Examining Historical Pedagogies Towards Opening Spaces for Teaching all Mathematics Learners in Culturally Responsive Ways

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The literature on culturally responsive and culturally sustaining practice calls for ensuring educational experiences are relevant for, and compatible with the wider experiences and lives of students while strengthening their cultural identities. Shifts in practice are called for to help reduce inequities in mathematics and statistics learning opportunities and achievement. Drawing from research within and outside mathematics education, we will consider the potential of three pedagogical approaches consistent with those of many diverse heritage cultures – song, story-telling, and metaphor – for promoting engagement with, and learning of mathematics and statistics. Frameworks for culturally responsive practice will be used to examine whether enhanced use of these pedagogies may assist in engaging learners in holistic, caring, diverse, and mathematically and statistically productive ways, and in conceptualising new avenues for research.

The kids see it and they're laughing and they start doing it. (Teacher Aide)

Thank you very much for inviting me to give this talk. I would like to challenge us to consider various rationale for broadening the research and practices used for the teaching and learning of mathematics. I will draw from a wide research base and from my teaching in initial and in-service teacher education. I begin by exploring factors that impact on mathematics teaching pedagogies and calls for teaching that draw from a wide range of pedagogies and that appeals to emotional as well as to conceptual development. I then discuss culturally responsive education including considering learning as a holistic personal and social experience. Three pedagogical approaches – singing, storytelling, and metaphor – are then discussed in turn in relation to research into learning, broader effects, and fit with culturally responsive teaching. We consider ways that these pedagogies can enhance opportunities for learning, pleasure, identity-development, and mathematical achievement, particularly for marginalised learners. Along the way I will include examples from my practice and research.

Similar to the work of many other mathematics educators, I promote the use of problem solving, inquiry, manipulatives, representations, using good questions, cooperative learning, and so on. However, other aspects of my teaching are different to many. We sing. We tell and listen to stories. We respond to protocols that enable some to feel comfortable to participate. We explore ideas using the power of metaphor. We draw from historical and cultural contexts. Many appreciate experiencing these pedagogies and they appear useful for learning and motivation. I have used preparing this talk as an opportunity to search the literature for reasons why these three comparatively neglected pedagogies – singing, storytelling, and metaphor – may be useful for mathematics learning and engagement, and to help us consider the extent to which they are likely to be essential for students traditionally underserved to engage successfully with our discipline. Thank you for being here.

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Experiences that started my using songs, storytelling, and metaphor in my own teaching of mathematics and mathematics education were in my work with bilingual (te reo Māori/English) primary initial teacher education mathematics methods classes and classes of second chance learners working towards senior secondary mathematics qualification-based assessment. Working with these groups showed me the power of pedagogies less often used for mathematics learning for enhancing motivation to learn, engagement with mathematics, and learning. With the bilingual student teachers I was concerned to ensure my teaching was as inclusive of, and as responsive as possible to te Ao Māori/the Māori world. I studied te reo me tikanga Māori (wananga-based) and worked consultatively and in partnership with Māori colleagues. Research about our learnings from this time has been reported at MERGA conferences and elsewhere (e.g., Averill et al., 2009). The second chance learners had recently left school without qualifications and, although capable, came with low mathematical self-efficacy and low interest in mathematics. The ways in which the second chance learners had been taught mathematics in school had not worked well for them, so more of the same would be neither comfortable nor effective. I used the opportunities of working with these groups of students to find pedagogies they would find effective. We sang for every topic to help remember key ideas for assessments. We linked learning to student interest areas, told stories, and explored metaphor for developing understanding and retention of ideas.

Pedagogies and Learning – Engaging the Whole Self and the Collective

Goals, emotions, and self-efficacy impact on motivation (e.g., Ford, 1992). In our work with students we have many layers of concerns – how to help them develop conceptual understanding, to see mathematics as relevant to their own worlds, and to be excited by and feel they are confident, capable mathematicians. Varied teaching approaches chosen to suit learner interests and needs and real and relevant tasks enhance motivation to engage with and learn mathematics (Bobis, Anderson, Martin, & Way, 2011). However, many students experience a narrower range of pedagogies in their mathematics learning than in their other subjects and can experience predominantly teacher-directed learning with infrequent opportunities for student autonomy, discussion, practical work, and movement, and limited exposure to ways in which the learning content relates to real-life contexts (e.g., Hagan, 2017). This situation is despite our long-standing work in initial and in-service teacher education promoting student-directed and innovative teaching strategies rich in mathematical problem solving, argumentation, relevance, discourse, and exploration.

