Chapter 8
Distribution, Recognition and Representation: Mathematics Education and Indigenous Students

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Abstract The research undertaken in the last four years on the learning and teaching of mathematics connected to Indigenous students is evaluated using Fraser's model for social justice, which consists of three elements: distribution (economic), recognition (cultural) and representation (political). Although at least one element, usually distribution, was the focus of the research papers, the occurrence of all three was rare—with representation seldom visible. Yet, evidence suggests that representation is an important element if Indigenous student achievement is to improve. As a consequence, there is a call for a moral change in how mathematics education research is promoted and undertaken with Indigenous students, with a need to include greater Indigenous community representation.

Keywords Capacity building · Community · Culture · Indigenous students · Language of instruction · Mathematics education · Māori students · Nancy Fraser · Parents · Social justice

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1 Introduction

In this chapter, we review research from the last four years that investigated various aspects of the teaching and learning of mathematics connected to Indigenous students. In doing this we use the same definition for Indigenous students as in previous reviews (Meaney, McMurchy-Pilkington, & Trinick, 2008; Meaney, McMurchy-Pilkington, & Trinick, 2012), namely, that Indigenous[1] students are indigenous to the land in which they are learning mathematics, such as those living in Australia, New Zealand, Papua New Guinea and the Pacific. Indigenous students living outside their country of origin, such as Pasifika students in New Zealand, are not part of this review but are included in the two previous chapters. Indigenous students should not be considered an homogenous group, but differ according to a range of factors such as geographical situation, language and involvement with traditional practices. In describing the different research projects in this chapter, we include contextual details for each study. For qualitative research, this information was generally provided in the original article. However, in most quantitative research, important distinctions in factors are often conflated (Leder, 2012). Furthermore, even when contextual details are available, there will be diversity within groups which is often lost even in qualitative studies.

In comparison with earlier reviews, there are fewer contributions from New Zealand, perhaps reflecting government funding drying up. However, there has been a resurgence of contributions from Papua New Guinea, with almost all of them connected to the work of Kay Owens. The paucity of research originating from the Pacific continues, with only three papers by two non-Indigenous researchers. The centrality of one or two researchers in Pacific countries makes this research fragile. Cutbacks in aid programmes by the larger economic powers (i.e., Australia and New Zealand), are likely to have a long-lasting impact on mathematics education in the Pacific.

In this chapter, we use the social justice framework of Nancy Fraser (2005), mentioned in Cazden (2012), because we consider Indigenous student outcomes to be inextricably tied to issues of social justice. Such an evaluation is important because, particularly in Australia, a large amount of resources has been committed to addressing the issue of underachievement of Indigenous students over the last decade, but with limited results. As Thomson, Hillman, and Wernert (2012) stated when comparing Indigenous students' mathematics literacy results in the Programme for International Student Assessment (PISA) tests between 1995 and 2011:

> None of the differences between years is significant, that is, the 2011 score for Indigenous students, as for non-Indigenous students, is not significantly different to the score in any of the other years of testing. The difference between Indigenous and non-Indigenous students is significant, as it has been in each year of testing, and has not decreased in size. (p. 30)

[1]We capitalise Indigenous when referring to people as a mark of respect.

Despite the best of intentions, the mathematical achievement of Indigenous students, at least in Australia and perhaps New Zealand (see Hāwera & Taylor, 2012), has failed to match that of their non-Indigenous peers. Therefore, without an evaluation of what has been done and the outcomes from it, we risk losing focus:

> The ultimate result of the huge effort being put into potentially futile initiatives is that we as educators will lose focus of the main purpose of education, to make it count in the lives of students. Instead, in the end we may just be counting education. (Guenther, 2013, p. 158)

1.1 A Theory of Post-Westphalian Democratic Justice

We consider that the lack of change in education achievement results is an issue of social justice:

> While it is normal and natural that educational outcomes vary between individuals, stable and substantial differences in educational outcomes between *groups* of individuals are a cause for concern. Such differences suggest that social and educational forces, policies, and structures are systematically privileging some groups over others. (Song, Perry, & McConney, 2014, p. 178, emphasis in original)

To better understand how privileging occurs and is identified in research on the teaching and learning of mathematics connected to Indigenous students, we use Fraser's (2005) three-element model for social justice. From her perspective, it extends beyond the borders and notions of egalitarian societies, based on income and wealth, in earlier perspectives on social justice. For example, earlier research—concerned with the social and political aspects of the learning of mathematics—idealised the provision of access to mathematics for everyone independent of skin colour, gender and class (Jorgensen & Perso, 2012). Jorgensen and Perso (2012) argued that such a view of social justice is limited because it does not take into account the diverse backgrounds of students. Fraser (2005) took this one step further in stating that "theories of justice must become three-dimensional, incorporating the political dimension of *representation*, alongside the economic dimension of distribution and the cultural dimension of recognition" (p. 5, emphasis in original). At the global level, representation includes acknowledging national and regional groups' demands for independence, and recognition of treaty and Indigenous rights. She deemed this version of social justice more valuable when issues were present in more than one country, calling it "a theory of post-Westphalian democratic justice" (p. 5).

