Chapter 10
Cultural and Mathematical Symmetry in Māori Meeting Houses (Wharenui)

Tony Trinick, Tamsin Meaney and Uenuku Fairhall

Abstract This chapter draws on the symbolism found in various artefacts in *wharenui* (meeting houses), with a particular focus on Rauru, a traditional Māori meeting house located in Hamburg, Germany, the location also of ICME 13, to illustrate an aspect of ethnomathematics: cultural and mathematical symmetry. This addresses a gap in Māori-medium education whereby much of the focus to date has been on revitalising the endangered Indigenous language of Aotearoa/New Zealand, *te reo Māori*. In contrast, reviving the associated cultural knowledge has been somewhat stymied for three key reasons: the dwindling number of elders with the knowledge, the tension associated with transposing traditional tribal knowledge to contemporary learning environments and resistance on the part of state agencies to acknowledging Indigenous knowledge. After 100 years of cultural and linguistic assimilation, reviving cultural knowledge is a big challenge for marginalised groups. Fortunately, aspects of both cultural and mathematical knowledge remain embedded in highly valued artefacts such as the meeting house, and are thus able to be reconnected in the contemporary Indigenous mathematics classroom. However, there is a need to better understand how the cultural significance can be connected to mathematical understandings in a way that gives value to both.

Keywords Ethnomathematics · Cultural & mathematical symmetry · Endangered indigenous languages · Indigenous language schooling · Mathematics classrooms

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10.1 Background to Māori-Medium Schooling

In this chapter, we explore the ethnomathematics connected to the symmetry found in a Māori meeting house called Rauru, relocated from New Zealand to Hamburg in Germany more than 100 years ago, and discuss the implications for the use of cultural artefacts in mathematics. Though a traditional meeting house from that period, much of its symmetrical nature is *reflected* in contemporary meeting houses, making it possible to transfer traditional understanding from this investigation to the more contemporary houses located throughout New Zealand and into mathematics classrooms.

This exploration is part of a wider Indigenous mathematics education project located in Aotearoa/New Zealand which responds to the challenge of reconnecting Indigenous knowledge to formal schooling. Such investigations are important because, although the Indigenous language of Aotearoa/New Zealand is now used successfully in Māori-medium schooling as part of an ongoing revitalisation project, much less work has been done on overcoming the challenges associated with revitalising Māori knowledge connected to mathematical ideas. One issue is to determine how to value the cultural and mathematical knowledge in contemporary settings such as schools, especially when these are isolated from traditional contexts, while simultaneously recognising that culture is not static but changes to meet contemporary challenges.

For Māori, the issue of access to Indigenous knowledge, how the knowledge is transmitted and where the knowledge is learnt and by whom was disrupted by colonisation in the nineteenth century. When the first missionaries and settlers arrived in Aotearoa/New Zealand, Māori had a robust system for educating their children in relevant and appropriate cultural contexts to ensure the survival of their communities (Riini and Riini 1993). After 1840, with the arrival of more and more European settlers and the establishment of the British colony, European forms of government were imposed alongside missionary schooling.

The hegemonic function of the missionary schools was to provide a formalised context to assimilate Māori communities into European beliefs, attitudes and practices, with the intent to “civilise” the Māori population (Simon 1998). The goal of assimilation was maintained by successive governments and their agencies over the next 100 years, resulting in a range of educational policies, both overt (English-language-only schooling policy) and covert (English-language-only workplaces), to privilege English as the sole language of education.

Consequently, mathematics was taught solely in the medium of English and was based exclusively on Western mathematical practices. For Māori students to progress through the education system to higher education, they had to achieve a variety of benchmarks (matriculation) at particular ages, such as transitioning from primary school to secondary, and then from junior secondary to senior secondary school in mathematics. For many native speakers of the Māori language, learning Western knowledge in an additional language was a challenge that they could not overcome and they exited the schooling system at a much earlier age than their European peers, generally into menial work with low pay (Simon 1998).

Bishop (1990) used the expression *cultural imperialism* in describing how "western mathematics' [has been] one of the most powerful weapons in the imposition of western culture" (p. 51). For colonised and marginalised Indigenous groups such as Māori, this view of mathematics and mathematics education resonates. Nevertheless, it may be the case that if schooling in Aotearoa/New Zealand had been allowed to continue to develop in the Indigenous language, from the colonial era into modern times, then some form of mathematics, related to what is currently taught in schools, would have been present.

This is because, from the Māori perspective, obtaining European knowledge, in particular, the knowledge associated with technology and trade, could enhance their traditional ways of life (Spolsky 2005). It may also have been the case that multiple, hybrid forms of mathematics would have been present, depending on the needs of individual communities or *iwi*[1] (tribe). Lamentably, for over 100 years Māori were denied the opportunity to incrementally develop subjects such as mathematics in their Indigenous language based on their cultural perspectives for schooling and higher education.

The change in the status of *te reo Māori* (the Māori language) to a low-status language in Aotearoa/New Zealand, including through its exclusion from use in schools, contributed to the language shift to English in the Māori community, to such an extent that by the 1970s *te reo Māori* was considered an endangered language (Spolsky 2005). It was against this background of rapid and significant language loss that the Māori community initiated Māori-medium education, in particular, *kura kaupapa Māori* schools such as Te Koutu (Meaney et al. 2012).

Initially, *kura kaupapa Māori*, a grassroots initiative, were developed from outside the state system, not only to revitalise *te reo Māori* but also as a resistance movement against the assimilationist nature of New Zealand European schooling (Penetito 2010). Along with language revitalisation, cultural knowledge revitalisation was also an aim for *kura kaupapa Māori* from the early days of its development (Smith 2004). However, as we discuss later, the revitalisation of mathematical practices embedded in cultural knowledge has somewhat languished in comparison with language revitalisation.

By the 1990s, *kura kaupapa Māori* agreed to become state funded in order to minimise the financial drain on the community, which was often manifested in, among other things, students being located in sub-standard dwellings for their schools. However, becoming state funded proved to be a double-edged sword, in that *kura* were required to implement state-mandated curricula, such as *pāngarau* (mathematics) and assessment practices developed from essentially Eurocentric interests (McMurchy-Pilkington and Trinick 2008). Furthermore, the Ministry of

[1]Māori terms are italicised with the English translations following in brackets for their first mention.

Education insisted that the structure of the first Māori-medium mathematics curriculum "mirror" the hegemonic English-medium version (McMurchy-Pilkington and Trinick 2008).