Bishop (1991) describes ‘enculturation’ of students into mathematics learning at a variety of levels – cultural, societal, institutional, pedagogical, and individual – reflecting that what we do in classrooms affects what students believe mathematics to be and how mathematics learning is acquired. Policy, assessment, research, and societal impacts on mathematics education over time have resulted in conflicting messages about what mathematics learning looks like and how it occurs, with many of these impacts helping to foster ‘impersonal learning’ such as textbook and teacher-led approaches (e.g., Walls, 2010). Mathematics learning environments have been affected by the ‘crowded’ curriculum, an increase in the directed nature of curricula and provided resources (e.g., numeracy projects), increased parental, societal, and governmental scrutiny of numeracy and mathematics teaching and learning, in part stemming from high stakes international assessment, and increased focus on assessment at many levels of schooling (Gonzales, 2009; Neyland, 2010; Walls, 2010). Many teachers have experienced effects of such

constraints on the pedagogies they use, resulting in enhanced focus on cognition and achievement and reduced attention to more personal, cultural, and creative dimensions of mathematics learning, as the:

> ...relentless quest for higher standards and curriculum coverage which dominated this period [1990s and 2000s] may well have obscured the personal and affective dimensions of teaching and learning and fostered a mindset characterised more by compliance and conformity than curiosity and creativity. (Pound & Lee, 2011, p. ix)

Pedagogical approaches consistent with meeting external policy and societal expectations have not always sat well with teachers' own philosophical views (English, Hargreaves, & Hislam, 2002), and there are increasing expectations from policy makers and mathematics and indigenous education researchers for creative teaching that supports links with the community and its cultures in a spirit of partnership (e.g., Education Council, 2017; Ministry of Education, 2011; National Council of Teachers of Mathematics, 2000). There are also repeated calls for research into links between pedagogical considerations and approaches and student affect (Attard, Ingram, Forgasz, Leder, & Grootenboer, 2016) to support our understanding of the effects of teachers' pedagogical choices on student learning. Examples from our own field of mathematics education show a varied and collective desire for teachers to move beyond focussing only on cognitive aspects of mathematics learning and traditional mathematics classroom patterns. Next we consider just a few of these examples which illustrate thinking about mathematics learning as a holistic, creative, and collective activity.

Askew (2012) refers to teaching as an improvisational activity and transformative mathematics teaching as paying attention to learning as a collective activity within cooperative learning environments, acknowledging that the social context can support or hinder learning. Similarly, Ernest (2011) draws attention to the importance for students of the places and ways that they learn, and the social context for mathematics learning:

> A growing body of research is suggesting that not only *what* students learn, but *where* they learn it is important. In other words, it is not only the *content* of learning that matters, but also the s*ocial context* of that learning that counts. (p. 126, italics in original)

Lakoff (2008) describes thought as a physical process, with the body and brain interconnected by how thoughts are processed by neurons and neural pathways. Neyland (2010) pleads for a return to education as a place for curiosity and wonder as primary motivators, seeing learning environments as places for creativity and 'full-bodied' knowledge (acknowledging learning as involving mind, emotions, and body) where learners can experience surprise with 'comical spirit'. Such a view of learning as being experienced holistically is shared by many indigenous cultures, who give:

> ...much higher priority to the *wisdom tradition* of thinking, reflecting, doing, and being. When that view is normal for Indigenous students, imagine how disappointed they must feel when studying mathematics and discover that the subject is *only* about an *intellectual tradition* of thinking, a much narrower view of education. (Aikenhead, 2017, p. 84, italics in original)

Reflecting on the excitement and motivation of Year 8 students after working with them on a topic beyond official curriculum content (the history of mathematics), Brahier (2011) also conveys the importance of creating emotive responses to mathematics learning:

> ...learning mathematics transcends acquiring skills and even developing conceptual understanding –
> ...beyond these goals, my role as a mathematics teacher is to spark the interests of my students and excite them about mathematics and its usefulness in our world… (p. 4)

To consider the role of emotion in learning in general a little further, enthusiasm and excitement are known to support engagement, learning, and memory (Eliot, 1999; Rhodes, 1988), and Goleman (1996) goes further to state that learning *requires* emotional engagement. Emotions, attitudes, beliefs, and values are all also believed to be interlinked with mathematical learning (e.g., Goldin, 1987, 1992).