In this section, we give examples of how we interpret each element. Distribution considers how social goods such as education are distributed to different groups. From analysing the appearance of the achievement gap in PISA results between Indigenous students and non-Indigenous students, Song et al. (2014) concluded that political decisions about how schools were funded contributed to higher level of inequitable resourcing in Australian schools compared with New Zealand schools: "This high level of segregation in Australia is associated with large differences in school resources, especially the ability to recruit and retain qualified and

experienced teachers" (p. 194). Although their study was about results in reading, viewing teachers as resources would have a similar impact on mathematical literacy results. In New Zealand, Turner, Rubie-Davis, and Webber (2015) found that teachers had different expectations of students' capacities for learning mathematics based on their ethnicity, regardless of their achievement. Interviews revealed that they had the lowest expectations of Māori students, blaming students' attitudes and their home backgrounds as the main contributors to poor achievement. The teachers' expectations were likely to restrict the distribution of mathematics learning to these students, thus achieving a self-fulfilling prophecy.

In regard to the element of recognition, a social justice approach to mathematics education would positively recognise students' cultural experiences as a useful basis for their mathematics learning (Meaney & Evans, 2013). Grootenboer and Sullivan (2013), in considering remote Indigenous students in the Kimberley, stated:

> Indeed, we are convinced that the current national testing programs in Australia do not provide a fair platform for remote Aboriginal children to display the extent and complexity of their mathematical knowledge and skills, and the validity of their results in these assessments need[s] to be viewed with some scepticism. (p. 187)

Although Grootenboer and Sullivan (2013) suggested that these students could achieve on these tests if the teaching they received built on what they knew, there is a contradiction in expecting only the students to change and not recognising that the assessments also need to change. Like the lack of familiar problem contexts for Indigenous students, raised in previous Mathematics Education Research Group of Australasia (MERGA) reviews (see Meaney et al., 2008, 2012), the aggregating of Indigenous students' results as though they are one homogenous group (Leder, 2012) is an issue of recognition. Such aggregation can "hide, rather than identify, the strengths and needs of the different sub-groups" (Leder, 2012, p. 12), thus leading to all Indigenous students being considered low achievers in mathematics. If students take on these messages of low achievement, then there is a risk that it too contributes to a self-fulfilling prophecy (Leder & Forgasz, 2012; Trinick, 2015).

The final element in Fraser's (2005) model is that of representation. If mathematics education for Indigenous students is to be socially just, then Indigenous communities need to contribute to decisions about what should be taught, what should be researched and by whom—yet this element is rarely present in this set of research papers. For example, in discussing the design of a literacy and numeracy strategy for Indigenous students living in remote communities in the Northern Territory (Perso, 2013), scant attention is paid to the possibilities for Indigenous communities to participate in the decision making of what should occur in classrooms. Although Indigenous Education Workers (IEWs) were recognised as being knowledgeable about the students' cultural contexts, the IEWs were considered to need professional development to impart this knowledge, as well as needing more knowledge about Western schooling. Described in this way, the possibility that IEWs could represent their communities by working with teachers to develop culturally appropriate mathematics education could easily be ignored.

The literature critiqued in this chapter is divided into four sections: pedagogy to enhance learning, language of teaching and learning, mathematical topics, and capacity building. We contend that without all three elements of Fraser's model being present, intervention programmes and their associated research are likely to have only the limited success identified in the longitudinal statistics on Indigenous students' achievement in mathematics.

2 Pedagogy to Enhance Learning

In this section, we discuss research on different pedagogical approaches for teaching Indigenous students and evaluations of the effectiveness of interventions. Programmes which focused on pedagogical approaches were often linked to the social justice element of distribution, specifically the distribution of Western mathematics knowledge. For example, structured mathematics teaching, with clear and explicit expectations and learning goals, and a timetable, was described by Jorgensen (2013) in her presentation of school mathematics as a game of which the rules need to be taught.

Another example of a structured approach was Pegg and Graham's (2013) *QuickSmart* programme, implemented in 600 Australian schools. An intensive intervention for middle school students, it focused on developing automaticity with arithmetic facts. The features identified as effective for teaching Indigenous students included explicit instruction with highly structured lessons, including focused games. Although the programme showed achievement gains for both Indigenous and non-Indigenous students, there is a need for a more nuanced assessment of the contribution that improving basic skills makes to performance on complex cognitive tasks. Otherwise, what is distributed as valued Western mathematics, arithmetic facts, might prove to be of little use to Indigenous students.

Exemplary practices with Aboriginal and Torres Strait Islanders, celebrating the success of quality teaching at a very remote Australian site over eight years, were described by Jorgenson (2015a, b). The principles and strategies used in the school included high expectations, being explicit, a whole school approach and supportive leadership, with a strong emphasis on linking mathematical language with Standard Australian English in an environment rich with resources (see Fig. 8.1). How or if the cultural experiences of the students were incorporated into the learning environment (recognition) or if the local community was involved in leadership or the curriculum (representation) were not reported. Rather, the focus seemed to be on the distribution of valued Western mathematics.