The old colonial hierarchies of European versus non-European remain in place. A number of studies show how imperial power is still exercised well after colonialism in an interconnected matrix of power that includes hierarchies of political, epistemic, economic, spiritual, linguistic and racial forms of domination where the racial/ethnic hierarchy of the European continues to position Indigenous knowledge as the *other* or inferior knowledge (Grosfoguel 2002).

As a consequence of these lingering Eurocentric interests, a major opportunity was denied to the Māori-medium schooling community to interrogate the place of traditional mathematics practices in a contemporary mathematics curriculum. At this time, there was still a pool of native speakers with the relevant knowledge to participate in and lead these discussions. However, these restrictions in curricula development have eased over time, as a response to changes in the prevailing discourse led by Māori campaigning for a greater say in the education of Māori children. Albeit slowly, such changes have been integrated into government policy about enabling Māori to live as Māori in contemporary society (McMurchy-Pilkington et al. 2013).

While providing considerable state support to elaborate the Māori language in a systemised way (McMurchy-Pilkington et al. 2013), thus enabling the teaching of mathematics in the medium of Māori to senior secondary school levels, the goal of supporting Māori to live as Māori has been much more challenging in terms of revitalising traditional knowledge and culture. Opportunities to formally advance traditional Māori cultural knowledge or alternative ways of thinking about mathematics have been lost. Whereas support for developing Māori language could easily be connected to improving students' mathematical achievement in assessments, something that successive governments have been keen to promote, there is still a belief held by many in positions of power in New Zealand that promoting non-Western knowledge is not in the interest of the state, particularly economic interests.

As well, as time has gone on, the access to native speakers who have the relevant knowledge for cultural revival has changed. The broad pool of elders who provided significant input into language revitalisation in the 1980s is no longer with us (McMurchy-Pilkington et al. 2013). Thus, the younger generation of speakers, often L2 learners who have been attempting to revitalise Māori knowledge have had to defer to the written historical record. However, identifying and understanding traditional practices via the written record have complications. Paradoxically, preserving the *authenticity* of traditional knowledge has often resulted in cultural knowledge being seen as unchanging and unchangeable.

Despite these challenges, our contention is that revitalisation and maintenance of the language must be considered insufficient unless cultural knowledge is also revitalised and maintained. Cultural knowledge and language loss as well as their revitalisation are human rights issues, connected to issues of power relations around who gets to determine what should be lost or saved (May 2005). The loss of a language and culture reflects the exercise of power by the dominant over the disenfranchised, and is concretely experienced “in the concomitant destruction of intimacy, family and community” (Fishman 1991, p. 4). However, in our view, revitalisation cannot be achieved if both language and culture are revered as fossilised, untouchable museum pieces, rather than aspects of Māori life that have changed and will continue to change to meet new circumstances.

10.2 The Relationship Between Culture, Language and Mathematics

The relationship between language and culture is deeply rooted. Languages are the repositories of cultural knowledge about the world, built up over many thousands of years of observations and experience, and it is argued that this knowledge is of benefit to all humankind (Chrisp 2005; Hale 1992). Consequently, language loss can be viewed as an erosion or extinction of ideas, of ways of knowing and ways of talking about the world, and is a loss, not only for the community of speakers itself, but for human knowledge generally (Harrison 2007).

Fishman (1991) noted that, traditionally, the primary argument for language maintenance in sociolinguistic work is that culture and language “stand for each other” (p. 22). It is argued that languages are a fundamental part of a people’s culture (Lemke 1990). They relate to local customs, beliefs, rituals and the whole display of personal behaviours (Crystal 2003). Fishman (1991) also presented the idea that most of the culture is in the language and is expressed in the language. He further added, “take language away from the culture, and the culture loses its literature, its songs, its wisdom, ways of expressing kinships relations and so on” (Fishman 1991, p. 72). Crystal (2003) linked language to the issue of identity: “if we want to make sense of a community’s identity, we need to look at its language” (p. 39). Therefore, when a community loses its language, it often loses a great deal of its cultural identity.

As noted, while there have been significant gains in addressing Māori language loss, the same cannot be said about reviving Indigenous knowledge. Nationally and internationally, incorporating cultural elements connected to mathematics education or mathematics is often met with strong resistance (Barton 2008; Ernest 1991), particularly from those who view mathematical thought as culture free (see discussions of this in Bishop 1994; Gerdes 1988).

This was certainly the approach taken by European educators to justify the exclusion of Māori knowledge and culture from the classroom for over 100 years, Western mathematics is universal, Indigenous particular to the group only. As Ernest (1991) pointed out, traditionally in Western mathematics philosophy based on hegemonic European paradigms, mathematical knowledge has been understood as universal and absolute, with the structure and objects of mathematics existing outside of human invention. A number of mathematicians, such as Thomas (1996), strongly argued that the contextualising of mathematics, such as is the case of ethnomathematics, needed to be resisted so that it did not become a watered-down version of mathematics in regard to what it should be considered to be and to be able to do.

In contrast, a number of scholars, including Bishop (1988), have long argued that mathematics is a cultural product arising from participation in various activities such as locating, designing, measuring and so on. For example, concepts such as rotation are often considered culture free. Yet, when examining this concept in Western mathematics, rotation is always considered to happen in a clockwise direction, unless stated otherwise. This suggests that a convention has developed over time within a societal group and thus the cultural history of mathematics can be recognised. When ideas are decontextualised and abstracted, understandings about these activities can be applied in a range of situations and so can be considered universal (Bishop 1988). However, the cultural connections still need to be recognised.

As a result, ethnomathematics has evolved since the 1980s to express the relationship between mathematics and culture (D'Ambrosio 1999). Ethnomathematics research examines a diverse range of ideas, including numeric traditions and patterns, as well as education policy and pedagogy in mathematics education. "One of the goals of ethnomathematics is to contribute both to the understanding of culture and the understanding of mathematics, and mainly to lead to an appreciation of the connections between the two" (D'Ambrosio 1999, p. 146).

Nevertheless, concerns have been raised about programmes that only consider the cultural nature of mathematics and the mathematics in cultural artefacts. For example, several authors have questioned whether ethnomathematics challenges the colonial structures imposed by the cultural imperialism of mathematics, because of its reliance on a comparison with Western mathematics (Meaney 2002). Pais (2011) suggested that although learners may engage in a range of activities, it is not until these activities are recognised as mathematics that they *become* mathematics and thus come to be considered valuable. Labelling traditional activities as mathematics runs the risk that they will be seen as having no intrinsic value in their own right, except as potentially Indigenous examples of Western knowledge (Roberts 1997).

