



Weaving together the threads of Indigenous knowledge and mathematics

Jodie Hunter¹ · Roberta (Bobbie) Hunter¹

Accepted: 4 July 2023

© The Author(s) 2023, corrected publication 2023

Abstract

As in many countries, for decades in Aotearoa (New Zealand), we have heard the story of the Pacific and Māori achievement gap in mathematics. This has become a widely accepted part of beliefs constructed across multiple communities about students and schools and who can do and learn mathematics successfully. A common response by policy makers and educators alike is to fix the problem of those deemed academically bleak by putting in place a range of interventions. In this article, we challenge the positioning of Pacific students as a problem to be fixed and instead focus on how we can address the practices inherent in historical forms of institutionalised racism related to colonisation. We use an Indigenous research model—Tivaevae—to develop an exemplary case study of the teachers and students from one low socio-economic urban school as they were involved in conscientisation and the reconstitution of educational practices to privilege indigenous knowledge systems. The findings highlight one model of how teachers and students can change institutionalised Western world practices in the mathematics classroom. We argue that the shift to honouring indigenous knowledge systems and a strength-based approach provided opportunities for Pacific students to learn mathematics in ways that supported them to build strong mathematical dispositions, and rather than being assimilated, retain their cultural identity.

Keywords Indigenous knowledge · Pacific mathematics education · Culturally sustaining pedagogy

For many decades, we have heard the story of the Pacific and Māori achievement gap in mathematics in Aotearoa (New Zealand). This mathematics achievement gap story (Faulkner et al., 2019) is a widely accepted part of beliefs (stories), constructed across multiple communities including students, educators, policy makers, and the wider community. These stories describe aspects of certain groups of students including ethnicity, and/or socio-economic status—and relate to who can do and learn mathematics successfully. A

✉ Jodie Hunter
j.hunter1@massey.ac.nz

Roberta (Bobbie) Hunter
r.hunter@massey.ac.nz

¹ Massey University, Atrium Building AT3.36, University Drive, Albany, Auckland, New Zealand

common response by policy makers and educators alike has been to fix the storied problem of those deemed unable to learn mathematics by putting in place a range of interventions. Pacific and Māori students in Aotearoa have over a long period experienced these multiple interventions with little gain in mathematical achievement and with increased cultural dissonance (Allen & Trinick, 2021; Hunter & Hunter, 2018). In this article, we aim to challenge these storied conceptions of a need to “fix” specific groups of students and instead explore how addressing practices inherent in historical forms of institutionalised racism (as the long arm of colonialism) and giving our Pacific students different opportunities embedded within culturally sustaining (Paris, 2012) and anti-colonisation practices (Koya, 2017; Stavrou & Miller, 2017) in mathematics classrooms change outcomes. Our research question asks, what happens when educators reconstitute educational practices to privilege Indigenous knowledge systems within a strength-based mathematical approach focused on providing *all* students with opportunities to access high levels of mathematical reasoning?

Aotearoa has been dominated by a Western world view of institutionalised education practices. Two centuries of ongoing colonisation has resulted in Pacific and Māori Indigenous knowledge systems within mathematics being made invisible within classrooms (Allen & Trinick, 2021; Hunter & Civil, 2021). Drawing on Indigenous ways of knowing and being is a neglected area, and moves towards privileging this knowledge within education settings have been slow and problematic (Allen & Trinick, 2021; Govender & Mutendera, 2020). There are a range of factors, but teachers hold a key role in centring what is valued in the classroom. To effectively model and include Indigenous knowledge systems in the curriculum, teachers need to develop deep understandings of their students’ socio-cultural and languages from which the Indigenous knowledge systems are comprised (Nicol et al., 2020; Nutti, 2013).

Indigenous knowledge systems are the local and cultural knowledge unique to groups of people and their society. These systems have been fundamental to survival as they draw upon holistic multidisciplinary systems that underpin practices related to food production, health, conservation, and education (Bianche, 2018; Govender & Mutendera, 2020). In countries like Aotearoa which have a history of colonisation, formal education is an imposed system of doing and knowing built on structures and processes associated with colonisation from the Western world (Stavrou & Miller, 2017). Although their knowledge systems are largely overlooked in the school setting, Pacific people view and engage in the world by bringing their own unique ways of being. Pacific people are multi-ethnic and include those of Pacific-heritage whose cultural origins are from small Pacific countries such as Cook Islands, Samoa, Tonga, Niue, Kiribati, Tuvalu, and Fiji. Although Pacific peoples are migrants to Aotearoa, they are also Indigenous to their homeland and have close ancestral ties to Māori through the connection to Moana-nui-a-kiwa, the great Pacific Ocean. These close ancestral ties include shared commonalities in languages and cultural values (Berryman & Eley, 2017; Ministry of Education, 2018).

Differing worldviews and pedagogical practices that align with the ways of knowing and being in Indigenous communities mean that education systems need cross-culturally literate educators (Garcia-Olp et al., 2019; Ruef et al., 2020). However, innovative approaches in research and development work across education that offer such empowering spaces and opportunities for the voice of Indigenous people are still in early development (Cammock et al., 2021). There are few studies in mathematics education which focus on using the Indigenous knowledge of Pacific people as a strength in mathematics classrooms. This article will draw on an Indigenous participatory research model—Tivaevae—and the voices of students and teachers to examine a longitudinal collective change process in a school setting through the use of a strength-based approach to centre Indigenous knowledge and

values in mathematics classrooms. A strength-based approach provides a way to counter deficit narratives while also contributing to knowledge related to methods needed to work with indigenous communities more generally.

1 Anti-colonisation practices and centring Indigenous knowledge in mathematics classrooms

Developing anti-colonisation practices requires educators to begin by surfacing the impact of colonisation on education systems and recognising and acknowledging racism as a key root of inequality (Nicol et al., 2020; Stavrou & Miller, 2017). In the context of mathematics classrooms, this means examining how cultural and cognitive imperialism represented in classroom interactions and the curriculum perpetuate inequality. Specifically, Nicol et al. (2020) highlight that practices guided by individualism, progress, and consumerism, undermine other ways of understanding the world. Anti-colonisation practices intentionally centre Indigenous knowledge and promote shifts from a focus on problems to a focus on possibilities (Nutti, 2013). In the mathematics classroom, de-colonisation requires educators to address two key interconnected areas, curriculum and pedagogical practices.