In contrast to the structured approach but still with an emphasis on distribution, Jorgensen and Lowrie (2013) described using a guitar-hero, digital game to motivate students' school engagement while providing a context for mathematical learning, such as percentages in scores for the game. The authors did not describe whether the mathematics learning was part of the rich task (a concert performance) that was the culmination of the program.

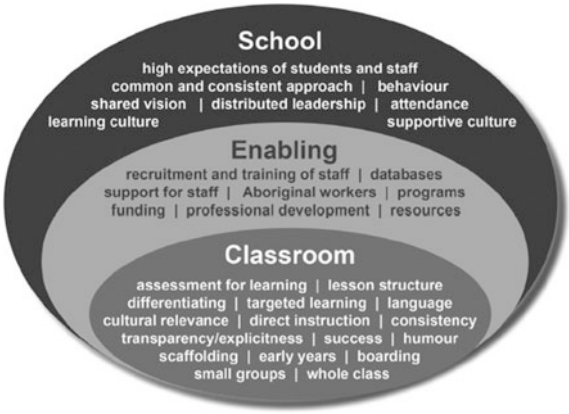

Fig. 8.1 Themes connected to levels of practice. Jorgensen (2015b, p. 666), Fig. 1 with permission from Mathematics Education and Society (MES).

The *Maths in the Kimberley* project has run over several years and sought to implement a complex programme, based on using rich mathematical tasks. It was a Australian Research Council funded linkage project in that researchers worked with the Association of Independent Schools in Western Australia (AISWA) from 2007-2011 (Jorgensen, 2015a). Related to the social justice aspect of recognition (Fraser, 2005), students' cultural practices and background knowledge were taken into consideration. For example, acknowledgement of consensus decision making processes in Indigenous communities contributed to the incorporation of group work (Sullivan, Jorgensen, Boaler, & Lerman, 2013). However, perceptions of questioning in whole class mathematics lessons and small group interactions were connected by students to the culturally-accepted response of shame, which resulted in the use of group work having to be reappraised.

Recognition of students' culture was considered valuable in linking teachers' mathematical and pedagogical content knowledge to their capacity for cultural responsiveness. Sparrow and Hurst (2012) found that teachers who began their project with low knowledge and competence in mathematics pedagogy and little specific awareness of each student's mathematical learning needs, were more able to be culturally responsive as they increased their mathematical and pedagogical content knowledge. The researchers suggested that cultural responsiveness and responsiveness to the individual are interlinked.

Yet knowing how to relate mathematics teaching to cultural activities of an Indigenous group is challenging. For example, in New Zealand the paradigm that Māori students should achieve as Māori underpins culturally responsive teaching. Investigating the views of teachers and an ethnically mixed group of Year 10 students, Averill (2012b) found that the teacher and the students identified that teachers needed to know about students as individuals and have some knowledge of their heritage cultures. However, teachers' practices were not always identified by either students or teachers as being culturally responsive. Neither teachers nor students valued teachers' knowledge of mathematical aspects of students' cultures. Students indicated that school mathematics was separate from their cultures. These

findings identified that teachers needed support to integrate cultural knowledge and mathematics teaching, while students needed help to recognise that using cultural activities could contribute to their learning.

The *Make It Count* project in Australia was an initiative of the Australian Association of Mathematics Teachers from 2009 to 2012, operating in eight clusters of schools with significant populations of Indigenous students. Clusters were paired with critical friends, mostly academics with expertise in mathematics education and/or Indigenous education. This project encouraged schools to develop mathematics programmes that were responsive to their contexts, while drawing on previous research and the expertise of the critical friends. Thornton, Statton, and Mountzouris (2012) highlighted how mathematics could be embedded into everyday learning contexts. They gave the example of the engagement of a student in a school garden programme, which contributed to her developing mathematical resilience, including a more positive disposition towards mathematics and the willingness to learn from mistakes and persevere with new strategies. This is one of the few projects which illustrated all three elements of Fraser's (2005) social justice model (albeit at an individual level). The possibilities for the student to gain Western mathematics were increased with recognition of her cultural background. Having the student choose the context enabled her to connect to wider family interests, indicating that the element of representation contributed to her education.

Recognition of community-specific needs and circumstances is imperative with financial literacy education (FLE), rather than assuming that an inappropriate "one-size-fits-all" approach, delivered across a range of contexts, will suffice (Blue, Grootenboer, & Brimble, 2015). Training local people to deliver FLE that may transmit a message to their community that financial problems can be "fixed" if only one acquires budgeting skills, and without regard to culturally inappropriate delivery and contexts, proved ineffective in a case study of a Canadian Indigenous reservation community. That resources are distributed inequitably throughout society cannot be fixed by FLE training when poverty is an issue of low wages or lack of employment opportunities.