Contributing to this process, ethnomathematical practices tend to be described in the mathematics register of the language of instruction and/or the language of the researcher rather than the language or dialect of the cultural activity. While it is important to make research accessible and contestable through describing it in international languages such as English, as Stillman and Balatti (2000) warned, this process potentially "divorces the cultural practices from their context and trivialises and fragments them from their real meaning in context" (p. 325).

If ethnomathematics is to support the decolonising of cultural knowledge, then there is a need to recognise that cultural considerations are as important as mathematical ones. For this to happen there is a need to define culture. In his seminal book, Geertz (1975) stated:

> Culture is best seen not as complexes of concrete behaviour patterns—customs, usages, traditions, habit clusters—as has, by and large, been the case up till now, but as a set of control mechanisms—plans, recipes, rules, instructions (what computer engineers call "programs")—for the governing of behaviour (p. 44).

If this is the case, then there is a need to make students aware that in learning about ethnomathematics, they are engaging in learning and responding to mathematics as well as how to learn and respond to the traditional understandings embedded within the cultural activity. This includes understanding the implications in regard to the language and culture, such as that a cultural practice or activity can change over time to meet contextual challenges.

This chapter continues two of the trends within ethnomathematics research—the investigation of mathematics in a non-Western culture, namely Māori (Gerdes 1986; Zaslavsky 1979), and the political and pedagogical trend challenging the colonial structures that imposed and maintained Eurocentric ideas and values (Bishop 1990; D'Ambrosio 1985). In addition, this chapter explores how ethnomathematics can be incorporated into the curriculum and simultaneously used to revitalise Indigenous cultural knowledge, without revering this knowledge as a museum artefact, frozen in time, and without denying the usefulness of Western mathematics. Our aim is not to position one knowledge as superior or inferior in some way, but to draw on cultural knowledge(s) that best support(s) the aspirations of children and families participating in Māori-medium education.

This investigation builds on our previous work in this area. We have noted for some time that Indigenous families are likely to have valuable insights into cultural practices that could be incorporated into mathematics lessons (Meaney and Fairhall 2003). Previously, we have described activities that Uenuku has used in his school, such as the mathematics activities in the division of land among descendants (Meaney et al. 2008, 2012) and traditional understandings about location and direction (Trinick et al. 2015, 2016).

In these papers, we emphasised how mathematics added value to the activity, rather than that the activity was valuable only because of the mathematics connected to it. Discussing the symmetry in meeting houses extends this research further in that we consider in greater detail how cultural knowledge can be revitalised in appropriate ways by connecting it to mathematics.

10.3 Symmetry in Traditional Meeting Houses

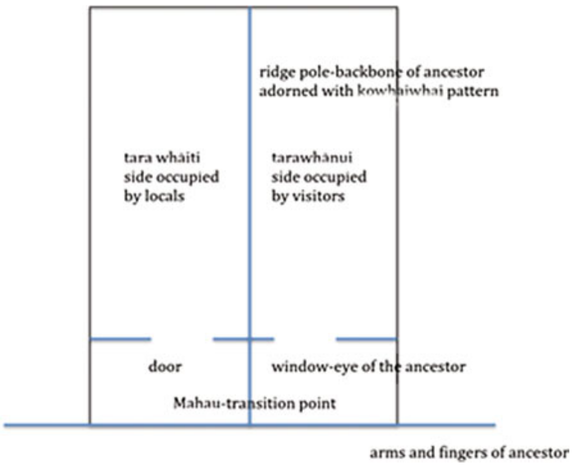
Wharenui (meeting houses) are important components of the *marae* (collection of buildings and sacred grounds) where many rituals and ceremonies take place (Hāwera and Taylor 2014). Nowadays, the term *marae* evokes two related meanings. In the first place, *marae* is used to denote an open space, a clearing or plaza in front of a meeting house, reserved and used for Māori assembly, particularly ceremonies of welcome. In the second place, the concept of *marae* is used in the broader sense for the combination of the *marae* proper, the courtyard and a set of communal buildings which normally include a meeting house, a dining hall and so on. As Selby (2009) wrote, “The marae is also a powerful symbol of place, of home, of belonging, of tradition and provides a link between today, yesteryear and the future” (p. 7).

Wharenui and *marae* are seen as “going together” in more than one way (Metge 1976, p. 230). The complementary relationship between *marae* and *wharenui* is often expressed by analogy with the gods of war and peace. Traditionally, the *marae* was the area of *Tū-matauenga*, the god and father of war, whereas the *wharenui* was associated with *Rongo-ma-tane*, the ancestor of the *kūmara* (sweet potato) and the god of all other cultivated food as well as the god of peace.

A *wharenui* is usually the dominant feature of any *marae* complex. *Wharenui* are generally named after an ancestor, of either gender of a particular group, and their structure frequently represents the body of an important ancestor, often the eponymous ancestor (Fig. 10.1). *Wharenui* are predominately rectangular, with a gabled roof and a front veranda, often, but certainly not always, marked by embellishments of carving, curvilinear rafter patterns (*kōwhaiwhai*) painted in black, red and white with lattice-work panels (*tukutuku*) on the wall. Houses range in length from approximately 12 or 13 m to nearly 30 m.

In many tribal areas, the rituals of engagement with other visiting groups, tribes and so on, often take place on the front veranda or just in front of it. The *tāhuhu* (ridge beam) represents the backbone, the *heke* (rafters) the ribs and the *maihi* (barge boards) the arms. The front window is seen as the *matapihi* (eye), and the interior of the meeting house is the *poho* (chest) of the ancestor (Fig. 10.1 provides an outline of the inside of a *wharenui*). Inside, the meeting house is divided into two separate yet complementary domains: the *tarawhānui* (the *big* side) and the *tarawhāiti* (the *little* side). The *tarawhāiti* is generally reserved for the home people and *tarawhānui* for visitors (Fig. 10.1). Within the spatial orientation of meeting houses, special places of honour are allocated to distinguished guests or family

Fig. 10.1 Symbolic structure of meeting house. *Source* Personal file



elders. Often, this is by the front window. Both the size and the degree of ornamentation of a *wharenui* say something about the *mana* (prestige) of its owner group.

Wharenui are bilaterally symmetric and because they often represent ancestors they have reflection in the sagittal plane, which divides the body of the house (thus ancestor) vertically into left and right halves with the exception of the front door and window (Fig. 10.1). Bilateral symmetry, the one most commonly used in *wharenui* designs, is where an axis of symmetry divides a shape into equal halves (Booker et al. 2010). As is discussed in the following sections, *wharenui* are highly decorated with symmetrical patterns in different positions, used in a range of artefacts. One of the challenges of working with *wharenui* is that the parts of the *wharenui* where particular symmetrical patterns are located need to be the focus of mathematical discussions; at the same time, they should not be disconnected from the culture embedded within the *wharenui*.