Decolonising mathematics classrooms requires developing mathematics curriculum content that makes visible the knowledge and strengths of Indigenous people (Ruef et al., 2020). Importantly, there is a need for teachers to develop mathematical problems that reflect appreciation of Indigenous culture rather than appropriation (Nicol et al., 2020). Nutti (2013) examined Indigenous teachers' experiences with designing and implementing culture-based mathematics activities in Sámi schools. The teachers designed culturally based mathematical tasks using contexts such as cooking and reindeer herding to explore measurement. A key finding of this study was that teachers need to mathematise cultural activities to construct tasks and potentially re-work aims to ensure that cultural knowledge can be used as integral knowledge to solve the tasks. Across research studies (Garcia-Olp et al., 2019, 2022; Nicol et al., 2020; Nutti, 2013; Ruef et al., 2020), it is evident that respectful relationships with Indigenous students and their families are important to support the growth of knowledge.

Disconnections between values and beliefs contribute to limiting opportunities for Indigenous people. Thus, to centre Indigenous knowledge in mathematics classrooms, there needs to be specific focus on developing pedagogical practices that align with cultural values and beliefs. Firstly, educators need to recognise the cultural values of students and the community and then to transform pedagogy to honour the values. Garcia-Olp and colleagues (2019) provide an example of their development of the IndigiLogix program with Indigenous students in the USA to show how pedagogy can be aligned with community, collectivism, and interconnectedness. Similarly, Nicol et al. (2020) contend that by placing mathematics in the context of practices and values linked to culture, genuine connections are made.

2 Pacific worldviews and experiences and the relationship to mathematics teaching and learning

Pacific people are from collectivist cultural groups which place importance on achieving for community benefit and where identity is closely linked to family and community (Bianche, 2018; Fa'avae, D., 2018). Although there are differences across the cultural

groups, there are also similarities in relation to cultural ways of life including emphasis on respect, reciprocity, relationships, humility, and service (Koya, 2017). However, these values and beliefs require contextualisation in relationship to Indigenous understandings of them rather than attributing meaning from a Western world individualistic approach. In this paper, we argue that taking a collectivist approach to mathematics learning can be a form of transformative learning which resists oppression and domination. This is because collectivism is a key value for Pacific people which challenges the colonialist view of individualism. Centring collectivism in a classroom can be achieved by having stated strategies for helping others in the community and to reach a common goal *as one* (Bianche, 2018; Garcia-Olp et al., 2019, 2022). However, this is not often seen in our Western world dominated classrooms in Aotearoa because most schools reflect the values of the dominant cultural group. This group is mainly comprised of original English immigrant settlers who tend to hold more Western world individualised values.

Within collectivist societies, the concept of self is positioned within relationships which are interconnected and interdependent within family groupings and extend beyond the nuclear family to include wider community (Markus & Kitayama, 1991). This positioning of self as more than a single individual contrasts sharply with a Western world view where self is perceived as a single, independent, self-reliant individual. Inherent within this Western perception of self are subtle messages which suggest what it means normatively to be a correct person within specific settings (Markus & Kitayama, 1991). In Western classrooms, messages are given that mathematics is an individual often competitive discipline, which requires independent goals rather than shared interdependent goals (Garcia-Olp et al., 2022; Nicol et al., 2020). In Hunter and Hunter (2018), we illustrated the dissonance Pacific students experienced in mathematics classrooms when required to work within the competitive environment of ability grouping in contrast to their sense of rightness when allowed to work together. Their normative sense of self and ways of being constructed within their home environment collided with the values they encountered within the individualistic school setting. This subtle form of oppression in mathematics classrooms in Aotearoa coupled with the invisibility of Pacific ways of knowing can be directly attributed to maintaining the achievement gap story.

Pacific people have a rich background of experiences and history related to mathematics across multiple aspects of life including construction, food production, voyaging, craft-work, and cultural activities (Hunter & Restani, 2021). For students from the communities of Pacific people living in Aotearoa, culturally based activities and those related to popular culture that connect with mathematics are part of everyday life (Hunter, 2022; Hunter & Hunter, 2019). For example, Hunter (2022) highlighted young Pacific students' informal recognition of concepts of measurement and ratio when preparing a Tongan drink called otai. Similarly, students described repeating patterns and geometrical aspects of their parents' cultural tattoos or their own items of dress for church. However, within mathematics classrooms in Aotearoa, educators rarely make connections with the cultural knowledge of Pacific people (Averill, 2012). In research (Hunter & Hunter, 2018, 2019), we illustrated the negative effects of the invisibility of their culture that Pacific learners encountered in mathematics classrooms. Likewise, we showed how mathematical disposition and cultural identity strengthened when tasks were structured around Indigenous ways of knowing and being. Transformative learning occurred because of these decolonising practices which involved drawing on the environment, Indigenous knowledge, and Pacific resources to learn mathematics.

3 Theoretical framework

Given the long history of colonisation in Pacific nations, we draw on decolonisation and anti-colonialism theories, as ways forward in mathematics education. Decolonisation has an important purpose in “subverting the taken-for-granted, everyday assumptions deeply held by society that work to routinely reinforce White power and privilege” (Sefa Dei & Jaimunga, 2018, p. 1). Decolonisation of mathematics education offers opportunities to contest dominant practices such as the Western world view of the normative self and whose knowledge is privileged in mathematics classrooms (Ruef et al., 2020; Stavrou & Miller, 2017). Given the different ways that Pacific people view and engage with the world, decolonisation of education, or specifically mathematics education, is required (Koya, 2017). Building on an anti-colonialism perspective, we centre the Indigenous knowledge of collectivist cultural groups as a key reference point rather than colonisation. This is not to ignore colonial histories but instead to view how Pacific peoples resist and engage in education in spite of, rather than in response to, colonial histories (Koya, 2017). We consider how agency and autonomy can be developed by positioning Pacific learners as collective communities who both create and share knowledge.

