather kūmara (sweet potato) before arriving at the marae. Such an approach aligned with the findings of Leonard et al. (2018) that the students were engaged in a space they were already familiar with and they can see themselves as developers and consumers of technology as well, which is the need for teaching computational thinking that Litts et al. (2021) emphasise.

With regards to teaching strategies, te Ao Māori is used through wānanga (programme of work) and ako (learning), and tauira who were struggling with understanding their own identity as Māori and with the learning concepts were given a safe space to express themselves free from judgement. Firstly, the integration of te reo Māori was seamless throughout the unit. As the words were intermittently changed between English and te reo Māori, kaiako (teachers) would not stop to offer a translation. This encourages the tauira to focus on the lesson and shows that their language is valued in the classroom. Secondly, the kaiako do not assume there is only one way to learn and assume all tauira can learn with existing knowledge and skills. Their multifaceted approach to learning gave tauira the confidence to explore digital technology according to their own strengths. To be specific, the kaiako were very vocal and explicit about learning, showing the tauira that they did not have all the answers and that they were sharing the same risks as the tauira in the learning experience. Thirdly, the kaiako used Tuakana/Tēina, allowing students to work together and assist each other as strong relationships between whanau and school are critical to engaging Māori learners. Berryman and Forde (2017) promote school home relationships which require teachers to be aware of the students' cultural backgrounds and their own cultural biases. Ensuring they feel comfortable and welcome at school is an important part of this.

Finally, Bee-Bots were used throughout the unit and as a final assessment tool and the students were thoroughly engaging. Is using Bee-Bots necessary in learning computational thinking? A person could walk on a map on the floor following the written sequenced instructions from a peer. However, the movement of the Bee-Bot in the three-dimensional setting to a linear two-dimensional set of arrows, a form of abstraction, tests students' abstraction skill, one of the challenging aspects of computation thinking. Therefore, we argue that a significant advantage of Bee-Bots was that they were programmed, trailing and debugged as a whole or partial programme rather than step-by-step as was evident with the testing with people role-playing robots.

5. CONCLUSION

This study investigated the teaching and learning of two specific computation thinking aspects (navigation and orientation) within Brennan and Resnick's (2012) three-dimensional framework—computational concepts, computational practices and computational perspectives. Students were introduced to and engaged with two specific concepts—sequencing and orientation—through programming Bee-Bots and undertook authentic technology practice to determine the reason for their learning. We particularly focused on computational perspectives which were a critical component that encouraged students to understand programming as an important aspect in te Ao Māori them and themselves as Māori. This study suggests that role-play and manipulatives are appropriate scaffolds to basic programming but not an end point.

Several limitations of the study were identified. Learning with manipulatives was introduced quite late in the study. This scaffold would have been useful earlier on to assist the transition from 3D thinking to 2D lines of code. This may have reduced some student confusion. In addition, opportunities to teach debugging were not capitalised on. However, debugging became a critical aspect when testing code and therefore should have been taught in parallel with the other two concepts. Unfortunately, the unit was not completed, and students did not reach the point where they could apply their learning to code the actual app. This was partly due to COVID 19 absences and an underestimation of how long the learning took. Despite this, data suggests that tauira were engaged, developing understanding about the role of sequencing and orientation in relation to coding a simple robot. The next step in the research project will include specific foci on testing and debugging and further development of the ideas of abstraction which presented the biggest challenge to the students.

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