A study that demonstrates well the power of emotional engagement for learning carried out in Auckland schools found that the energising uplifting atmosphere and connections of emotion, cognition, psyche, and spirit created between performers and their audience is essential for the learning of New Zealand Tongan students (Manu'atu, 2000). Such activities and feelings also help form a sense of shared experience and community and help us persist when we meet challenging tasks.

Owens (2015) sees pedagogical change as necessary for enhancing mathematics learning opportunities of indigenous students. In an Australian-based study involving teachers and community, she found that partnership with the community and teachers valuing students' family and cultural heritage resulted in increased warmth and communication between school and community, which in turn impacted on the curriculum and teaching approaches used. Owens reported decolonisation of teachers' thinking and approaches as their cultural understandings developed, over time, through the teachers and communities:

> Learning about different approaches, trying appropriate changes, experiencing change in student attitude, behaviour, and mathematical performance, and through affective experiences that unsettle their current ways of acting and thinking. (p. 59)

In Owens' project, students' cultural identities were enhanced through inclusion of art, dance, and telling stories, enabled by the increased communication with community and the wider professional development. Teachers' beliefs about effective teaching and the goals of their work changed during the project. They reported using more narrative, non-verbal communication, and action learning, including learning with small groups outside the classroom. Increasingly during the professional development, students identified as aboriginal, and with mathematics positive changes in relation to student identity development similar to those found in the Kotahitanga professional development project in Aotearoa New Zealand (Bishop, Berryman, Tiakiwai, & Richardson, 2003).

Culturally Responsive and Sustaining Pedagogies for Mathematics

In light of the calls for moving beyond the cognitive focus in mathematics learning, we take a look into some of the work focussed on teaching indigenous and marginalised learners. When students do not see themselves reflected in the classroom curriculum, they can find it difficult to engage (Barton, 2008; Lunney Borden, 2013). A broad array of research calls for and describes pedagogies that are culturally 'relevant' (Ladson-Billings, 1994), 'responsive' (Gay, 2010), 'specific' (Irvine, 2002), and 'sustaining' (McCarty & Lee, 2014; Paris, 2012; Paris & Samy Alim, 2014). Attending to 'cultural brokering' and 'border crossing' (Aikenhead, 1997) and 'diversity pedagogy' (Sheets, 2005) are also advocated for effective teaching of indigenous and other learners served less well by traditional western classroom practices. However, while there are increasing calls for creative, innovative, interactive, and adventurous teaching for engaging indigenous learners (e.g., Ka'ai, 2012) and increasing literature in the area of culturally responsive pedagogy, there is little to date that focusses directly on the potential of our pedagogies of

singing, story-telling, or metaphor for provoking holistic perspectives in mathematics learning.

Marginalised and indigenous people, cultures, and languages are frequently "in subordinate positions in schools and curricula, with national priorities frequently determined by the needs and aspirations of the majority" (Meaney, Edmonds-Wathen, McMurchy-Pilkington, & Trinick, 2016, p. 159). Ways that have been described to reflect students' lives and cultures in mathematics teaching include examples such as ethnomathematics research (e.g., Barton, 1996; Civil, 2002; d'Ambrosio, 1985; Lipka et al., 2005; Nicol & Archibald, 2009; Sterenberg et al., 2010; Wagner & Lunney Borden, 2015), using groupwork with consensus decision-making (Sullivan, Jorgensen, Boaler, & Lerman, 2013), and rich investigative tasks (Averill, 2018). However, drawing mathematics activities from culturally-based experiences (e.g., Leonard, 2008) is predicated on educators having deep knowledge of the cultures of their students (e.g., Sterenberg, 2013; Trumbull, Nelson-Barber, & Mitchell, 2002), understanding how to incorporate such ideas suitably, and being willing and able to shift their own cultural beliefs, values, and practices to encompass approaches new to them (Whitinui & Kaiwai, 2012). Insight that cultures develop and change over time (Battiste, 2002), and that all students are different within and across cultural groups is also needed. Fortunately, strong examples of research into culturally responsive pedagogies and practice exist in our Merga community (e.g., Howard, Perry, Lowe, Ziems, & McKnight, 2003; R. Hunter & J. Hunter, 2018; Jorgensen, 2018; Jorgensen, Sullivan, & Grootenboer, 2012) but many of the ideas in this powerful work are yet to be widely reflected in practice.