Aotearoa has had a long history of institutionalised colonial education; schools have been the sites of “assimilation, domination, and inculcation of values, beliefs, and practices” (Sefa Dei & Jaimunga, 2018, p. 6). This is clear in mathematics classrooms where practices largely draw on individualistic values (Garcia-Olp et al., 2019; Nicol et al., 2020; Stavrou & Miller, 2017). For example, in Aotearoa, dominant practices in mathematics classrooms include the use of ability grouping and streaming, competition, and individual teaching, learning, and assessment (Hunter & Hunter, 2018). These institutionalised practices remain unquestioned because those from Indigenous cultural backgrounds have experienced their education within Western world environments (Rogoff et al., 2017). Most educators from Pacific backgrounds have experienced a colonised education system which has impacted on and shaped their identity. Through drawing on decolonisation theory, Pacific understandings of reality, values, and knowledge generation are positioned as the basis of a research paradigm without needing to link and justify this in relation to Western perspectives (Sanga & Reynolds, 2017).

4 Methodology

4.1 Research context

Developing Mathematics Inquiry Communities (DMIC) is an evidence-based comprehensive professional learning and development (PLD) project. DMIC has been funded by the Ministry of Education in Aotearoa since 2010 and has been introduced within high poverty schools with predominantly Pacific students (aged 5–12) and a range of teachers from diverse backgrounds and teaching experience. Drawing on culturally sustaining practices (Paris, 2012), elements of complex instruction particularly the use of heterogeneous grouping (Featherstone et al., 2011), and ambitious mathematics pedagogy (Kazemi et al., 2009), a key goal is to reposition *all* learners to access equitable opportunities to learn mathematics with deep reasoning using a range of mathematical practices. An important element of this is positioning educators to recognise that mathematics education, in and of itself, has been a tool of assimilation associated with colonisation. Consequently, a direct focus of the

DMIC is working in partnership with educators and the wider school community to change many normatively taken as granted western world practices which perpetuate the gap story and cultural dissonance for Pacific learners.

The DMIC professional learning and development project is grounded in a Pacific worldview. The leaders of this work (authors) are New Zealand born of Kuki Airani (Cook Island) heritage. They draw on the Pacific value of family in leading this work as mother and daughter. A relational approach aligned with a Pacific worldview (Cammock et al., 2021; Tamasese et al., 2010) is taken, in which mathematics education researchers and teacher educators work alongside school personnel, students, and inclusive of wider family and local community. Both authors of this article were involved with leading DMIC and working with the teachers as mentors during mathematics lessons. This approach aligns with participatory research methodology (Cammock et al., 2021) in that we engaged with participants in their local environment. As part of this approach, we worked towards instituting changes to pedagogical and assessment practices in ways that transferred power and knowledge to those marginalised in our education system and foregrounded Indigenous knowledge systems.

Over a period of 3 years or more, schools are involved in ongoing PLD. This includes working with educators to critically conscientise (Smith, 2017) all participants to practices which marginalise learners. Professional learning sessions both outside and within the classroom focus on mathematics and pedagogy with an emphasis placed on participants critically reflecting on and interrogating their own worldview including values and beliefs and re-aligning classroom practices with Indigenous knowledge systems. Pedagogy is introduced that builds the use of heterogeneous and family groupings, and explicit inclusion of Pacific worldviews. Intensive work in the classroom involves the teacher and mentor working collectively with students to co-construct mathematics lessons aligned with culturally sustaining pedagogy and ambitious practice.

For the study reported here, the participatory research study was of one low socioeconomic school in Aotearoa. The student population (aged 5–12) consisted of approximately 239 students (66% Pacific heritage and 27% Māori heritage). The school began the 4-year program in 2015 with nine teachers including one teacher of Pacific heritage, three teachers of Māori heritage, and five teachers of Pākehā (European) heritage. In the second and third year, the teacher participants included two teachers of Māori heritage, and four teachers of Pākehā heritage; in the fourth year, one teacher of Pākehā heritage had left. All teachers had been educated in classrooms in Aotearoa where western views prevailed. Data were collected over the 4 years of the program. Student participant ages ranged from 10 to 12 years old. Interviews were undertaken with both teachers and students and during these they were asked open response questions about their experiences in the classroom including ongoing changes, goals, and areas for future focus.

In the next section, we describe how we draw on the researchers' Kuki Airani (Cook Island) heritage to focus on Indigenous knowledge systems to innovate upon an existing Indigenous research model and show how we applied this to the participatory research project and change process within the school.

4.2 Research design: Tivaevae

Tivaevae is a hand sewn artistic quilt which uses patterns and design including flowers, leaves, and traditional symbols to tell a story (see Fig. 1). The quilt is made collectively through an applique *process* by a group of people, usually women. It is

Fig. 1 Tivaevae quilt created by Eileen Cavanagh, authors' mother and grandmother



a highly sought-after and treasured artefact which embodies Indigenous Cook Island knowledge and values (Futter-Puati & Maua-Hodges, 2019). The Tivaevae research model aligns with the process of crafting a Tivaevae and uses the metaphor of making a Tivaevae to highlight how Cook Island knowledge, values, and practices can be embedded within a research cycle (Futter-Puati & Maua-Hodges, 2019; Te Ava & Page, 2020). We innovate on this model to show how it can be used to describe the process of transformative change within mathematics classrooms. The research model has three key dimensions, *koikoi*, *tuitui*, and *akairianga*, that parallel key aspects of crafting a Tivaevae. We used these dimensions to understand and illustrate how teachers can engage in participatory research to both lead and enact change in relation to mathematics teaching and learning.

Koikoi refers to the process of gathering the patterns needed to tell the story through the design. This requires knowledge of symbols and designs to plan the patterns while also gathering appropriate materials (e.g., cloth and thread) as needed. A key element in making a Tivaevae is bringing together knowledge, viewing how patterns fit together, and evaluating the design to see if planning has been successful (Te Ava & Page, 2020). In the context of this participatory research study, we adapted the dimension of *koikoi* to have the first step of gathering patterns, as interrogating the interview data to establish what factors were required to position teachers to engage collaboratively in the change process.

