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ORIGINAL ARTICLE

Cultural horizons for mathematics

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Abstract As a result of a number of government reports, there have been numerous systemic changes in Indigenous education in Australia revolving around the importance of partnerships with the community. A forum with our local Dubbo community established the importance of working together and developed a model which placed the child in an ecological perspective that particularly noted the role of Elders and the place of the child in the family. However, there was also the issue of curriculum and mathematics education to be addressed. It was recognised that a colonised curriculum reduces the vision of what might be the potential for Indigenous mathematics education. This paper reports on the sharing that developed between our local community and some researchers and teachers from Sweden,

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Papua New Guinea and New Zealand. It has implications for recognising the impact of testing regimes, the teaching space, understanding the ways children learn, the curriculum, and teacher education. As a result of these discussions, a critical pedagogy that considers culture and place is presented as an ecocultural perspective on mathematics education. This perspective was seen as critical for the curriculum and learning experiences of Indigenous children.

Keywords Ethnomathematics · Indigenous mathematics education · Australia · Sami Sweden · Papua New Guinea

Introduction

Current western education practices stipulate a curriculum which is developed under government guidelines with varying degrees of input from stakeholders. The curriculum in practice may vary as a result of teacher knowledge, textbooks, availability of computer-based practice-and-test programs, and external testing regimes with high stakes for success. Usually test items are as close as possible to the curriculum intentions but restricted by the type of testing (usually paper-and-pencil) and marking. The universality of the testing fails to allow for geographic and cultural difference. Furthermore, the curriculum and emphasis on testing that has resulted from neo-liberal tendencies of consumerism and globalisation as western-isation is reducing the development of mathematical diversity (Atweh et al. 2007). The centralised curriculum prevents full potential in any system of mathematical reasoning for the student from a minority group, with a first language background different to the official school language, from a class or gender group that prevents full opportunities for learning particularly in a neo-colonial society.

Centralised curricula and testing fail to do justice to minority or non-western sociocultural groups who have been encultuated with their own concepts, systematic reasoning, and techniques involving some general principles of mathematics such as generalising patterns of relationships and variance (Johnston-Wilder and Mason 2005). The extent and context of the relationships varies because of the sociocultural situation but it is ignored, unknown, or untestable. The relationship might be about a physical position or it might indicate a whole set of societal relationships as found with the way houses are positioned in a village in the Trobriand Islands, Papua New Guinea (PNG) (Costigan 1995), or in Africa where self-similarity is evident (Eglash 2007). Similarly, the naming, valuing and positional representation of land connects to clan groups of the Yolngu, in the Northern Territory, Australia (Thornton and Watson-Verran 1996).

However, although the extraction of the relationship from the data or situated problem occurs in mathematical modeling, the extent to which the relationship should be divorced from the context is debatable. In terms of the sociocultural approach to mathematics, the debate is about how mathematics should be viewed, be learned and be used. It is a debate about values in education (Adler 2002; Atweh, et al. 2007; Barton 2008; Bishop 1988; Clarkson and Presmeg 2008; Frade and Falcão 2008; Valero and Zevenbergen 2004). We take the stance that the mathematics embedded in culture should be understood, maintained, valued and not lost. It should be strengthened through cooperative pedagogies that involve community and

schools (Verlot and Pinxten 2000) and place pedagogies that emphasise the use of space and relationships in that space to manage learning (Somerville 2010). Cultural mathematics enhances learning of mathematics in formal settings, and ensures a continuity rather than a dissonance between home and school learning (Presmeg 2007; Valsiner 2000).

Current school education in Australia is strongly influenced by western views of mathematics. However, Pinxten et al. (1983) argued that western mathematics can be viewed as one version of mathematics which should be incorporated into Indigenous mathematical understandings. For example, the dynamic approach in the Navajo worldview (USA) requires building blocks about space and geometry associated with (a) the essence of movement, the lack of recognition of static objects and a slice in time of the objects or actions, (b) the sense of volumeness/flatness, and (c) the notion of dimension, not necessarily as an orthogonal grid. Pinxten and his colleagues shared the approach that these basic concepts must be developed within the Navajo context before expanding to take in school mathematics (primarily linked to topology). Alternative systems in Aboriginal Australia could also require distinct starting blocks from which to encompass school mathematics.

Similar examples and principles can be found in studies by Chinn (2007) on Hawaiian science; Lipka and Adams (2004) in reference to Yup'ik culture, and Barnhardt (2007) to Alaska, USA; Litteral (2001) and Matang (2008) in talking about reforms in education in Papua New Guinea (PNG), and Rohrer (2010) with Makonde, and Cherinda (2001) in Mozambique. Although one argument dismisses mathematics embedded in culture as mere application (Bishop 1988), others such as Pinxten (Pinxten et al. 1983), Furuto and Furuto (2010) and Adam (2010) do not accept this premise basing their argument on long-standing research in culturally based mathematics. They have identified ways of thinking that are not in western mathematics but are systematic, reasoned techniques (Barton 2008; D'Ambrosio 2006). However, culturally-based mathematics may go unnoticed due to the lack of connection with formal, westernised mathematics (Civil and Andrade 2002). The recognition of mathematics within a culture requires a deliberate attempt to make the connections by teachers. In some cases, this is within the curriculum documents. Documents such as those from the Alaskan communities (Barnhardt 2007; Lipka and Adams 2004) and those prepared for elementary teachers in PNG are examples of explicating cultural mathematics. The Papua New Guinea Education Reform included a recognition that education was best developed from the home culture and community of the students (Litteral 2001).