There has been critique that the work on culturally relevant/responsive/specific pedagogy focusses on helping indigenous and ethnic minority learners manage in Eurocentric educational settings and does not go far enough in challenging and changing the status quo towards greater equity of opportunity and liberation (Watts, Williams, & Jagers, 2003). Martin and McGee (2009) call for framing mathematics education in ways that address historical oppression and achieve liberation, leading us to reconsider what we teach as mathematics and the contexts and pedagogies we use to teach it. There is also growing recognition that learning is acquired in different ways depending in part on learners' cultural heritage/s and that pedagogical approaches, compatible with culturally-linked pedagogies and ways of being and doing, are important for improving access to mathematical thinking and achievement (e.g., Aikenhead, 2017; Gay, 2010; Owens, 2015; Rhodes, 1988; Sterenberg, 2013). For example, in the American context, Martin and McGee (2009) advocate for mathematics education that is "worthy of being experienced as part of African-American children's development as full human beings" (p. 208) and Lee (1994) calls for African-centred pedagogy which "positively exploits and scaffolds productive community and cultural practices" (p. 297). In a Canadian example, policy states that a "variety of teaching and assessment strategies is required to build upon the diverse knowledge, cultures, communication styles, skills, attitudes, experiences and learning styles of [Aboriginal] students" (Alberta Education, 2006, p. 3). Despite the useful work already done in the areas of indigenous and culturally responsive mathematics education, further ways to enhance our teaching are needed to ensure equity of access to mathematics learning and achievement – ways that involve full-bodied knowledge, enthusiasm, excitement, the creative, and improvisation. To inform this work, suitable research is also necessary.

Achieving equitable teaching of mathematics requires that teachers learn, experiment, and reflect. Teaching for equity and for social justice that enables strengthening of

students' cultural identities requires a shift for many teachers in their views about their own identity, their teaching identity, and their identity as a teacher for social change (Gonzales, 2009). Many of the strategies advocated within the culturally responsive and sustaining teaching literature require deep cultural knowledge, knowledge that takes time, effort, opportunities, and commitment to acquire. In multicultural contexts such educator learning is even more demanding.

There are many frameworks suitable to ground exploration into pedagogical practices for mathematics. For example, one of the cultural competencies for teachers of Māori students (Ministry of Education, 2011) intended to lead to Māori students enjoying educational success as Māori by improving New Zealand teachers' responsiveness to this group, ako, is being used alongside cogenerative dialogue to develop mathematics teaching practices and enhance engagement and learning in a secondary school setting (Saunders, Averill, & McRae, in press). The competencies (Ministry of Education, 2011) draw from concepts from the Māori world in relation to communication, relationships, care, socio-cultural awareness, and teaching and learning, portraying learning as a partnership between students, their whānau (family), the teacher, and school. Another indigenous model, the whare tapa wha (four-sided house) (Durie, 1998), originally described to assist thinking about the holistic nature of health and well-being, has also been used to examine learning environments for responsiveness to Māori students (Averill, 2012). Durie's model identifies physical, emotional and cognitive, social, and spiritual aspects as four interrelated aspects of health and well-being. The cultural competencies and the whare tapa whā frameworks have similarities with those described for indigenous and minority learners outside of New Zealand in relation to the importance of partnership between teachers and community and their emphasis on the cognitive domain being intertwined with broader holistic dimensions (e.g., Aikenhead, 2017; Doolittle & Glanfield, 2007; Lunney Borden, 2013; Owens, 2015).