Tuitui refers to sewing the patterns to the underlay material, embroidering the patterns, and the final completion of the Tivaevae. This is a collective process of coming together to sew the Tivaevae in different stages and throughout this process family and community relationships are made and developed. Importantly, the strengths of the connections between people determine the beauty and complexity of the finished Tivaevae (Te Ava & Page, 2020). In this participatory research study, we frame this as the extended period of developing layers of transformative change in mathematics classrooms and across the school. Our part as Kuki Airani researchers is to analyse interview data from the teachers and students to establish the different dimensions that contributed to changes in mathematics teaching and learning.

Finally, *akairianga* involves evaluating the finished Tivaevae and offering it as a gift to the community. In Cook Island culture, Tivaevae are always blessed for a special occasion and gifted. Embedded within a Tivaevae and the process of making this are the values of *a'roa* (love) and *tu akangateitei* (respect) (Te Ava & Page, 2020). In this participatory study, we see *akairianga* represented in the interview data and lessons which shows the beauty of the outcomes which resulted from changes in mathematics teaching to draw on Pacific Indigenous knowledge systems. We analyse a mathematics lesson as a metaphorical example of *akairianga*. Table 1 shows an overview of the timeline of the project.

Table 1 Tivaevae participatory research model, professional learning activities, and data collection

Tivaevae participatory research process	Professional learning activities	Data collection
Koikoi: gathering of the patterns	<p>One whole-day DMIC session (January 2015)</p> <p>Four in-class mentoring sessions over 10 weeks (February–April 2015)</p> <p>Two teacher meetings (March and April 2015)</p> <p>One whole-day DMIC-focused session (April 2015)</p>	<p>Small group interviews with 34 students (February 2015)</p> <p>Individual teacher interviews with nine teachers (May 2015)</p>
Tuitui: sewing of the patterns	<p>Eight whole-day DMIC sessions (July 2015–December 2017)</p> <p>Four in-class mentoring sessions every term for four terms per year (May 2015–December 2016)</p> <p>2× staff meetings each term (May 2015–December 2017)</p> <p>One reflective lesson study cycle and two in-class mentoring sessions each term (January 2017–December 2017)</p>	<p>Small group interviews with 34 students (November 2015) and with 29 students (November 2016)</p> <p>Individual teacher interviews with nine teachers (November 2015), six teachers (November 2016), and five teachers in February 2018</p>
Akairianga: offering the finished tivaevae as a gift		<p>Video-recorded lesson in one Year 6–8 classroom (students aged 10–12 years) (November 2019)</p>

4.3 Data analysis

Data analysis within the Tivaevae research model was a collective process of examining layers within the data. Initial analysis consisted of three researchers individually developing codes and themes which emerged from the first set of data. Then, collaboratively we refined codes and themes common across their analysis. We used a process similar to layering within a Tivaevae, and as Powell (2013) describes this helped to make that which is invisible become visible. Through this process, salient themes (for example, collectivism or knowing your students) were identified, and alternative sub-themes within layers (a need for a wider view of culture) also surfaced. A decision to use a video-recorded lesson to illustrate akairanga was made. This lesson was taught by one of the teachers who was involved in DMIC throughout and selected as representative of the practices across the five teachers who were involved in DMIC from the beginning. It provides a model of a strength-based mathematics lesson in which Indigenous knowledge systems were privileged.

5 Findings and discussion

In this section, the process and layers of transformative change through the Tivaevae research model are presented by drawing on the voices of the teachers and students. These voices are used to frame how mathematics educators/researchers, teachers, and students can collectively institute changes within mathematics teaching and learning and centre Indigenous knowledge systems.

5.1 Koikoi: Gathering of the patterns, viewing how the patterns fit together, and analysing the initial design

An initial aspect of koikoi is the act of gathering together the patterns to understand the need for change. At the beginning of the participatory research process, it was important to develop a collective drive for transformative change through surfacing the impact of colonialisation in promoting cultural and cognitive imperialism in the mathematics classroom. Part of this process was listening to student voices of their experiences in mathematics lessons including their feelings of belonging in relation to their ethnicity. While many students ($n = 15$ out of 34) when asked to describe how they felt about their culture and its relationship with mathematics stated that they felt good or proud of their culture, others ($n = 7$ out of 34) stated that they felt the same as everyone else and more than one-third of students ($n = 12$ out of 34) negatively framed their cultural heritage. For example, Ineleo a student of Tokelauan heritage stated: "From my point of view, I don't think our culture has anything to do with maths." His Samoan classmate, Sione continued: "Not that many people learn that much from in the Islands." Other students noted their sense of alienation, Tiana: "It feels like I'm a different person from a Samoan person [pause] because whenever I'm learning maths I think I'm a Palagi (White) person." It appeared that these students were reflecting the dissonance they felt in their mathematics classrooms. Similar to the findings of other research studies (Sefa Dei & Jaimunga, 2018; Stavrou & Miller, 2017), mathematics classrooms for these students had been a site of assimilation into a Western world view.

Professional learning experiences at this stage focused on gathering the patterns to support teachers to understand the need for change. Activities to conscientise teachers included sharing the student interview data, reading and discussing equity focused research articles, and developing understanding of Pacific values by reflecting on what the values meant in a Western framing versus how they played out within a Pacific frame within the home and community. We also worked with the teachers to plan high-level learning tasks within contexts relevant to their students. Other activities included working with the teachers using in-class dynamic in-the-moment mentoring to co-construct mathematics lessons. A key focus across these activities was positioning teachers to critically reflect on current practices and consider what should change and the reasons for change.