Underpinning this ethnomathematical approach was a recognition that learning is more than a simple cognitive process since social context also impacts on self-esteem and learning. Concepts are understood in terms of interactions with others but also through reflection on ideas that may at first seem unrelated such as out-of-school and in-school experiences. The result is self-negotiated knowledge mediated through practice (Radford 2006). Education systems, curriculum, school, and teachers play a role in ensuring opportunity and encouraging self-negotiated knowledges. However, learning needs to occur without loss of self-esteem and this may be achieved through an ecocultural pedagogy in which mathematics is situated in a context and place (Gruenewald and Smith 2008).

When this ecocultural pedagogy of place involves Indigenous knowledge and ways of learning, one can begin to decolonise the curriculum and its pedagogy. This critical approach to pedagogy involves schools, policy-makers, teachers and students knowing the history and culture of Indigenous communities, acknowledging the impact of colonisation, and acknowledging the students' Indigenous community languages including Aboriginal English. Decolonising education changes values and perspectives and instils the desire to reinhabit people's thoughts, their cultural lives, and their land. "Decolonizing becomes a metaphor for the process of recognizing and dislodging dominant ideas, assumptions and ideologies as externally imposed" (Smith and Katz 1993, p. 71). Indeed, decolonising requires recognition of the impact of past and present colonial practices and thinking and the power relationships that are established for the system and teachers over the Indigenous communities. These colonial impacts are recognised by teachers when there are relationships established with the Indigenous community and the teachers hear the stories directly from the sharing Indigenous community (See also the Bidialectal approach to writing English, Owens 2004; Reid et al. 2005). "Decolonising depends on recovering and renewing traditional, non-commodified cultural patterns such as mentoring and intergenerational relationships" (Bowers 2001; Gruenewald 2008, p. 9, citing Bowers). The teacher becomes an enquirer in the situation learning from the Indigenous community.

However, recognising diversity in the community and decolonising the curriculum and education are still problematic (Paredes-Canilao 2006). Concern is expressed that the issues of difference and decolonising are still perceived in terms of the dominant or western culture. Although "difference" may not be seen as "othering", that is the attribution of deficit in relation to the mainstream and not like "us", none-the-less "difference" is still a term that emphasises heterogeneity and individuality which may not be the perception of Indigenous communities who consider balance as critical both for the community and the land (Verlot and Pinxten 2000). In fact, the role of the Elders is critical and pervasive in overcoming the concerns about difference and establishing a critical pedagogy of place. The Elders are guiding and mentoring the learning that occurs in that place.

Furthermore, decolonisation involves the establishment of Indigenous pedagogies rather than the undoing of a loss created by colonisation. The hybridity is positive in terms of continuity and synergy rather than reductionist and dualistic. Critical pedagogy of place entails the self-identity of the Indigenous culture connecting to others, the land, and the bigger worldview (Pinxten et al. 1983). The key issue for this paper is that the Indigenous community has a key role in presenting an alternative worldview of learning and sustainability for establishing a critical pedagogy.

An ecocultural pedagogy that considers place in the sense of being physical, geographic, cultural and social is particularly pertinent for Indigenous communities whose close links with the land in social and cultural ways are significant. There are cultural patterns that sustain the capacities of environmental systems (Gruenewald 2008; Gruenewald and Smith 2008). Embedded in Indigenous education are literacies of place; practices that value and maintain place; and the narratives and stories of the links between people and place. Education for sustainability is *in, through*, and *about* these places (Aboriginal Education and Training Directorate, 2005). Central to an Indigenous perspective on sustainability is the essence of relatedness, "defined as sets

of conditions, processes, and practice that occur among and between elements of a particular place, and across contexts that are physical, social, political, and intellectual" (Martin 2008, p. 61). The interrelatedness with ancestors, place and people forms the basis for relationships with schools. It is through yarning stories with embedded purpose and connections to other knowledge, people and place that deep knowledge is expressed and even created (Somerville et al. 2009). Such approaches will reduce stereotyping and generalisations of Indigenous cultures.

Theoretical perspective into practice

This understanding of ecocultural pedagogy became a shared understanding between some Charles Sturt University (CSU) lecturers and members of the Dubbo Aboriginal community although the introduction is expressed in the formers' discourse. The authors met and yarned and shared knowledge over 3 days and continued our communications about Indigenous mathematics education and sociopolitical issues in subsequent months. A particular strength of the meeting was the sharing by Indigenous community representatives from four countries—Sámi from Sweden, Maori from Aotearoa, New Zealand, Tolai from Papua New Guinea, and Wiradjuri and Gamilaraay Aboriginal communities from the Dubbo region.