Wharenui, built from about the middle of the nineteenth century, were redesigned from earlier versions, so that among other things they could hold the political community meetings for discussing colonisation of Māori land (Jackson 1972; McCarthy 2005). From a cultural perspective, the *wharenui* and the various symmetrical artefacts that adorn it generally represent a family's links to an ancestor (Jackson 1972; Salmond 1978).

Ironically, both the state agency responsible for schooling and schools themselves, even with large Māori populations, resisted the erection of *wharenui* on their premises for many decades. As a result of strong lobbying from Māori communities and Māori teachers, policy was eventually changed so that such decisions defaulted to schools if they were prepared to pay for them. Most Māori-medium schools, including Te Koutu, where Uenuku is principal, have meeting houses located on their premises. Therefore, students may be familiar with them as a cultural construct, although not necessarily as a mathematical one.

Many mathematics educators highlight the importance of teaching symmetry as it is embedded in reality, and this is considered to help students connect geometry with their real-life experiences (Leikin et al. 2000). Potentially, symmetry connects to both cultural and mathematical aspects, and this was the reason why *wharenui* were chosen as the focus for this chapter.

However, the use of symmetrical designs found in *wharenui* as contexts for teaching school mathematics has had a somewhat tumultuous history in Aotearoa/New Zealand, as have other concepts decontextualised from their Māori contexts (Anderson et al. 2005). In the 1980s, with the first endeavours and good intentions to make connections to Māori culture in mathematics, some of the symmetrical patterns within the *wharenui* found in the community rather than on school grounds were identified and used as examples of cultural mathematics (Knight 1984a, b; MacKenzie 1989). However, by the 1990s, the sole focus on patterns as mathematics objects was disparaged as insufficient to count as ethnomathematics (Barton 1993).

Barton (1993) stated, “in our search for cultural mathematics, it is not enough to find examples of mathematics in use—we need to study systems which describe patterns and make powerful generalisations that can be used in more than one practical application” (p. 60). Some of the earlier dissatisfaction with using the symmetry found in *wharenui* came from the abstraction, which enabled students in English-medium schools to gain mathematical understandings without visiting *wharenui* or needing any knowledge of the cultural significance of those patterns. Some felt that in this way an iconic cultural focus had been relegated to a desultory mathematical activity. In recent times, the symmetrical nature of some of the designs found in *wharenui* are again being incorporated into Māori-medium mathematics lessons, but this time in connection with cultural understandings (Manuel et al. 2015).

In the next section, we discuss the symmetrical and cultural knowledge connected to one *wharenui* and suggest some strategies for ensuring that it would add value to Māori students’ understanding of their mathematics and culture.

10.4 The Wharenui (Meeting House)—Rauru

We draw on examples of symmetry in Rauru, a traditional meeting house built around 1900 and now located in the Hamburgisches Museum für Völkerkunde, Hamburg, Germany, where the International Congress of Mathematics Education (ICME 13) was held (information about it can be found at http://www.voelkerkundemuseum.com/247-1-Maori-Haus.html). A number of ancient *wharenui* are also found within museums within Aotearoa/New Zealand. In discussing the placement of *wharenui* within museums in Aotearoa/New Zealand, McCarthy (2005) discussed the relationship between the impact of a building (the *wharenui*) within a building (the museum) as a movement from one culture, Māori, into another, Western/Pākehā:

> The exhibited *wharenui* (Hotunui, Te Hau ki Turanga, or Mataatua) bring their own contextual and interior space into the museum. These spatialities test the conceptual perimeters of the museum as a building which determines relationships between inside and outside. These *wharenui* also exist as venerated artefacts which have been translated into and consumed as museum objects (p. 80).

Wharenui encased within museums have an impact on visitors which is different to their viewing of the smaller artefacts housed in isolated, glass cases. They also often have histories that are different to those of *wharenui* still in use on ancestral land. This is the case for Rauru, the meeting house, which is named after Rauru the son of Kuraimonoa and her husband Toi-te-huatahi (Fig. 10.2). Rauru is synonymous with the art of carving in Te Arawa, a Māori tribal group (Thomas et al. 2009). Te Koutu, the school of which Uenuku Fairhall is principal, is located on Te Arawa traditional land, and most staff and students belong to this tribe. As is

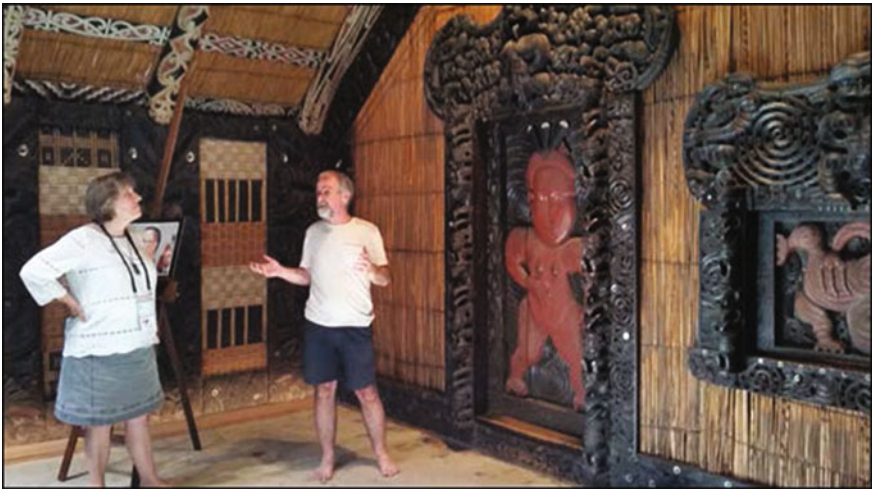


Fig. 10.2 Two of the authors at Rauru in Hamburgisches Museum für Völkerkunde. *Source* Personal file

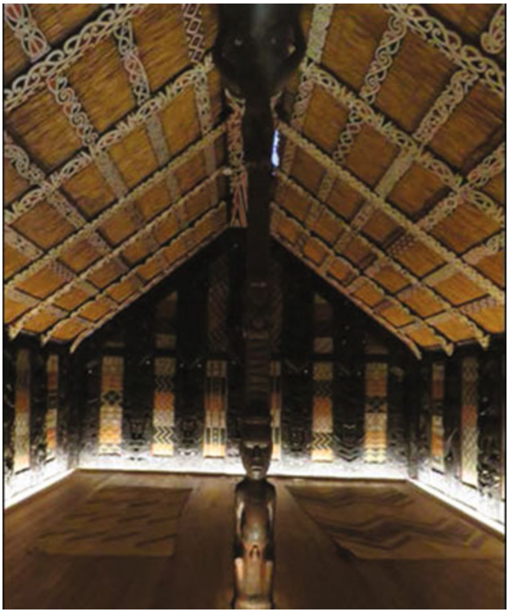
discussed later, members of Te Arawa retain a strong connection to Rauru, even though it is situated on the other side of the world, in Germany.