This initial stage of gathering patterns to understand the need for change required the development of high levels of relational trust both between colleagues and between teachers and teacher educators. The importance of this was foregrounded as a teacher described what she perceived as the successful aspects of the professional learning: “I think what Bobbie and Jodie and co are doing inspires. You get an understanding of the reason behind; you know the philosophy behind and the values and beliefs” (Kimmie, T1, Y1). By providing a space within a safe zone, teachers were supported to begin to apply a critical eye to previous practices they had used in mathematics. When asked why they thought change was important, Jill stated: “the way we’ve been doing it, well it isn’t working for the majority of the kids” (2015). Toni critiqued her previous practices saying: “I decided that my job was to accelerate progress, fill the gaps, put more stuff in” (2015). These statements indicate that teachers were beginning to reflect on how their pedagogical practices were central to how their students were positioned. At the same time, there was excitement at possibility of transformative change. When asked about the initial impact of the professional learning, a teacher responded:

As soon as we had our first day, I was like ‘Oh that sounds so awesome’ and I wanted to be like an expert. So, I had to realise, no actually I can’t do that and it is a long journey that we actually have to move along so I can’t just be there.

The interview data shows indications of the teachers’ willingness to begin challenging what they had previously taken as normal. However, there was recognition that this was a journey and that they needed to consider the layers of change needed. As Nutti (2013) described, the teachers were moving towards a possibility-framed perspective.

Through the collective engagement in *koikoi*, the teachers were beginning to view how the patterns fit together by surfacing knowledge and experiences. As part of this process, there was recognition of the multiple layers of pedagogical learning required including increased mathematical and pedagogical knowledge, but also consideration of how cultural values can reframe classroom practices. For example, when reflecting on changes and future goals, Lydia outlined her need to draw on notions of family within the social norms of the classroom, while Toni reflected: “I am thinking a lot more about my Pasifika students in terms of Pacific values (...) reciprocity and respect and service and how important these values are” (2015). The need to consider the contexts of mathematical tasks was in the forefront. Four teachers highlighted this as their key concern and growth area. As Ariana responded when reflecting on the impact of change to her pedagogy: “Even if I search on the internet for problems, I find it really hard to adapt the problems into a cultural context because of my lack of knowledge and understanding” (2015). Student interviews at the beginning of the project also indicated this as a key learning area for teachers given that a very small number of students ($n = 3$ out of 24) were able to recount solving a mathematics problem in a context that related to them. It was clear to all of us that centring Pacific knowledge systems within a strength-based approach required considerable new learning.

Aligned with the findings of Nicol et al. (2020), these teachers were becoming aware of their need to grow understanding of Indigenous knowledge systems.

In this stage, the teachers began to see the power in working as a collective. Ariana's thoughts when reflecting on the impact of the professional learning parallel other teachers' comments:

It's opened up more opportunities to be really collaborative with other teachers and I think that that has happened because we're all at the same level and so we're not feeling kind of threatened or scared about other people seeing us or knowing where we are at in our teaching. (Ariana, TI-2015)

In alignment with collectivist cultural values that they were learning about in professional development, they acknowledged a need to include their students as part of the collective change process. Trina, reflecting on the barriers to change in the classroom, stated: "we're challenging their [students] position and wanting them to make a change. We can't make them make the change. We can only help them to see the value of doing that" (2015). Here students were positioned as active participants with autonomy to contribute to or resist new ways of working.

Overall, through the process of *koikoi*, a sense of collectivism began to develop along with both an understanding of the need for change and an initial design for change. The understanding of the need for change surfaced the ongoing impact of colonisation in relation to the everyday practices in the classroom as described by Stavrou and Miller (2017). Similar to the teacher in the study by Nutti (2013), both time and opportunities for self-critical reflection were important components in this initial process.

5.2 Tuitui: Collectivism and connections, sewing of the pattern onto the blank canvas

Tuitui is the process of sewing the designs developed in *koikoi* to the material and using embroidery to further enhance the *Tivaevae*. Both the beauty and complexity of the *Tivaevae* are determined by *tuitui*, and this requires the development of collectivism, relationships, and connections during the sewing. In this participatory research study, *tuitui* involved an extended period of transformative and collective change in the mathematics classrooms. Longitudinal data analysed from interviews over the course of the professional learning indicated a growing collectivism and connections between teachers, students, and the wider community.

A strong sense of collectivism continued to grow between the teachers as they engaged in transformative change. Taking a relational approach to changes, the teachers' reflections indicated they had developed high trust multi-level models of connection which were sustained over the 3-year period of professional learning. Teachers described the changes and compared these to the previous siloed individual approach that had been taken to planning and teaching mathematics. Kimmie, when describing her own relationship with mathematics which had previously been negative, reflected: "there is plenty of support through collaboration. We seem to be able to work out what the big idea is, or we have access to resources" (2016). Similarly, when considering how her practice had shifted from previous years, Toni noted the multi-dimensional aspects of planning including content, solution strategies, mathematical ideas, misconceptions, student reasoning, and cultural contexts which highlighted to her the need for collegiality: "it makes it a more richer pool to look at" (2018). Over time, the teachers had

recognised the multiple strengths they all brought to the collective to share and grow their practice: “we’ve formed a little team where we will often just find ourselves in the staffroom talking about what’s happened and our ideas and sharing planning” (Lydia, end of 2015). The teachers were drawing on collectivism as a way of change and support for each other in ways which Bianche (2018) and Ruef et al. (2020) describe as transformative.

Students, families, and community members were acknowledged for their understanding of Indigenous experiences, values, and beliefs and, in this stage, began to be framed as key partners in the process of transformative change. The knowledge of the members of the community supported teachers because they had realised their personal need to know their students’ home and community contexts. Kimmie reflected that despite teaching 20 years at the school and living locally, she lacked deep knowledge to authentically draw upon context in developing mathematical tasks. Consistently, all teachers recognised the need to develop connections. For example, when a teacher was asked to describe how she considered culture in her mathematics lessons, she replied:

you have to know your learners really well because you’ve got to know about their family, about their life, what happens outside the classroom, in their community for them. We want them to see maths embedded in their culture and their lives as well, so that they can see that they are mathematicians. (Toni, 2018)

Indigenous knowledge was positioned as an important element of the mathematics classroom and both students and community members were included as participants in the co-construction of mathematics teaching and learning. Teachers referred to newly developed connections with Pacific members of the school community from Tokelau or Samoa who worked in school support roles: “I do a lot of talking to them and what’s relevant to them” (Toni, 2018). In another example, Trina (2018) explained how she collectively mathematised cultural activities with her students to develop authentic culturally based tasks:

the kids are our experts, because they know, and it gives them that sense of ownership of the problem... They had a problem about waka ama, now I know nothing about waka ama, so I had to consult the students in my class first about what would be appropriate distances? What’s the terminology used? Do you row or do you paddle?