3 Language of Teaching and Learning

In this section, research on how the choice of the language of instruction affects Indigenous students' learning of mathematics is discussed, as well as Indigenous teachers' learning of the language of instruction. This issue is often tied to the distribution element of social justice through increasing Indigenous learners' opportunities to acquire Western mathematics, generally in the medium of English. Edmonds-Wathen, Sakopa, Owens, and Bino (2014) noted teaching in Indigenous languages can be contentious, even when the Indigenous population comprises the majority in a country. In Papua New Guinea and Australia, the perception of English as providing access to education and future employment makes it a valued language of instruction. While the choice of which language to use is linked to local

political issues, readiness to participate in the global economy is increasingly being used as a means to suppress and further marginalise minority languages. This can be considered an example of Fraser's (2005) argument that globalisation on the politics of nation states, including language policies, can have an impact at the micro level of schooling.

One approach where students did not have the language of instruction as their first language was to reduce the emphasis on verbal language. This included considering what explicit teaching means in relation to mathematical concepts while considering students' cultural and linguistic context. This can be seen in this analysis from Halls Creek District High School:

> What I think might be a very explicit explanation or demonstration of a core idea, and can be successful in some classrooms, may well have no meaning in a class of Indigenous learners for whom standard Australian English is a second and sometimes third or fourth language. The challenge then is to make the identified core knowledge accessible to Indigenous learners without relying on traditional expository pedagogies. (Tomazos, 2012, p. 2)

Braid and Sullivan (2012) described mathematics lessons that used an "economy of words" in order to avoid the cognitive overload that can come from students being submerged in a "sea of blah" (p. 1). During these lessons, the focus was solely on the mathematics, temporarily de-emphasising a primary focus on the learning of English. Although the reduced focus on oral explanations was done to support the distribution of Western mathematics, it would have also limited possibilities for recognising Indigenous culture and language as having a place in mathematics classrooms.

Elsewhere in Australia, several studies described strategies for students to make use of their first language, Kriol. Treacy (2013) found that some Indigenous students confused everyday meanings of mathematical terms in Standard Australian English (SAE) and Kriol. Treacy (2013) suggested that "students first need to learn the concept and the associated word in Kriol, and then learn the English word that matches the concept" (p. 640). Baxter and Gilligan (2012) described a code-switching strategy where mathematical narratives were presented in both SAE and Kriol, using planned mathematical vocabulary that highlighted differences and similarities between the two languages and their mathematical registers. Jorgensen and Kanwal (2015) also described one school's planned use of SAE and Kriol as providing recognition of the students' language and culture by attributing a high status to Kriol, even if not used as the language of instruction.

There were some studies that focused on the element of representation. Wilkinson and Bradbury (2013) described the collaborative process of creating mathematical terms in the Djambarrpuyŋu language with Indigenous assistant teachers. They noted the success of this work, but also the complexity of the process. Many linguists today accept a moderate or limited Sapir-Whorf hypothesis (named after the linguists, Sapir and Whorf), that the ways in which groups of people see the world may be influenced by the language that they use (Trinick, 2015). Therefore developing terms for Western mathematical ideas in a non-Western language is likely to be challenging. Wilkinson and Bradbury (2013)

highlighted the importance of schools providing Indigenous and non-Indigenous teaching teams with sufficient time to plan together.

Similarly, in a study on teacher education, Trinick, Meaney, and Fairhall (2014) focused on teachers who taught in an Indigenous language but who had completed their teacher education in English. They raised the issue of how school systems and initial teacher education programmes can support teachers in learning the registers of mathematics and mathematics education in an Indigenous language. Similarly, Edmonds-Wathen et al. (2014) found that teachers who had received their own education in English were not necessarily equipped to teach mathematics in their first languages. Thus if an Indigenous language is to be used to support both the recognition and representation elements of social justice, system support is needed.

Discussing the first two iterations of the Māori mathematics curriculum, McMurchy-Pilkington, Trinick, and Meaney (2013) highlighted curriculum development as a site of ideological contestation, i.e., international neo-liberal ideologies versus Indigenous language rights. They described how the development of Māori-medium schooling was used to produce the first Māori mathematics curriculum, enabling Māori to promote their agenda of language revitalisation. Both curricula took into account the need of Māori students to progress to tertiary education and so be competent with Western mathematics (distribution). While the first articulation of the mathematics curriculum was largely a translation of the English version (recognition), the second incorporated a stronger reflection of Māori worldviews and was more supportive of language acquisition and revitalisation goals, thus including the social justice element of representation.

4 Mathematical Topics

In the previous review (Meaney et al., 2012), the mathematical topics covered were number, probability, and space and geometry. In 2012–2015, many articles originated from two well-funded projects about the teaching of pattern and early algebra, while studies about number, space and geometry, and probability tended to be stand-alone projects. Although the main focus was generally on the distribution of Western mathematics to Indigenous students, many papers included recognition of students' cultural backgrounds. Representation was present generally when Indigenous researchers were included.

4.1 Number

Interestingly, most of the studies on number focused on Indigenous number systems and numerical thinking (recognition) rather than on the direct learning of the Western number system (distribution). The first two studies, mentioned below, included Indigenous researchers and so also included the element of representation.