The carvings, *kōwhaiwhai*, painted along the ridge poles and *tukutuku* (woven panels) represent Te Arawa ancestors, heroes and gods, including Tāne-Te-Pupuke, Kataore, Hinenui-Te-Pō and Māui (Thomas et al. 2009). Māui is represented in the narrative of fishing up the North Island of New Zealand (Fig. 10.7). *Kōwhaiwhai* refers to the traditional red, white and black coloured patterns most often found on the ridgepole or rafters in meeting houses such as Rauru.

Tukutuku panels sit between the posts (Figs. 10.2, 10.4 and 10.5) and are an integral part of the story of the meeting house. While the *pou* (posts) are carved by men, the *tukutuku* panels are woven by women (Jackson 1972). As Jackson (1972) stated, although there are distinctions of this kind present in the artefacts within a *wharenui*, "the house presents time past and present in a totality and a unity and it also effects a unity, through its symbolic design, among human events" (p. 64).

As noted earlier, the shape of meeting houses such as Rauru is an example of bilateral reflection (Witehira 2013). When we look at the meeting house front on, the figures and designs tend to be reflected on either side of the structure with a vertical axis of symmetry in the form of the *pou* (Fig. 10.3). Culturally, this focus on symmetry mirrors the pervasive duality in Māori culture as seen in origin stories and social exchanges (Hanson 1983). For example, the Rauru story is associated with the prototypical duality of celestial and terrestrial beings. Bilateral symmetry is the most common type of symmetry found in nature. An understanding of symmetry would also have had a functional application when building Māori meeting houses.

Fig. 10.3 The inside of Rauru, showing its symmetrical nature. *Source* Personal file



Although Rauru is a *traditional* meeting house, the carvers were experimenting with new techniques and designs while simultaneously preserving traditional stories (Thomas et al. 2009). The original carver, Tene Waitere, was one of the most renowned carvers of his time, producing amazing stylised figures, such as the one in Fig. 10.4.

However, family illness caused Tene Waitere to withdraw from building Rauru, before he[2] was completed. The carvers, who came in to finish the carving, Anaha te Rahui and Neke Kapua, instead of continuing the style of Tene Waitere, challenged the design parameters of their time, just as modern mathematical exploration challenges traditional mathematics. As can be seen in Fig. 10.7, their carvings are more realistic. It is interesting to note that since the time of Rauru's initial construction, many *wharenui* now incorporate realistic carvings which are considered just as traditional as those of Tene Waitere.

The possibility for experimentation was probably supported by the fact that Rauru was commissioned, not to be placed on a *marae*, but as a tourist attraction, to be situated near Whakarewarewa, the village near the main geothermal visitor site in Rotorua (Thomas et al. 2009).

[2]Rauru, like all *wharenui*, was given the same personal pronoun as the ancestor whose name he shares.

Fig. 10.4 One of the traditional stylised carvings of Tene Waitere. *Source* Personal file

Fig. 10.5 *Pūhoro*, glide reflection. *Source* Personal file

Fig. 10.6 *Pātiki*, vertical and horizontal translation. *Source* Personal file

10.4.1 Kōwhaiwhai Patterns

Kōwhaiwhai patterns express important cultural values such as unity, genealogy and family interconnectedness (Witehira 2013). The patterns painted on the ridgepole represent the tribal genealogy, power and spirits of the ancestors (Fig. 10.3). The patterns differ from tribe to tribe, many having *kōwhaiwhai* unique to their particular areas, defining the environment where the tribe exists. One of the patterns in Rauru is *pūhoro* (Fig. 10.5), which represents power and speed, and another is *pātiki* (flounder) (Fig. 10.6), which symbolises hospitality.

Kōwhaiwhai patterns involve combinations of transformations including reflection, rotation, translation (Fig. 10.6), enlargement, glide reflection (Fig. 10.5) and shears. Knight (1984a) identified seven different groups connected to the symmetry used in the freeze patterns of *kōwhaiwhai* and stated that these were present in traditional *wharenui* throughout Aotearoa/New Zealand:

1. Translational symmetry only;
2. Glide reflectional symmetry (together, of course, with translational symmetry);
3. Vertical reflectional symmetry;
4. Half-turn symmetry;
5. Half-turn and vertical symmetry (these two together ensure that there is glide reflectional symmetry too);
6. Horizontal reflectional symmetry (this, together with the translational symmetry, means that there is also glide reflectional symmetry); and
7. Horizontal and vertical reflectional symmetry (these ensure that there is also half-turn and glide reflectional symmetry) (p. 37).

In Figs. 10.2 and 10.3, it is possible to see translation, glide reflection, vertical reflection and half-turn with vertical reflection in the *kōwhaiwhai* in the rafters. The furthest to the right rafter in Fig. 10.2, next to the wall, appears to show a shear. A shear involves stretching a shape, in this case *pūhoro*, and distorting it on an angle (MacKenzie 1989).

Meaney et al. (2012) include several examples of patterns related to *kōwhaiwhai*, but they mostly examine them from a language and mathematical perspective. More recently, Manuel et al. (2015) took a class of Māori children to their local *wharenui* to investigate the symmetry in the *kōwhaiwhai* patterns. Before they began the mathematical investigation, an elder, *kaumatua*, described the cultural meaning behind the patterns. According to the researchers, "these children learned how tribal stories, reo Māori and transformation geometry were all connected and could be viewed in an integrated, meaningful way" (Manuel et al. 2015, p. 141).

10.4.2 Tukutuku Patterns

In contrast to the spirals, swirls and curved lines of the carvings and *kōwhaiwhai* paintwork, straight lines form the basis of *tukutuku* panels (Averill et al. 2009). The traditional *tukutuku* is a lattice-like frame made of vertical and horizontal rods, and flexible material is threaded through the rods to form the patterns and designs (Figs. 10.2, 10.3, 10.4 and 10.7).

They provide a visual representation of legends, in which *tukutuku*, like the *kōwhaiwhai* designs, are representational rather than figurative (Witehira 2013). The design of the *tukutuku* could represent an object or operation in the physical world as well as from nature (*tukutuku* on the left of Fig. 10.7 represent a fern frond and on the right side represent a fish).