In this way, the Indigenous knowledge and expertise of students and the wider community was centred in a way that positioned them as partners in the co-construction of their mathematics classrooms.

Along with shifts in the ways of working for teachers and the context of tasks, other transformation included the development of pedagogical practices aligning with Pacific cultural values. This included opportunities for students to work collectively within mathematics lessons, a shift positively referenced by most students ($n = 27$ out of 34) as their favourite part of mathematics in the small group interviews at the end of the first year. Their justifications aligned with their values: “I feel like it’s a family because we’re doing it together.” Students also framed newly introduced mathematical practices such as argumentation as a part of working collectively: “you can share ideas and have a friendly argument, like you talk about maths but you say ‘no, that’s not the answer’ but just in a friendly way.” Teachers reflected the importance of integrating cultural values and beliefs as ways to embed mathematical practices within productive discourse:

they're sharing their ideas, they're looking out for everyone in their little crew, so there's kind of that sense that they are caring for each other, supporting each other, encouraging each other. They're taking risks to share ideas, they're thinking about if they agree with each other or not, and if they don't agree they're asking for further clarification from the person who shared that idea (Trina, 2018).

In this way, new pedagogical practices were enacted that aligned with Pacific values including respect and reciprocity and centred Indigenous knowledge systems.


Over time, the introduction of relational and responsive pedagogy led to a stronger sense of collectivism evident through the student reflections. In subsequent student interviews over the length of the PLD, no students made negative comments in relation to their cultural identity within the mathematics classroom. Instead, many referred to their classmates as family although from different Pacific nations: "there's other cultures too, like Cook Islands and Māori who support me too whenever I'm doing maths and I'm in a group" (end of 2015). They described the most important thing about their mathematics classroom was that they worked together and helped each other: "everyone can learn from each other. It's about coming together, no worries about who you're working with." The inclusion of Pacific worldviews supported students to develop positive cultural and mathematical identities.

5.3 Akairianga: evaluating the finished Tivaevae and offering this as a gift


In this participatory research study, we position akairianga as the outcome of the transformative changes that the teachers undertook to reconstitute their pedagogical practices in mathematics classrooms to privilege Indigenous knowledge systems. We present the analysis of a mathematics lesson facilitated by Kimmie to show how she implemented pedagogical practices founded within Indigenous knowledge systems. We gift this back to the community to highlight what Pacific learners should expect from policy makers, teacher educators, and teachers as a counter response to the achievement gap story.

The teacher developed a mathematical task (see Fig. 1) positioned within a local context in which the students had a wealth of prior knowledge. This included watching vaka (canoe) building, hearing stories of Pacific voyaging, and participating in waka ama (competitive outrigger canoeing). An algebraic problem was constructed around a pattern on the hull of a Tokelauan vaka (canoe) from the local Tokelau Hall (Fig. 2).

The vaka at Matauala Hall has a pattern where the fauato (coconut fibre twine) joins the planks. What would happen if the vaka kept getting longer and longer?
 How many pieces of fauato would there be if the pattern went up to iva (nine)?
 What about hefuluiva (nineteen)?
 What about ivahefulu (ninety)?



Tahi (three)



Lua (one)

What rule you could use to find the number of pieces of fauato for any number of the pattern?

Fig. 2 Problem (Gibbs, 2020, p. 44)

The teacher began by positioning different students as experts to explain how a vaka is constructed using local materials. After facilitating extended discussion, she said:

Our problem today is thinking about some people that have made a vaka and they've worked out a really clever way of making the planks on the side of the vaka stay together... really clever maths that they've been thinking about.

This statement highlighted respect for Pacific knowledge systems and the mathematics within them. She continued to use students' contextual knowledge to shift further discussion towards the task's cognitive demands:

We've got the holes that Bless was talking about, then we've got the coconut fibre that's making a pattern. So when the vaka grows what happens to the pattern? What's happening to the vaka if the pattern goes up to nine?

This positioned students to both draw on their cultural knowledge and their developing mathematical understandings of growing patterns.

In the next section of the lesson, students worked in small collaborative groups drawing on the norms and value of fono (family) to work as a single unit. The students represented their reasoning through use of materials, pictures, and symbols as they ensured collective understandings about the relationships between the variables. They closely watched each other's actions and questioned their own and others' growing understandings. For example, Junior recorded and then asked the other three students in the unit:

Is that the answer? Adding on five? The pattern is growing by five and adding on one. Maybe we should say why we think that's the answer. Why we timesed it by five. Do you get it? What don't you get?

Further discussion including challenges followed as each member of the group examined the reasoning; then, Malaikai added another explanation using the cultural context:

It's growing by five but you'll have to add another one. It's actually growing by six. One, two, three, four, five and then one. It's one pattern. Tahi. Next one, it always adds on one. So lua is one, two, three, four, five and then one. So it basically grows by six. Every time you add on another one you add on six.

Another student adds: "So every time the pattern goes up by one the fauato goes up by six." Pedagogical practices constructed around understandings of family premised within concepts of interrelationships and interdependence supported both individual and group accountability. Students' normative sense of self (Markus & Kitayama, 1991) as a collective led to a natural flow of talk and construction of rich understandings as the students worked on a shared explanation.

The lesson concluded with the teacher selecting and facilitating two groups to provide mathematical explanations and justification. The talk flowed naturally with one student explaining and representing a groups' collective reasoning while listeners actively tracked emerging reasoning and politely interjected with questions or comments. These often took the form of extending or elaborating on parts of the explanation. The teacher positioned herself as a member of the collective and gave students agency to explore their own group's mathematical explanations with those being presented to them as her questions and comments pressed the students to compare explanations:

What was the difference between their group going plus six, plus six, plus six. But then all together we developed that rule—timesing and taking away one. We are

looking and seeing that it's growing by six. When they saw it was plus six, straight away Bless said, 'oh that's times six'.