Further research tools for exploring the learning of marginalised students include Fraser's (2013) theoretical lens of redistribution, recognition, and participation, understanding indigenous knowledge systems as ways of 'knowing', 'being', and 'doing' (Martin, 2003), and considering learning environments and pedagogies in relation to community values, such as Pasifika values of belonging, inclusion, respect, leadership, reciprocal relationships, service, spirituality, family, and love (Ministry of Education, 2013). Such research is challenging and regardless of the framework or methodology used, essential is deep consideration of the nuances and complexities of challenges for equity, social justice, and culturally responsive and indigenous education in relation to aspects such as culture, context, and collaboration (Ismail & Cazden, 2005; Leonard, Brooks, Barnes-Johnson, & Berry, 2010; Vale, Atweh, Averill, & Skourdoumbis, 2016). The nature and scope of these and other models that encompass learning as a culturally-located and holistic experience and draw from non-Eurocentric worldviews also help show that broadening our mathematics pedagogical practice base is important for marginalised learners. They may provide useful frameworks for considering research into the use for mathematics engagement and learning of the focus pedagogies of this talk.

Next, in light of the ideas above about mathematics learning, motivation, and culturally responsive teaching, we consider the affordances for mathematics learning of singing, storytelling, and metaphor, pedagogies shared across many cultures. As a brief aside, we can think more generally about the extent to which these pedagogies may support effective learning communication. Alda (2017) describes in an engaging way how research into communication can inform how we understand ways of creating community, developing

empathy, and encouraging listening. For example, doing things together in time, be it as simple as tapping the desk in time with one another, can build a sense of community and empathy for one another. Alda talks of the power of improvisation techniques for communication, describing the same 'yes, and' technique discussed by Askew (2012) in relation to how teachers can best respond to student questions, difficulties, and progress. Singing, storytelling, and metaphor may open more spaces for communication strategies than are enabled by traditional classroom pedagogical approaches. Let's consider these spaces as we consider what these pedagogies can offer.

Singing, Storytelling, and Metaphor as Pedagogies for Mathematics

> The arts provide a continuous thread that connects generations through imagery, movement, and voice … Through the process of making art, we engage in an experiential activity that affects us internally, touching upon emotion and thoughts while also offering a tangible object that serves as a source of inspiration. (Dalton, 2015, p. 131)

Music is thought to be the biological and cultural starting point for the field of mathematical thinking (e.g., Egan, 1991), with rhythm, tune, and understanding of time, key ideas drawn from music and dance. Music is multi-sensory and supports the development of language, concentration, and self-discipline (Pound & Lee, 2011), with music therapy an established field that explores how music can improve cognitive, psychological, and emotional well-being. Using music in mathematics learning is highly motivating and can help strengthen links between students' in and out-of-school-lives (Pound & Lee, 2011). A wide range of sing-along YouTube clips with a mathematical focus exist and are used in classrooms. Research into their use and effectiveness for learning, and their use in contrast to teacher or student-generated or led singing is timely.

Making music with others enhances group cohesion and understanding, strengthening the sense of the collective. Singing in particular is known to help language development, memory, concentration, self-discipline, motivation, and understanding (Good, Russo, & Sullivan, 2015), and the melody and rhythm of song can enhance short and longer-term memory of native and foreign text (Good et al., 2015). How music can be used to enhance learning has been explored in some disciplines (e.g., memory, language learning, literacy, listening, and comprehension), but there has been little such research to date in relation to mathematics learning.

In addition to assisting cognitive development, there can be social and emotional benefits of singing with others. An Australian study into the meaning and importance of group singing to singers (Judd & Pooley, 2014) is among many finding that regular singing with others is a joyful activity that fosters a sense of belonging, promotes well-being and camaraderie, develops cognitive skills, and is life enhancing (e.g., Beaton, 1995; Mellor, 2013; Pearce Launay, Machin, & Dunbar, 2016). Such researchers call for greater understanding of the benefits of singing and wider acceptance of singing as a valuable activity (e.g., Judd & Pooley, 2014). Singing can also have physiological and neurological benefits, particularly when the song has associated actions, such as kapa haka. Although the mechanism by which it occurs is not yet well understood (Pearce, et al., 2016), studies have found that across age groups and participant types, group singing can create chemical changes in the body, reducing singers' stress and enhancing their immune system (Beck, Cesario, Yousefi, & Enamoto, 2000; Fancourt et al., 2016; Kreutz, Bongard, Rohrmann, Hodapp, & Grebe, 2003). Singers also report that singing with others is relaxing, uplifting, helps them cope with stress, and enhances their well-being. Singing helps participants to

express emotions and facilitates mood changes (Davidson, 2004; Hays & Minichiello, 2005). Singing also helps us listen to one another and together create a shared experience.