Tukutuku designs consist of patterns which repeat and translate (see left-hand panel in Fig. 10.7), or which have reflection or rotational symmetry. Reflectional symmetry is seen in the top part of the left-hand panel in Fig. 10.2 as well as in the

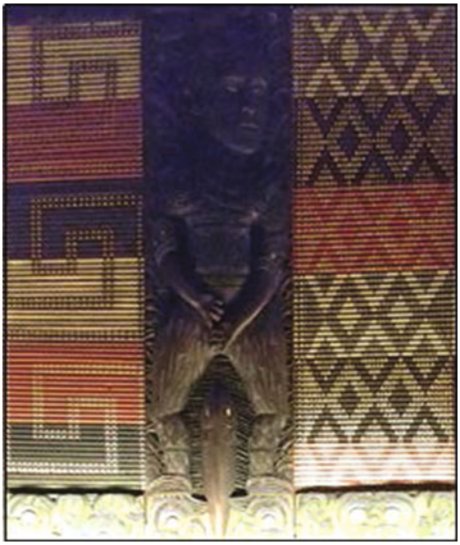


Fig. 10.7 Māui flanked by *tukutuku* panels in Rauru meeting house. *Source* Personal file

right-hand panel of Fig. 10.7. The left-hand panel of Fig. 10.7 shows rotational symmetry. Whereas *kōwhaiwhai* patterns only have translational symmetry in one direction, *tukutuku* patterns are two-directional and so are known as wallpaper patterns (Knight 1984b).

Consequently, "they may have other symmetries in addition to their translational symmetry" (Knight 1984b, p. 80). Knight (1984b) identified 10 different examples of patterns based on different combinations of transformational geometry approaches in Māori art, which had been documented at the beginning of the twentieth century by Augustus Hamilton (1901).

Averill et al. (2009) described how they used *tukutuku* with preservice teachers both as a metaphor for the different mathematical topic covered in the course and as a practical activity whose final product was described in regard to the mathematics incorporated into it. The mathematics identified in the students' completed *tukutuku* included symmetry, although without specific descriptions of the types of symmetry involved (Anderson et al. 2005).

Using *tukutuku* as a metaphor for the whole course and engaging in the practical activity of making one seemed to make the preservice teachers understand better the responsibility and possibilities connected to incorporating Māori cultural activities into mathematics lessons:

> Reasons given by students for planning to use cultural activities such as tukutuku panel-making in their own teaching included cultural, pedagogical, and motivational aspects. They felt such activities would assist them to teach in a culturally responsive way (Averill et al. 2009, p. 171).

Therefore, it seems that if cultural understanding is connected to mathematical understanding, activities such as *kōwhaiwhai* and *tukutuku* could widen children's horizons in being able to transition (Meaney and Lange 2013) between the mathematics and the cultural learning. This is in contrast to focusing solely on mathematical understandings which might result in children restricting the value that they consider the cultural activity to have in its own right.

10.5 Cultural Symmetry in the Mathematics Classrooms

In Māori-medium contexts, when teaching symmetry, such as that found in *wharenui*, it is necessary to ensure that cultural knowledge is valued. If this does not occur, then the cultural context for the "real" mathematics learning is tokenistic and unlikely to be considered valuable by students. Nevertheless, just as Rauru should not be seen as referential to the mathematics, he should not be only considered as being reverential to the culture. Rauru shows that what it means to be a *wharenui* and how that meaning is expressed not only draws on traditional understandings, but is refigured as times and contexts change. Identifying mathematical understandings about symmetry in the different features of Rauru, like the incorporation of new carving techniques, can also be considered a renewal of the meanings attached to *wharenui*.

Rather than detracting from the cultural meanings already embedded within the designs, mathematical understandings can potentially provide another layer to the existing meanings. In this way, the mathematical understandings deepen and enrich the cultural meanings already present. Similarly, as Rauru is not simply a museum exhibit, locked behind glass doors, to be looked at with reverence but not to be touched, the existing cultural meanings can be enriched.

Members of Te Awara continue to value Rauru for his connections to the past, but celebrate his continued existence in the present by allowing new meanings to be developed. However, to support an enrichment rather than a colonisation of the existing cultural understandings, there is a need to engage in cultural symmetry in a respectful manner.

Consequently, we suggest a three-step approach. This three-step approach allows for mathematical understandings to be reflected into the cultural meanings already associated with cultural activities or products, such as *wharenui*, in a holistic manner. In this way, we anticipate that the valuing of the mathematical meanings will not colonise or distract from other understandings connected to cultural processes and artefacts such as *wharenui*.

The first step is for the cultural knowledge to be at the forefront of any learning, thus acknowledging the cultural dimension of mathematics. For example, if Rauru is to be discussed in mathematics classrooms, then it is important that the stories and cultural knowledge that are represented within the *wharenui* are discussed first and foremost. Only by knowing about the ancestors represented in the house and the legends to which they are connected can the cultural knowledge be valued. The use of *te reo Māori* in this discussion is important.

As Fishman (1991) argued, culture is in the language and is expressed in the language. He further added, "take language away from the culture, and the culture loses its literature, its songs, its wisdom, ways of expressing kinships relations and so on" (Fishman 1991, p. 72). It would also mean that the cultural nuances connected to symmetrical designs of *kōwhaiwhai* and *tukutuku* would be lost if they were discussed in the mathematics register of English only.

The second step is to identify the designs which have been used to create the different artefacts such as the *kōwhaiwhai* and *tukutuku* designs and what they symbolise. The designs used in Rauru are highly valued for their artistic qualities (Thomas et al. 2009) because although they are well-known designs, they were used in innovative ways, which makes them unique. Identification of the different design elements allows students to recognise their use in other Māori designs. To do this, students need to participate in the production of the patterns, not just see them as static artefacts that can be dissected for the knowledge they contain.

The most appropriate way to do this is for the students to be involved in the production or reconstruction of artefacts in an actual *wharenui*. However, it this is not possible, and then reproducing existing patterns (Fig. 10.8) or producing new patterns can be done with pencil and paper. Producing patterns provides possibilities for the students to learn some architectural terms as well as mathematics terms in order to discuss what they are doing and seeing and how they relate to the *wharenui* as a whole. The third and final stage is to discuss the designs in relationship to the symmetrical principles in order to understand how a pattern is repeated to produce the meanings connected back to the stories.