Again, mathematical explanations and connections unfolded in a manner which resembled a cohesive whole rather than a group of individuals. Asked to comment at the conclusion of the lesson, a student said:

I was proud because Tokelau's not a big culture and not a big island. But being mentioned in this problem it's like there's a big amount of people that know about it. They care about our culture, and know things about our culture (Gibbs, 2020, p. 64).

The lesson is a gift to show how rich mathematical learning opportunities can be made available to Pacific learners when their Indigenous knowledge systems are privileged within a strength-based approach.

6 Conclusion and Implications

Equity for Pacific and other Indigenous learners is at the heart of this research. Our aim was to challenge the storied achievement gap (Faulkner et al., 2019) of Pāsifika learners which pervades Aotearoa classrooms. We do this through showing how transformative change from institutionalised Western world practices in mathematics classrooms occurred through use of anti-colonisation-oriented practices. Nicol et al. (2020) argued the need for teachers to develop deep knowledge of their Indigenous students' lives. In this study, as teacher knowledge grew of their students' ways of knowing and being, they increasingly embedded the key values of Pacific people in their classroom practices. Collectivism was central to changes in classrooms as the teachers centred their pedagogy towards the Indigenous knowledge of the students including their local contexts, values, and beliefs.

This article contributes to the field through use of an Indigenous participatory research model, Tivaevae. The three-stage model is aligned with both the research design and change process. Although this is a local model, we argue that there are wider lessons from the use of this metaphorical process of crafting a Tivaevae to show how mathematics teaching and learning can be established that demonstrates and makes visible the strengths of an Indigenous community.

Firstly, during *koikoi*, use of professional learning activities challenged and destabilised the taken for granted dominant practices and positioned teachers to consider whose knowledge and ways of being were emphasised in the classroom. Both Stavrou and Miller (2017) and Nicol et al. (2020) argued the need for educators to recognise limitations in their knowledge and understanding before the journey of decolonisation and anticolonisation could begin. This occurred at this stage as the teachers recognised the ways in which cultural and cognitive imperialism had dominated both their pedagogical and curriculum practices. This led to their recognition for need for multiple layers of pedagogical learning and change.

Similarly, in the second stage of crafting a Tivaevae, *tuitui*, the beauty of the re-conceptualised mathematics teaching and learning required both relationships, collectivism, and connection. As Allen and Trinick (2021) previously described, developing change to established curriculum, pedagogy, and beliefs aligned with western thinking is a challenging and risky process. Garcia-Olp and colleagues (2019) and Nicol et al. (2020) outline the need for relational connections to be constructed for change to be enacted. In this research, this was a lengthy process between the educators/researchers, teachers, students, and

wider community. A safe space for support and collective change among participants was required as knowledge of the socio-cultural contexts of different students was constructed. Constant critical reflective shifts required support both internal to the collective group of teachers and external within the professional learning and development process as teachers grappled with what Sefa Dei and Jaimunga (2018) describe as the effects of white power and control.

Finally, the last stage of the Tivaevae involves evaluating the creation and gifting this as a symbol of aroa (love) and tu akangateitei (respect). Both aroa and tu akangateitei between the students and the teacher were evident throughout the lesson we presented. This was also clear as Kimmie (the teacher) reflected on the shifts in her classroom practices: “Students’ most significant learning will be when they can learn, like a Pasifika learner as a Pasifika learner. It is drawing out, acknowledging and valuing who they are and what they bring to school.” Anti-colonisation practices intentionally centre Indigenous knowledge systems in the mathematics classroom (Ruef et al., 2020), and we see this article as making a key contribution in this area through the longitudinal examination of change and the use of both teacher and student voice.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Allen, P., & Trinick, T. (2021). Agency–structure dynamics in an indigenous mathematics education community in times of an existential crisis in education. *Educational Studies in Mathematics*, 108(1-2), 351–368. <https://doi.org/10.1007/s10649-021-10098-1>
- Averill, R. (2012). Reflecting heritage cultures in mathematics learning: The views of teachers and students. *Journal of Urban Mathematics Education*, 5(2), 157–181. <https://doi.org/10.21423/jume-v5i2a166>
- Berryman, M., & Eley, E. (2017). Succeeding as Māori: Māori students’ views on our stepping up to the Ka Hikitia challenge. *New Zealand Journal of Educational Studies*, 52(1), 93–107. <https://doi.org/10.1007/s40841-017-0076-1>
- Bianche, C. (2018). Reflections on the implications of Western theories on Indigenous populations: Decolonizing and indigenizing the classroom. In G. J. Sefa Dei & C. S. Jaimunga (Eds.), *Indigeneity and decolonial resistance: Alternatives to colonial thinking and practice* (pp. 51–76). Myers Education Press.
- Cammock, R., Conn, C., & Nayar, S. (2021). Strengthening Pacific voices through Talanoa participatory action research. *AlterNative: An International Journal of Indigenous Peoples*, 17(1), 356–368. <https://doi.org/10.1177/1177180121996321>
- Fa’avae, D. (2018). Complex times and needs for locals: Strengthening (local) education systems through education research and development in Oceania. *The International Education Journal: Comparative Perspectives*, 17(3), 80–92 <https://openjournals.library.sydney.edu.au/index.php/IEJ>
- Faulkner, V. N., Marshall, P. L., & Stiff, L. V. (2019). *The stories we tell: Math, race, bias and opportunity*. Rowman & Littlefield.
- Featherstone, H., Crespo, S., Jilk, L. M., Oslund, J. A., Parks, A. N., & Wood, M. B. (2011). *Smarter together! Collaboration and equity in the elementary math classroom*. National Council of Teachers of Mathematics.
- Futter-Puati, D., & Maua-Hodges, T. (2019). Stitching tivaevae: a Cook Islands research method. *AlterNative: An International Journal of Indigenous Peoples*, 15(2), 140–149. <https://doi.org/10.1177/1177180119836788>