Singing with others is common to many cultural groups including Māori, Pacific groups, Blackfoot (an indigenous group in Canada), (e.g., Hemara, 2000; Sterenberg, 2013), as well as many western cultures (e.g., Scottish, English, Welsh, Irish, French…). In a New Zealand study, student interviews showed that participating in kapa haka had a range of benefits for students including fostering students' identity, self-worth, cultural connectedness, group connectedness, and learning success (Whitinui & Kaiwai, 2012). Students reported that kapa haka is fun, exciting, and challenging and instils in them the desire to aim high and achieve. Similarly, African American students were more motivated in mathematics learning when music was used (Albert, 2000) and students have sought to use rap as a way of providing evidence of their learning (Leonard, 2008).

Given what we have just heard about the benefits of singing, it would be strange and sad not to sing together now. Using an example from our initial teacher education programme, we will sing an action song designed to help us think about measurement concepts while learning measurement terms in te reo Māori, the indigenous language of the place of this talk (Figure 1). The tune we will use is a French one, *Frère Jacques*.

Whānui, whānui
Whāiti, whāiti
Teitei, poto, iti, teitei, poto, iti
Tāwhito, tāwhito

Figure 1. Measurement action song.

Looking to our second focus pedagogy, storytelling is another historic pedagogy common to many cultures and oral traditions. Storytelling has served both as entertainment and a teaching pedagogy. Storytelling is a powerful way to share ideas, illustrate a point, generate curiosity, emphasise learning objectives, and to "promote reflection, engage creative thinking and imagination, stimulate meaning making, awaken insight, and pose critical questions for discussion of perplexing issues faced in today's world" (McDonald, 2009, p. 181). Storytelling appeals to imaginations and emotions, connects people, and creates mental images of the listener's making (Goral & Gnadinger, 2006). As humans, we love story. Stories give us a way to draw from familiar contexts to cope with complex and abstract ideas (Devlin, 2000; Paley, 1990) and help develop mathematical understanding (Haven, 2007). The power of storytelling is shown by recent Pacific education leadership conferences, where research presentations are now told in story form and conventional research presentations have been abandoned. Explorations in science education have shown the value of storytelling for developing understanding of, learning about, and remembering scientific concepts (e.g., Barker, 1997, 2004; Gilbert, 2001; Miller & Osborne, 1998; Solomon, 2002).

Stories enable us to identify our own feelings, strengths, and insecurities and consider them towards change. An example that strongly exemplifies this is a chapter about changing attitudes to learning mathematics from fear and loathing to positivity and enjoyment (Yaffee, 1996) that we have used for many years at the start of our initial teacher education mathematics courses. We have found this story-based chapter generates strong discussion and elicits powerful responses from our student teachers as they identify with their own mathematics learning experiences and reflect on the type of mathematics

teacher they wish to be. The power of storytelling for engaging students with learning is also emerging from a study into exploring Pasifika values in practice, as indicated in the following quote from a Māori teacher aide working with a New Zealand Samoan teacher in a New Zealand primary classroom with a high proportion of Pasifika children:

> [When I was at school] it was like cold, you know, you did this, this, this, whereas now I think you need to engage more with your children… [the teacher is] really good, she gets very emotional sometimes you can hear her yelling … and she's not yelling at the kids she's getting excited, like about a story they've got to use, getting them to use their imagination and it can be quite loud, but that's alright, that's ok because the kids see it and they're laughing and they start doing it…

Storytelling has been used to explore, understand, and develop our work as teachers and teacher educators from early childhood to tertiary settings, as stories provide rich contexts for exploring the intricacies and dilemmas of teaching (e.g., Carter, 1993). Calls for more use of storytelling in mathematics have been made for some time (e.g., Pound & Lee, 2011; Whitin & Wilde, 1995). Explorations into using storytelling in relation to mathematics learning include studies showing that storytelling can enhance kindergarten children's learning of geometrical concepts (Casey, Erkut, Ceder, & Young, 2008) and early primary children's understanding of place value (Goral & Gnadinger, 2006). Stories can be told by the teacher or by students. In Butterworth and Lo Cicero's (2001) study, four- and five-year-old children were asked to tell a story; the stories were then used to present mathematical concepts (addition, subtraction, multiplication and division) using the real-life situations from the children's lived family experiences.