Recognition of the designs in the parts needs to be done in a constant interaction with recognition of the design of the whole *wharenui*. Discussions which include considerations of how meanings are represented in other *wharenui* and other cultural artefacts also allow for an understanding about how cultural meanings can change across both space and time. In this way, Māori culture is recognised as a living dynamic culture, not as a revered museum piece. For this to occur, the

Fig. 10.8 Student example of work explaining the symmetrical properties of kōwhaiwhai. *Source* Personal file

teaching of mathematics must add value to understanding the cultural knowledge embedded in the designs of the different artefacts, rather than detracting from that knowledge by purely focusing on the mathematics.

Cultural symmetry in mathematics classrooms is complex to achieve in that there are a number of different aspects that need to be considered simultaneously. Mathematical understandings are a form of cultural understandings but if they are merely presented as representative of Western mathematics, then the possibilities for using them to discuss Māori cultural artefacts and processes are likely to result in cultural imperialism: Māori culture is only considered valuable if mathematics can be connected to it.

Instead, giving equal balance to Māori cultural knowledge and mathematical cultural knowledge involves considering not just the language that is used, the mathematics register, for example, but also the purposes for employing cultural symmetry. As is the case with *wharenui*, adding value to learning needs to ensure that the learning is considered holistically and one small part does not become isolated from the rest.

10.6 Further Considerations

It is very convenient that *Rauru*, as the focus of this chapter, is presently located in Hamburg, where ICME 13 was held. Māori visiting Hamburg, from whence the *wharenui* originated, would consider it culturally unacceptable that the house be overlooked. It is as though *Rauru* were setting the agenda for the presentation, as much as that of such an important conference. Rauru the meeting house may be situated in Germany, but he is highly valued for the cultural knowledge he contains by members of Te Arawa tribe who travelled there in 2012 to celebrate his more than 100 years of being in Germany and the conservation of many of the features of this *wharenui*.

For the sake of brevity, we hope we are not contradicting ourselves by providing a very abbreviated narrative of *Rauru* the person. *Rauru* himself was human, the son of *Kuraimonoa* and her husband *Toi-te-huatahi.* However, a celestial being, Pūhaorangi, desired the mother and caused the infant Rauru to wet the sleeping mat he shared with his parents over several nights. Finally, his father left their house in disgust, whereupon Pūhaorangi descended from the sky, disguised himself as Toi-te-huatahi and entered the house to sleep with Kuraimonoa, who was unaware that it was not her husband who had returned.

Kuraimonoa conceived a child with Pūhaorangi, a son who was named Ohomairangi. The half-brothers' descendants would intermarry, giving rise to Te Arawa and many other tribes. And so the symmetry plays out, celestial/terrestrial, divine/human. Exploring the house, Rauru, could, and should be, much more than a desultory mathematical activity. It invites us to consider our place in *te ao tangata*, *the world of humans*, and *te ao tūroa*, *the world that is*: how we measure and make sense of our internal and external worlds. The discussion would continue well beyond the mathematics classroom but would also enrich what happens within it.

A final note is that Rauru's full name was Rauru-kī-tahi, *Rauru-of-the-single-utterance*. Now what could that utterance have been or possibly be?

References

Anderson, D., Averill, R., Easton, H., & Smith, D. (2005). Use of a cultural metaphor in pre-service mathematics teacher education. In P. Clarkson, A. Downton, D. Gronn, M. Horne, A. McDonough, R. Pierce, & A. Roche (Eds.), *Building connections: Theory, research and practice (Proceedings of the Annual Conference of the Mathematics Education Research Group of Australasia, held at RMIT, Melbourne, 7–9th July, 2005)* (Vol. 1, pp. 81–88). Melbourne, Australia: MERGA.

Averill, R., Anderson, D., Easton, H., Maro, P. T., Smith, D., & Hynds, A. (2009). Culturally responsive teaching of mathematics: Three models from linked studies. *Journal for Research in Mathematics Education, 40*(2), 157–186.

Barton, B. (1993). Ethnomathematics and its place in the classroom. In E. McKinley, P. Waiti, A. Begg, B. Bell, F. Biddulph, M. Carr, M. Carr, J. McChesney, & J. Young-Loveridge (Eds.), *SAMEpapers 1993* (pp. 47–65). Hamilton, New Zealand: Centre for Science and Mathematics Education Research, University of Waikato.

Barton, B. (2008). *The language of mathematics: telling mathematical tales*. New York, NY: Springer.

Bishop, A. J. (1988). *Mathematical enculturation: a cultural perspective on mathematics education*. Dordrecht, The Netherlands: Kluwer.

Bishop, A. J. (1990). Western mathematics: the secret weapon of cultural imperialism. *Race & Class, 32*(2), 51–65.

Bishop, A. J. (1994). Cultural conflicts in mathematics education: Developing a research agenda. *For the Learning of Mathematics, 14*(2), 15–18.

Booker, G., Bond, D., Sparrow, L., & Swan, P. (2010). *Teaching primary mathematics*. Sydney, Australia: Pearson.

Chrisp, S. (2005). Māori intergenerational language transmission. *International Journal of the Sociology of Language, 172,* 149–181.

Crystal, D. (2003). *Language death*. Cambridge, England: Cambridge University Press.

D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics, 5*(1), 44–48.

D'Ambrosio, U. (1999). Literacy, mathematics and technology: a trivium for today. *Mathematical Thinking and Learning, 1*(2), 131–153.

Ernest, P. (1991). *The philosophy of mathematics education*. London, England: Falmer Press.

Fishman, J. (1991). *Reversing language shift: Theoretical and empirical foundations of assistance to threatened languages*. Clevedon, England: Multilingual Matters.

Geertz, C. (1975). *The interpretation of cultures*. London, England: Hutchinson.

Gerdes, P. (1986). How to recognize hidden geometrical thinking? A contribution to the development of anthropological mathematics. *For the Learning of Mathematics, 6*(2), 10–17.

Gerdes, P. (1988). On culture, geometrical thinking and mathematics education. *Educational Studies in Mathematics, 19*(2), 137–162.

Grosfoguel, R. (2002). Colonial difference, geopolitics of knowledge and global coloniality in the modern/colonial capitalist world—system. *Review, 25*(3), 203–224.

Hale, K. (1992). On endangered languages and the safeguarding of diversity. *Language, 68*(1), 1–3.

Hamilton, A. (1901). *Maori art*. Wellington, New Zealand: New Zealand Institute.

Hanson, F. (1983). *Counterpoint in Māori culture*. London, England: Routledge & Paul.

Harrison, K. D. (2007). *When languages die: the extinction of the world's languages and the erosion of human knowledge*. Oxford, England: Oxford University Press.