In Papua New Guinea, the first three years of school (Prep to Grade 2) have been until recently taught in the vernacular language of the local community, known as *Tok Ples*. The students learn their vernacular number systems before transitioning to learning in English and the Western number system at Grade 3. Matang and Owens (2014), investigating the number understanding of students from 22 schools, found that "children learning to read and write and count in their own language Tok Ples performed better than those learning early number knowledge without Tok Ples" (p. 550). Although work discussed in previous MERGA reviews indicated that the situation is extremely complex, this result indicates that learning vernacular number systems can be used as a bridge to learning Western number systems.

Meaney and Evans (2013) drew attention to some of the erroneous historical accounts of the quantifying practices of different Australian Indigenous groups which had suggested that these groups did not quantify. They pointed out that looking only for number and reckoning systems parallel to the Western system can prevent researchers from seeing Indigenous number practices. They emphasised the need for representation by suggesting that Indigenous researchers working in their own communities should control how traditional number practices are connected to Western mathematics.

Núñez, Cooperrider, and Wassman's (2012) investigation into number concepts of unschooled Yupno people from Papua New Guinea demonstrated that number lines are a cultural construct—a widely used and useful one, but nevertheless not an innate part of mathematical thinking. This highlights the problem of mathematical artefacts being considered innate instead of the cultural products of those who design and implement mathematics education. It also illustrates that a focus only on the social justice aspect of distribution can lead to reduced rather than increased learning opportunities for Indigenous students.

Treacy, Frid, and Jacob (2015), looking at quantifying strategies of Indigenous students from the Goldfields Area of Western Australia, found that the students performed a quantity matching task without counting. Although uncertain what students did, the researchers suggested that a form of family matching or subitising might have been used. Treacy et al. (2015) concluded that there was a need to take recognition into consideration, possibly in alignment with representation: "The findings highlight a need to further examine the world views, orientations and related mathematical concepts and processes that Indigenous students bring to school" (p. 18), specifically to determine the actual strategies the students used.

Taking the approach recommended by Treacy et al. (2015), Ewing (2012, 2014) documented the mathematical practices of mothers in a Torres Strait Islander community as cultural "funds of knowledge", such as sorting through classification, repeated patterning and partitioning. She discussed similarities and differences between the community practices of sharing through partitioning in the distribution of fish that have been caught and division though equal sharing in school mathematics. Ewing (2014) argued that mathematics is located in children's lives and social relationships and that development of their mathematical understanding needs to come from these practices and contexts.

One study focused only on the learning of Western number concepts by Indigenous students, with the division strategies of 44 students (Year 7–8) from Māori-medium schools being documented (Hāwera & Taylor, 2012). Twenty-nine students used a wide variety of strategies of varying efficiency, even when they had not been explicitly taught these strategies. However, the researchers expressed concern about the students being unable to provide appropriate answers and recommended that teaching of mathematical concepts such as multiplication should include teaching relevant mathematical language.

4.2 Patterns and Early Algebra

Two externally funded projects in Australia focused on developing young children's patterning skills. The approaches for the two projects were different. The Patterns and Early Algebra Preschool (PEAP) Professional Development project (Papic, 2013b) was a 3-year early numeracy project, conducted across New South Wales and the Australian Capital Territory, that focused on developing young children's awareness of pattern and structure in order to promote the foundation for mathematical thinking (Papic, Mulligan, Highfield, McKay-Tempest, & Garrett, 2015). It thus could be considered as focusing on distribution. Children aged 4 to 5 years were assessed on their patterning understandings. Professional development was provided for the early childhood educators, who implemented an intervention which had a positive impact on the children's mathematical thinking (Papic et al., 2015). Notably, the children's Indigeneity was conflated with low socioeconomic status and a perceived lack of school readiness (Papic, 2013a, b). Making tasks culturally relevant was mentioned, with "hands-on" experiences described as critical for engaging Indigenous students (Papic, 2013b). However, the programme used the same material that had been developed for non-Indigenous students, with minimal discussion about the need to modify it. This raises questions about how recognition and representation could be included in such programmes.

The Representations, Oral Language and Engagement in Mathematics (RoleM) project from Queensland was developed specifically for Indigenous students, ESL students and students in low socioeconomic contexts; however, the researchers were careful not to conflate these groups (Warren & Miller, 2015). The researchers involved individual communities, thus recognising the importance of representation, so that they could learn with them about how best to support students' learning. "Collaboration between the school, local communities, parents, teachers, students and Indigenous education workers is seen to be crucial to success" (Warren & Miller, 2013, p. 153). A project developed alongside RoleM investigated how young Indigenous students learn to generalise with growing patterns, with findings focused on the importance of gesture as a semiotic system in generalising about such patterns (Miller, 2015; Miller & Warren, 2015).