Oral storytelling is common to many cultural heritages and has been advocated as a pedagogy for multicultural settings (Schiro, 2004). Many have described ways of using mathematical aspects of stories in story and picture books to help develop mathematical thinking (e.g., Perger, 2010; Wilburne & Keat, 2011), particularly in early childhood and primary settings. Oral storytelling can be an even more personal activity than reading stories, as the teller has greater flexibility to match the content and development of the story to their audience, enabling support for developing the intended thinking and concepts and greater communication by way of eye contact, body language, and facial expression.

For Māori, Pasifika, and many others, stories and legends are a way of conveying information, community expectations, and ways of understanding their world and one's place within it (e.g., Mutonyi, 2016; Rameka, 2012). For example, traditional Māori narratives are:

> …fundamental to Māori symbolism, culture and world-views. They serve as an illustration of culture, reflecting the philosophy, norms and behavioural aspirations of the people. They highlight current social practice, and present a model for people to aspire to. The Māui traditions provide a culturally authentic way to reorientate and interact with the world as Māori. They therefore contribute to our perceptions of Māori in New Zealand society today, and can provide legitimate pathways for future schooling change and development. (Rameka, 2012, pp. 119-120)

Looking to research about learning, Mutonyi's (2016) study of Ugandan secondary school science students found that stories, proverbs, and anecdotes drawn from the students' everyday world and cultural context helped them understand science concepts. Nicol and Archibald (2009) worked in partnership with the Haida Gwaii, an indigenous group in Canada, drawing mathematics learning from traditional community stories.

It seems that more attention has already been given in mathematics education research and writing to metaphor than to singing and storytelling. Metaphor is another ancient and long-standing teaching and learning tool, with research indicating the power of metaphor for expanding the mind, developing critical thinking, categorisation, and memorising

(Low, 2008). Metaphor can deepen understanding and enable underlying meanings to be more easily grasped (Lakoff & Johnson, 1980). Metaphors enable learners to generate inferences and testable predictions. They can motivate learners and allow tailoring of teaching to individual needs (Duit, 1991; Low, 2008). Metaphor, analogies and similes are widely used to help learning in various fields (e.g., science education (Mutonyi, 2016), language education (Low, 2008), computer science (e.g., Colburn & Shute, 2008; Dufva & Dufva, 2016), and teacher education (e.g., exploring the role of the teacher; e.g., Askew, 2012)). Metaphor can be used in deliberate ways to help students clarify and connect new concepts to their existing schema (e.g., Browne, 1992; Dagher, 1995). Metaphor has also been used to understand students' dispositions to mathematics, such as by considering student responses to completing sentence starters like "if mathematics was a food, it would be…" (e.g., Cai & Merlino, 2011).

Lakoff and Johnson (1980) help us realise that, whether or not we are aware of it, much of our language and teaching of mathematics has a metaphorical base, as linking abstract ideas with physical activity aids sense-making. They describe that deliberate and unintentional use of metaphor is always present in mathematics teaching and learning (e.g., flipping a coin as a random event, using container schema to consider operations and number lines and movement along them to represent using number systems, using objects to assist in considering manipulation of variables). Neyland (2004, 2009) also drew metaphorical parallels to help explain how we can work with mathematics facts and ideas, describing mathematics as a creative form of improvisation, playing within and around structure. Our challenge is to ensure unintended metaphors and those intended as bridges to understanding are in the experience of all students and that they enhance rather than limit understanding (Low, 2008).

We can consider two types of metaphor, the first grounded in our everyday experience (e.g., life is a journey), and the second, more complex or elaborate, linking ideas to existing schema, framework, or theories (Aubrey, 2009). Metaphors assist learning as they can give visual images which stick in the mind, enabling neural-binding and concept blending (Duit, 1991; Fauconnier & Turner, 1998; Lakoff, 2008), and they invite interrogation of the idea the metaphor focusses on. González (2013) found that using metaphor along with an image assisted students to remember and apply geometrical theorems to solve a problem and prove a new theorem, suggesting the use of metaphor may facilitate students' retrieval of their geometrical learning for later work.