Hāwera, N., & Taylor, M. (2014). Researcher-teacher collaboration in Māori medium education: Aspects of learning for a teacher and researchers in Aotearoa New Zealand when teaching mathematics. *AlterNative: An International Journal of Indigenous Peoples, 10*(2), 151–164.

Jackson, M. (1972). Aspects of symbolism and composition in Maori art. *Bijdragen tot de taal–, Land-en Volkenkunde* [Contributions to Linguistics, Land and Ethnology], *128*(1), 33–80.

Knight, G. H. (1984a). The geometry of Maori art-rafter patterns. *NZ Mathematics Magazine, 21*(2), 36–41.

Knight, G. (1984b). The geometry of Māori art—weaving patterns. *The New Zealand Mathematics Magazine, 21*(3), 80–87.

Leikin, R., Berman, A., & Zaslavsky, O. (2000). Learning through teaching: The case of symmetry. *Mathematics Education Research Journal, 12*(1), 18–36.

Lemke, J. (1990). *Talking science*. Norwood, NJ: Ablex.

MacKenzie, D. F. (1989). *Kōwhaiwhai: Geometry of Aotearoa*. Auckland, New Zealand: D. F. MacKenzie.

Manuel, H., Hāwera, N., & Taylor, M. (2015). Transformation geometry: Mate nekehanga, mate whakaata, mate hurihanga. In R. Averill (Ed.), *Mathematics and statistics in the middle years: evidence and practice* (pp. 131–145). Wellington, New Zealand: New Zealand Council of Educational Research.

May, S. (2005). Language rights: Moving the debate forward. *Journal of Sociolinguistics, 9*(3), 319–347.

McCarthy, C. (2005). Boundary arbitrations: Spatial complexities and tensions in recent New Zealand museum architecture. *New Zealand Sociology, 21*(1), 68–88.

McMurchy-Pilkington, C., & Trinick, T. (2008). Potential & possibilities. In V. Carpenter, J. Jesson, P. Roberts, & M. Stephenson (Eds.), *Ngā kaupapa here: Connections and contradictions in education* (pp. 133–144). Melbourne, Australia: Cengage Learning.

McMurchy-Pilkington, C., Trinick, T., & Meaney, T. (2013). Mathematics curriculum development and Indigenous language revitalisation: Contested spaces. *Mathematics Education Research Journal, 25*(3), 341–360.

Meaney, T. (2002). Symbiosis or cultural clash? Indigenous students learning mathematics. *Journal of Intercultural Studies, 23*(2), 167–187.

Meaney, T., & Fairhall, U. (2003). Tensions and possibilities: Indigenous parents doing mathematics education curriculum development. In L. Bragg, C. Campbell, G. Herbert, & J. Mousley (Eds.), *Mathematics Education Research: Innovation, networking, opportunities: Proceedings of the 26th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 507–514). Sydney, Australia: MERGA.

Meaney, T., Fairhall, U., & Trinick, T. (2008). The role of language in ethnomathematics. *Journal of Mathematics and Culture*, *3*(1). Retrieved from http://nasgem.rpi.edu/index.php?siteid=37&pageid=543.

Meaney, T., & Lange, T. (2013). Learners in transition between contexts. In K. Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, & F. Leung (Eds.), *Third international handbook of mathematics education* (pp. 169–202). New York, NY: Springer.

Meaney, T., Trinick, T., & Fairhall, U. (2012). *Collaborating to meet languages challenges in Indigenous mathematics classrooms*. Dordrecht, The Netherlands: Springer.

Metge, J. (1976). *The Maoris of New Zealand: Rautahi*. London, England: Routledge & Kegan Paul.

Pais, A. (2011). Criticism and contradictions of ethnomathematics. *Educational Studies in Mathematics, 76*(2), 209–230.

Penetito, W. (2010). *What's Māori about Māori education?*. Wellington, New Zealand: Victoria University Press.

Riini, M., & Riini, S. (1993). Historical perspectives of Māori and mathematics. In M. Ohia (Ed.), *Pāngarau: Māori mathematics and education* (pp. 16–20). Wellington, New Zealand: Ministry of Māori Development.

Roberts, T. (1997). Aboriginal maths: Can we use it in school? In N. Schott & H. Hollingworth (Eds.), Mathematics: Creating the future. *Proceedings of the 16th Biennial Conference of the Australian Association of Mathematics Teachers (AAMT)* (pp. 95–99). Adelaide, Australia: Australian Association of Mathematics Teachers.

Salmond, A. (1978). Te ao tawhito: a semantic approach to the traditional Maori cosmos. *The Journal of the Polynesian Society, 87*(1), 5–28.

Selby, R. (2009). Indigenous voices, indigenous symbols. In R. Selby (Ed.), *Indigenous voices, indigenous symbols* (pp. 4–9). Guovdageaidnu, Norway: Sàmi University College.

Simon, J. (1998). *Ngā kura Māori: The native schools system 1867–1969*. Auckland, New Zealand: Auckland University Press.

Smith, G. H. (2004). Mai i te maramatanga, ki te putanga mai o te tahuritanga: From conscientization to transformation. *Educational Perspectives, 37*(1), 46–52.

Spolsky, B. (2005). Māori lost and regained. In A. Bell, R. Harlow, & D. Starks (Eds.), *Languages of New Zealand* (pp. 67–85). Wellington, New Zealand: Victoria University Press.

Stillman, G., & Balatti, J. (2000). Contribution of ethnomathematics to mainstream mathematics classroom practices. In B. Atweh, H. Forgasz, & B. Nebres (Eds.), *Sociocultural research on mathematics education: An international perspective* (pp. 201–216). Mahwah, NJ: Lawrence Erlbaum.

Thomas, R. (1996). Proto-mathematics and/or real mathematics. *For the Learning of Mathematics, 16*(2), 11–18.

Thomas, N., Adams, M., Schuster, J., & Grant, L. (2009). *Rauru.* Dunedin, New Zealand: University of Otago Press.

Trinick, T., Meaney, T., & Fairhall, U. (2015). Reintroducing Māori ethnomathematical activities into the classroom: traditional Māori spatial orientation concepts. *Revista Latinoamericana de Etnomatemática, 8*(2), 415–431.

Trinick, T., Meaney, T., & Fairhall, U. (2016). The relationship between language, culture and ethnomathematics. *Journal of Mathematics and Culture, 10*(2), 175–191.

Witehira, J. (2013). *Tārai Kōrero Toi*. Doctoral thesis. Massey University, Palmerston North, New Zealand. Retrieved from http://mro.massey.ac.nz/handle/10179/5213

Zaslavsky, C. (1979). *Africa counts: number and pattern in African culture*. Brooklyn, NY: Lawrence Hill Books.