From the *Make It Count* project, Barnes (2012) described how contextually relevant word stories were used to engage interest in algebra, and teach algebra and

abstract concepts to girls at a boarding school. While the paper was not developed and structured as a research paper, Barnes emphasised that the girls were "easily engaged" with algebra, and that they managed abstraction well "once they [saw] that it [was] a powerful way of solving complex problems" (p. 6).

4.3 Probability

In one of the few papers from the Pacific, Morris (2014) discussed his initial investigation into his failure to teach probability at the university level in the Kingdom of Tonga. He used the Sapir-Whorf hypothesis to suggest that Tongan students' interpretations of uncertainty were linked to their language not having ways to discuss uncertainty, with cultural views that suggest "future events are not uncertain but are waiting to be revealed" (p. 246). This seemed to be about the need for recognition of difference but the paper did not extend the ideas about how to resolve the issue in a way that would support students' learning.

Pickles (2013) explored in Goroka, Papua New Guinea, how the introduced practice of gambling was connected to older traditions of competitive giving. As such, he problematised considerations of gambling as just being about chance and therefore the provenance of mathematics. This suggests that gambling is not a "natural" context for teaching probability, something also raised by Meaney and Evans (2013) in relationship to card games and number understandings.

4.4 Space and Geometry

Drawing on a wide body of research, Owens's (2015) book on an ecocultural perspective on visuospatial reasoning argues that "education besides recognising a school, system, and global perspectives as contexts may benefit from connecting to place and culture to understand and strengthen visuospatial reasoning" (p. 12). Owens (2013, 2015) described several projects undertaken to investigate the spatial and measurement concepts of different language groups in Papua New Guinea. Acknowledging the importance of distribution and recognition, Owens was concerned that Western mathematics should neither be used to replace the existing mathematics within Papua New Guinea cultures nor be ignored so that students were not provided with opportunities to learn it.

> By ensuring mathematics is part of an ecological perspective provided by culturally competent teachers who establish educational partnerships with the communities around their activities, then the teaching of mathematics will support cultural knowledge and relationships as well as advance school mathematics. (Owens, 2013, p. 967)

In Australia, Sullivan and van Riel (2013) focused on geometrical topics because of "an often stated assumption that the prevalence of direction words in some

Indigenous languages implies that the learning of aspects of geometry may be closer to Indigenous students' experience than the learning of number" (p. 142). Sullivan and van Riel's study was on students connecting 2D and 3D representations of objects. However, Sullivan and van Riel's goal for Indigenous students to learn "conventional" mathematics precluded any questioning of "the appropriateness of an early emphasis on geometric shapes in some mathematics syllabi, when other types of spatial knowledge are more precisely defined and much more highly valued in the Aboriginal child's home culture" (Harris, 1991, p. 142). It seemed the goal for more equitable distribution of Western mathematics knowledge overrode concerns for recognition.

Edmonds-Wathen (2013) investigated spatial concepts of the Iwaidja, a northern Australian Indigenous cultural group, and suggested that spatial concepts in Indigenous languages can influence children's use of similar terms in English (Edmonds-Wathen, 2014). In New Zealand, Hāwera and Taylor (2013) described an intervention study on transformational geometry for Year 7 and 8 students in a Māori-medium class. The intervention wove mathematical language learning with cultural understandings into a range of tasks, including the use of ICT. This was one of the few studies in this review which actively sought and reported on children's own experiences of learning, thus acknowledging the need for Indigenous students' representation in research.

Trinick, Meaney, and Fairhall (2015) have begun a project to consider how traditional Māori cultural knowledge can be revived in regard to spatial orientation. Their initial results showed that students needed support to orientate themselves outside of classrooms, regardless of what system of knowledge they drew upon. Although Indigenous researchers were involved in this research, the focus was on the social justice elements of distribution and recognition.

5 Building Capacity

Research on professional development for Indigenous and non-Indigenous teachers about teaching mathematics did involve, to varying degrees, all three social justice elements. When Indigenous staff and community provide expert knowledge about the teaching of mathematics to Indigenous students, then the representation element of social justice is present (Fraser, 2005).

5.1 Professional Learning Needs to Be Ongoing and Collaborative for Sustainability

It is acknowledged that "deliver and run" professional development is unlikely to lead to sustainable transformation of teacher practices (Owens, 2014a). Instead, changes come from job-embedded professional development, with an emphasis on

personal learning, reflection and pedagogical change (Warren, Quine, & DeVries, 2012), taking place over extended periods with expert mentoring and informal support within and beyond the school (Owens, 2014a). Sustainability of these changes comes when teachers engage in their own professional growth in a collaborative context with support from experts in the field over time (Hāwera & Taylor, 2014; Jacob & McConney, 2013; Owens, 2014a; Warren & Miller, 2013; Warren et al., 2012). This is particularly important in rural or remote areas in Australia where teachers often are at the beginning of their careers and/or change positions regularly (Jorgensen & Kamal, 2015).