Looking to mathematics teacher education, we have found using metaphor useful for developing students' conceptual understanding as well as to describe their development as teachers of mathematics in several of our methods courses (Anderson, Averill, Easton, & Smith, 2005; Averill et al., 2009). Metaphor was used in several ways in this work – as an overarching theme for the methods course, to link mathematical ideas across the focus mathematical content areas (measurement, algebra, and number), and through a practical culturally-based activity of making a physical representation of their learning in a tukutuku-style panel (traditional woven design panel).

Now we have briefly explored each pedagogy separately, we consider them used together. Singing with others and story-telling have known positive cognitive, physical, psychological, and social effects (Mellor, 2013; Pearce et al., 2016), factors important for learning and likely to enhance motivation, pleasure, and engagement of learners. These and metaphor tap into teachers' and students' creativity and emotional responses. Music, dance, narrative, and physical activity all enhance enjoyment, which can lead to increased student engagement (Paquette & Rieg, 2008; Sandberg, 2009). Several studies have

explored using combinations of music and narrative for learning. For example, Colwell (1994) found an increase in kindergarten students' attention and participation levels when big story-books were first introduced using song, finding that children made more eye contact with books and participated verbally more than the control group with no music. Kouri and Telander (2008) found richer vocabulary was used by children in retelling stories when music was used in narrative-based learning than in the non-music control group.

In a Māori worldview, similar to the worldviews of some other indigenous groups, pedagogies are interconnected and interdependent. For example, Hemara (2012) describes that waiata (song), ancient kōrero tawhito (stories), whaikōrero (speeches) and whakataukī (proverbs), "none of which exist in isolation" (p. 127), support understandings of whakapapa, a fundamental principle of Māori culture.

Conclusions and Ngā Wero

In summary, there is much research that shows it is past time to broaden our approaches to the teaching and learning of mathematics. Preparing this talk has helped me reflect on some perspectives on why using singing, storytelling, and metaphor to develop mathematics learning can be appreciated and effective for cognitive, emotional, psychological, and social engagement, can enhance classroom communication, and can fit with culturally responsive and sustaining practice. We need to engage every learner in holistic, culturally sustaining, and innovative ways. There is useful and diverse research that indicates that greater use of singing, storytelling, and metaphor has the potential to broaden and strengthen our students' experiences of learning mathematics, leading toward more full-bodied ways of learning and knowing. These powerful pedagogies with the potential to breathe life, warmth, and creativity into our work and to enhance health, well-being, and a sense of community are inherent in many heritage cultures, yet they are infrequently experienced by many learners of mathematics. We need greater understanding of the impacts of purposeful use of singing, storytelling, and metaphor on mathematics learning, affect, and motivation to learn across mathematics learning contexts.

In aiming to improve experiences of indigenous and marginalised students, care is needed to ensure sensitivity and respect are paramount, that pedagogies and research are neither tokenistic nor respond to stereotypes, and that both are developed in consultation and partnership with students and the community. Given the mismatch in many settings between the heritage cultures of mathematics teachers and their students, particularly for students historically and currently underserved, suitable research is vital to ensure the voices of those often underserved are not only heard but are sought in suitable ways and are understood.

Persistent inequity in mathematics learning opportunities shows that we must seek to make big waves to disrupt thinking to enhance and supplement commonly found mathematics teaching practices. The ideas in this talk are presented as starting points for considering new directions in broadening our students' experience of learning mathematics. However, it is clear that there is evidence from a range of sources that singing, storytelling, and reflecting on metaphor in and beyond traditional classroom settings have the potential to open spaces for more learners to enjoy learning mathematics, and potentially to increase teachers' sense of pleasure, satisfaction, purpose, and community. In using these pedagogies, we help protect the treasures handed down to us, and enhance the creativity, flavour, and colour of our teaching, and the feel, nature, and ownership of our learning environments. Evidence indicates that using these pedagogies

well will strengthen the cohesion, and social, physical, spiritual, and emotional aspects of our learning communities, while promoting stronger desires to be engaged in, and learn mathematics.

Evidence suggests that we can feel confident to open up a wider range of pedagogies for mathematics learning, collectively powerfully aligned with the pedagogies of many of our cultural heritages. Doing so will certainly give us stories to tell, metaphors to draw from, and songs to sing. Research into our efforts will ensure we are well-informed and confident in doing so.

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