- Garcia-Olp, M., Nelson, C., & Saiz, L. (2019). Conceptualizing a mathematics curriculum: Indigenous knowledge has always been mathematics education. *Educational Studies*, 55(6), 689–706. <https://doi.org/10.1080/00131946.2019.1680374>
- Garcia-Olp, M., Nelson, C., & Saiz, L. (2022). Decolonizing mathematics curriculum and pedagogy: Indigenous knowledge has always been mathematics education. *Educational Studies*, 58(1), 1–16. <https://doi.org/10.1080/00131946.2021.2010079>
- Gibbs, B. (2020). *“It makes me feel proud of who I am”: Developing functional thinking through culturally located tasks* [Master’s thesis, Massey University]. Massey Research Online. <https://mro.massey.ac.nz/handle/10179/16237>
- Govender, N., & Mutendera, G. (2020). Teachers’ and custodians’ views and dilemmas arising thereof regarding the integration of indigenous knowledge in the primary school. *AlterNative: An International Journal of Indigenous Peoples*, 16(4), 356–368. <https://doi.org/10.1177/1177180120970935>
- Hunter, J. (2022). Challenging and disrupting deficit discourses in mathematics education: Positioning young diverse learners to document and share their mathematical funds of knowledge. *Research in Mathematics Education*, 24(2), 187–201. <https://doi.org/10.1080/14794802.2022.2088607>
- Hunter, R., & Civil, M. (2021). Collaboration in mathematics: Taking a sociocultural perspective. *AIEM - Avances de Investigación en Educación Matemática*, 19, 7–20.
- Hunter, R., & Hunter, J. (2018). Maintaining a cultural identity while constructing a mathematical disposition as a Pāsifika learner. In E. A. McKinley & L. T. Smith (Eds.), *Handbook of Indigenous Education*. Springer. https://doi.org/10.1007/978-981-10-1839-8_14-1
- Hunter, R., & Hunter, J. (2019). Using culturally embedded problem solving tasks to promote equity within mathematical inquiry communities. In P. Felmer, B. Koichu, & P. Liljedahl (Eds.), *Problem solving in mathematics instruction and teacher professional development*. Springer. https://doi.org/10.1007/978-3-030-29215-7_21
- Hunter, J., & Restani, R. (2021). Uncovering everyday mathematics as a vehicle for equity: Investigating the funds of knowledge of diverse communities. In D. Burghes & J. Hunter (Eds.), *Mathematics education for sustainable economic growth and job creation* (pp. 51–62). Routledge.
- Kazemi, E., Franke, M., & Lampert, M. (2009). Developing pedagogies in teacher education to support novice teachers’ ability to enact ambitious instruction. In R. Hunter, B. Bicknell, T. Burgess (Eds.), *Crossing divides: Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 1, pp. 12–30). MERGA.
- Koya, C. F. (2017). Rethinking research as relational space in the Pacific: Pedagogy and praxis. In U. L. Vaai & A. Casimira (Eds.), *Relational hermeneutics: Decolonisation and the Pacific Itulagi* (pp. 65–84). Pacific Theological College, University of the South Pacific.
- Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion and motivation. *Psychology Review*, 98, 224–253.
- Nicol, C., Gerofsky, S., Nolan, K., Francis, K., & Fritzlan, A. (2020). Teacher professional learning with/in place: Storying the work of decolonizing mathematics education from within a colonial structure. *Canadian Journal of Science, Mathematics and Technology Education*, 20(2), 190–204. <https://doi.org/10.1007/s42330-020-00080-z>
- Nutti, Y. J. (2013). Indigenous teachers’ experiences of the implementation of culture-based mathematics activities in Sámi school. *Mathematics Education Research Journal*, 25(1), 57–72. <https://doi.org/10.1007/s13394-013-0067-6>
- Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and ractice. *Educational Researcher*, 41(3), 93–97.
- Powell E. E. N. (2013). *Stitching to the back-bone: A Cook Islands literary tivaivai* [Master’s thesis, The University of Auckland]. Retrieved from <http://hdl.handle.net/2292/20287>
- Rogoff, B., Coppens, A., Alcalá, L., Aceves-Azuara, I., Ruvalcaba, O., López, A., & Dayton, A. (2017). Noticing learners’ strengths through cultural research. *Perspectives on Psychological Science*, 12(5), 876–888. <https://doi.org/10.3102/0013189X12441244>
- Ruef, J. L., Jacob, M. M., Walker, G. K., & Beavert, V. R. (2020). Why indigenous languages matter for mathematics education: A case study of Ichishkín. *Educational Studies in Mathematics*, 104(3), 313–332. <https://doi.org/10.1007/s10649-020-09957-0>
- Sanga, K. & Reynolds, M. (2017). To know more of what it is and what it is not: Pacific research on the move. *Pacific Dynamics Journal of Interdisciplinary Research*, 1(2), 198–198.
- Sefa Dei, G. J., & Jaimunga, C. S. (2018). Indigeneity and decolonial resistance: An introduction. In G. J. Sefa Dei & C. S. Jaimunga (Eds.), *Indigeneity and decolonial resistance: Alternatives to colonial thinking and practice* (pp. 1–14). Myers Education Press.
- Stavrou, S. J., & Miller, D. (2017). Miscalculations: Decolonizing and anti-oppressive discourses in Indigenous mathematics education. *Canadian Journal of Education*, 40(3), 92–122.

- Te Ava, A., & Page, A. (2020). How the tivaevae model can be used as an Indigenous methodology in Cook Islands education settings. *The Australian Journal of Indigenous Education*, 49(1), 70–76. <https://doi.org/10.1017/jie.2018.9>
- Ministry of Education. (2018). Tapasā. Wellington: Ministry of Education. <https://doi.org/10.1108/S1479-368720220000039004>
- Smith, G. (2017). Kaupapa Māori theory: Indigenous transforming of education. *Critical Conversations in Kaupapa Maori*, 70–81.
- Tamasese, T. K., Parsons, T., Sullivan, G., et al. (2010). A qualitative study into Pacific perspectives on cultural obligations and volunteering. *Pacific Section and The Family Centre Social Policy Research Unit* <https://www.jstor.org/stable/90014773>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.