An ethnomathematical project in Papua New Guinea, with an emphasis on the representation element of social justice, encouraged Indigenous teachers to link their cultural mathematics with school mathematics (Owens, 2014b). A strong sense of their cultural identity encouraged teachers to recognise the value and relevance of their cultural heritage to mathematics education. In turn, their mathematical identities were strengthened by linking to their community contexts. Part of the project's aim was to create a sustainable community of learners (Owens, Edmonds-Wathen, & Bino, Owens et al. 2015). Teachers living in remote areas participated in a week of face-to-face professional development. The workshop used an electronic resource package, accessible offline. This included videos of cultural activities from different parts of PNG, and videos exemplifying children's learning, the latter featuring Australian learners (Bino & Edmonds-Wathen, 2014). These videos will be replaced by others that reflect learners from PNG and their environment. In evaluating the workshop, participants reported that they had learnt about making links between cultural mathematics and school mathematics, teaching mathematics, providing group activities, and asking questions to enhance thinking (Owens et al., 2015). The facilitators recognised ongoing challenges to deliver the professional learning on a larger scale.

Teachers need good knowledge of mathematics to make links to their Indigenous learners' out-of-school contexts so the learners can "see themselves as mathematicians doing maths in their everyday lives" (Jacob & McConney, 2013, p. 98). After a year of professional development, teachers reported a growing confidence in planning for and monitoring student learning (Jacob & McConney, 2013). Nevertheless, many teachers still were not confident in areas like diagnosing learning and making mathematics explicit to learners. The classroom teachers worked together with a mathematics specialist to overcome conceptual hurdles facing Indigenous learners. As well the role of Aboriginal and Islander Education Officers (AIEO) was essential. This acknowledges the need for representation, as well as distribution and recognition, in order for socially just mathematics education programmes to be provided.

In a project to improve numeracy outcomes for early years Indigenous learners, numeracy specialists worked with teachers, Aboriginal Education Assistants (AE) and AIEOs to enhance their pedagogical content knowledge, confidence in teaching mathematics and their development as participants in professional learning communities (Hurst & Sparrow, 2012). Results indicated that the AE and AIEOs improved their confidence and ability to take on greater responsibility for teaching

and began to see themselves as integral members of a professional learning community. They reported on genuine team work with the teachers and they felt valued as equal members of staff. The AEIOs believed that their confidence to teach and support children's learning came from knowing more content.

In the *Maths in Kimberley* project, Jorgensen, Grootenboer, and Niesche (2013) developed a pedagogical model to assist teachers in six remote schools to promote effective pedagogical practices in mathematics. A comparison was made between teachers' answers to a questionnaire and video recordings of their lessons. The results showed that professional development could support teachers to make significant changes to their pedagogy. However, facilitators noted the difficulties of supporting teachers, given the large distances between the researchers, development teams and schools, and suggested alternative working processes. The researchers also emphasised that communities were unique and pedagogical activity was not always transferable.

Similarly, Owens (2014a) cautioned against assuming that all Indigenous learners are strongly steeped in their cultural practices. In an urban Australian school, teacher pedagogy and the school environment changed for Indigenous students when funding supported professional development which involved the community, the social justice element of representation. The school revised their teaching approaches and curriculum to better include family and Aboriginal cultural heritage. Shared ownership developed with the community feeling welcome in the school and taking on leadership roles. Teacher perceptions, skills and pedagogy changed and a place-based mathematics curriculum resulted. Learners acknowledged their Indigenous connections and learnt the Indigenous language. Changes eventuated for students because there were not only high expectations about test results (the distribution element), but also an expectation students would be comfortable identifying as Aboriginal and being proud of their heritage (the recognition element).

Indigenous students live in a range of circumstances. For remote communities, one of the most challenging issues is high staff turnover which is considered counter-productive for initiatives designed to increase Indigenous learners' achievement (Jorgensen, 2012; Owens, 2014a; Warren & Quine, 2013). There is substantial evidence that shared leadership and power, inclusive of Indigenous culture, knowledge and values, along with high expectations of learners, can lead to improved Indigenous student learning outcomes (Ewing, Sarra, Cooper, Matthews, & Fairfoot, 2014; Warren & Quine, 2013). Distributed leadership proved valuable in schools where principals and teachers remain for short periods (Jacob & McConney, 2013; Jorgensen, 2012). As one principal stated, "Teachers come and go but the community stays" (Owens, 2014a, p. 76). Distributed leadership may be incongruent with established local practices, based on a Western perspective that uses vertical structures (Warren & Quine, 2013). However, sharing power and authority with Indigenous staff and communities helps to build capacity (Warren & Quine, 2013) and is clearly connected to the social justice element of representation.

One approach to improving representation is to increase the number of Indigenous mathematics education researchers through partnering and mentoring Indigenous academics (see Owens, 2014b; Owens et al., 2015). Dawson (2013, 2015) reported on a capacity building project for Indigenous mathematics educators from across Micronesia. The educators, who were co-researchers in the *MACIMISE* (Mathematics and Culture in Micronesia: Integrating Societal Expectations) project, involved local experts, familiar with community culture and practices, to develop 17 culturally based mathematics units (Dawson, 2015). The educators completed advanced degrees at the University of Hawaii-Manoa that honoured the mathematical practices of their respective Micronesian communities.

The mathematics education research community in Australasia has not yet developed similar projects to MACIMISE, as a way of supporting the inclusion of the representation element of Fraser's (2005) social justice model. Hāwera and Taylor (2014) discussed fluidity of engagement and power sharing between researchers and participant teachers in a Māori-medium setting and argued for the importance of working relationships, modelled on whānau lines (family), with Indigenous experts from outside the school.

5.2 *Parent-Community Involvement*

Parent and community involvement was visible in some professional development projects reported in previous sections, but were also the focus of other projects. Such involvement supports the inclusion of the representation element of social justice.

Preschoolers in an Aboriginal community in New South Wales transitioning to school learnt best when there was a partnership between their parents and teachers (Sarra & Ewing, 2014). This partnership promoted a sense of continuity between home and school, which enabled numeracy language and understanding to develop in contexts similar to those in the preschoolers' homes. With elders and community members sharing their knowledge, the school was able to develop a culturally rich curriculum. Culturally appropriate resources and the learning environment enabled these learners to reduce cultural, linguistic and contextual barriers and be more able to engage in mathematics learning.

Similarly, Averill (2012a) in New Zealand argued for teachers to develop culturally responsive mathematics teaching by considering the families of learners from the different cultural groups in their classrooms as cultural models and advisors. Forming relationships with these families could provide continuity between teachers and the community.

Ewing et al. (2014) explored how the learning and teaching of Vocational Education and Training (VET) courses could contribute to successful outcomes for Indigenous learners, including increasing their future employment opportunities. Effective community relationships were considered to lead to young people enrolling in Certificate courses and to act as a conduit for gaining feedback and support from community elders.

6 Conclusion

Much of the research focusing on the relationship between Indigenous students and mathematics can be broadly grouped around two major themes; research which seeks to explain why Indigenous students underachieve and solutions for redressing the underachievement. Explanations for underachievement of Indigenous students include low teacher efficacy and low teacher and student expectation (Jorgensen et al. 2013; Owens, 2014b; Turner et al., 2015); inadequate teacher subject, pedagogic and cultural knowledge (Edmonds-Wathen, 2012, 2015); and conflict between the culture of home and school (Meaney & Evans, 2013). As well, when mathematics and mathematics education are considered culturally free (Owens, 2013) and not taking place in culturally and socially loaded contexts (Averill, 2012b), Indigenous students can become alienated from the learning environment and mathematics education.

A number of researchers suggest Indigenous students' underachievement is related to the power relationships in schools and classrooms (Cazden, 2012; Jorgensen & Perso, 2012). Indigenous people, their culture and language, are frequently in subordinate positions in schools and curricula, with national priorities frequently determined by the needs and aspirations of the majority, which is most often European (Trinick & May, 2013). Trinick et al. (2015), in relation to Māori in New Zealand, provided the example of national curricula advantaging Western spatial perception to the detriment of traditional Māori cultural knowledge. The ongoing tendency of government agencies to frame initiatives in terms of mainstream education (the distribution element), in the first instance, assumes that these will naturally "translate" to the Indigenous education context.

Some programmes, such as *Make it Count*, did embrace an approach which enabled individual schools to frame their interventions to match the needs of their students, and communities (recognition and representation). However, gaining systematic data on whether these resulted in improved outcomes for students has proven difficult (Forgasz, Leder, & Halliday, 2013).

From our perspective, some of the issues raised in the last two reviews do not seem to have been resolved. Only a few studies actively included Indigenous representation, either in the planning of interventions or in undertaking research. This suggests that changes need to be made by the mathematics education research community to influence policy, if the aspirations of Indigenous communities in regard to mathematics education for their children are to be achieved. In 2015, it seems incongruous that the majority of research done in Indigenous mathematics is still carried out by non-Indigenous researchers.

One point that we have noted in doing this four-yearly review is the influence of funding bodies on the type of research which is done. Although many researchers had only the research time granted to them by their universities, the most prolific research outputs generally came from externally funded projects (see Grootenboer & Sullivan, 2013; Owens et al., 2015; Warren & Miller, 2013). In order to gain the increasingly rarer grants, applications need to be written in an acceptable way with

a particular focus. Increased Indigenous representation within research environments could be achieved by including this requirement within application guidelines. Reduced aid funding from Australia, in particular, has curbed the possibilities for Indigenous researchers from the Pacific and Papua New Guinea to complete graduate degrees. Consequently, there is a need to consider other ways to support capacity building of Indigenous researchers. There is a moral responsibility for research communities, such as MERGA, to advocate for more funding for Pacific nations. Many of these nations, threatened by rising sea levels as a result of global warming, need mathematically literate advocates to support their nations' future in international gatherings, such as the one held in Paris in December 2015.

We support Fraser's contention that without all three social justice elements being considered in research—namely, redistribution (economic), recognition (cultural) and representation (political)—intervention programmes and their associated research are likely to have only limited success, as identified in the longitudinal statistics on Indigenous students' achievement in mathematics.

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