During the forum we expressed this ecocultural perspective as Working Together, *ngadhubandalongngindhu* meaning "I join you and so you join me". The teacher meets the students–they join together and we are all continuing to learn together, we form our community–*searvodat min searnodagas* (Sámi-Swedish)–or we work together as one does around a campfire, and in Tolai as *da turwarurung,* working together. This perspective formed the basis of our discussions on how we can consider mathematics within a cultural context. The meeting involved yarning and sharing talks, papers, policies, and experiences. We shared our knowledges whether they came from research experiences guided by university communities or from Elders and family and personal research. Records of the yarning were kept and circulated each day. These records noted who specifically contributed to points raised in this paper but a consensus was reached on these points. Points were often revisited and elaborated in discussions.

In another paper (currently under review) we have presented a diagram that summarised our thinking and which was developed from an ecological model of education (presented by Beatrice Murray during the forum). It emphasised that the child could not be separated from what he/she brought to school, and the subsequent education was influenced by the continuing roles of the family, the community and the school with the Elders significant in all these influences. We also learnt from and shared with other colonised Indigenous communities in other parts of the world. They brought both sociocultural and ethnomathematics research perspectives as well as teacher education experiences from an ecocultural perspective. We extended our horizons but we needed to link this to our own local context.

Furthermore, we present a perspective that recognises that ethnomathematics has a critical education role in pursuing social justice in education. By this we emphasise the diversity of thinking mathematically when that thinking is embedded in cultural ways of thinking. The ecocultural perspective ensures that the cultural aspects are

not taken out of context to be pursued as mathematical applications nor as loosely connected ideas to mainstream mathematics education (Pais 2011). Indeed, a continuity between home and school in Indigenous education was seen as a basis for achievement in school mathematics. Discussions revolved around the impact of testing regimes, a broadened perspective on the ways children learn mathematics, the importance of environmental and cultural learning spaces, reforming curriculum, and the implications for teacher education. This is what we share with you, the reader as we provide a summary of our discussions intertwined with a theoretical perspective and key issues.

Key issues in the discussions

One social justice issue that received acclaim during the forum was the importance of all students being exposed to mathematics of different cultures through which they obtain a more comprehensive view of culture and mathematics and become more socially aware of difference. Such approaches also reinforce cultural self-respect. For this reason, it is important for Indigenous Australian students to know that cultural difference is valued and recognised within a mathematical bank of knowledge.

One of the aspects about curriculum and learning that was raised by the forum was a recognition of the value placed on ways of learning by Indigenous students. This included the use of storytelling and the sharing of stories and knowledge by a significant, respected Elder or other person with whom a caring relationship had been established. Learning to listen is one of the strengths of Indigenous learning that is undervalued in school education and under utilised by teachers themselves and in their teaching. Talents like life-skills are not recognised. It was noted that having the space to try and solve problems in everyday situations with social support in the background was valued by Aboriginal communities. Schools and classrooms are unnatural with too few Indigenous older people in positions of leadership from whom to learn. The schools are strictly controlled inside places. Ability to perform well is nearly impossible in such a culturally disconnected place. Coupled with the lack of links with community for a child who is struggling will be the teacher's lack of familiarity with the community. Aboriginal tutors, Aboriginal Education Officers, and Aboriginal teachers can provide that necessary link in circumstances where the family or community life has changed rapidly to provide the necessary social support for taking risks to learn in the classroom and to mentor the teacher.

A further example of how cultural approaches to education can be incorporated into school education and into mathematics curriculum was provided by Ylva about Sámi children who are raised to connect with the land and relatives. Importance is placed on belonging and on independence such as knowing your way through the forest and mountains. Designs in handicraft are also handed down. It was noted that the sharing of knowledge was done in a Sámi way such as the use of storytelling, seeing, hearing and doing, trying and testing. Carefulness was valued just as it was in reindeer herding (Jannok Nutti 2008). This discussion resonated with the Aboriginal authors who had expressed similar values about their culturally based education.

Ecocultural perspectives provide for a hybridity of culture which is also evident in programs such as those by Eglash and Bennet (2009) in which culturally congruent computer software can foster agency, identity and mathematical patterning and problem solving in a computing environment. Computer programming using *Scratch* has also been an engaging pedagogy in the Northern Territory (Haber, personal communication), Wagga Wagga (Meaney, personal communication), and New Zealand (Calder and Taylor 2010).

Diversity exists between individuals by nature but the social world adds significantly to the differences which are affected by the power of those who structure "the production and reproduction of knowledge" (de Abreu 2002, p. 175). The local place-based education may require processes by which the teachers become aware of the diversity of the mathematics of the family. The ways of representing cultural resources and maintaining wellbeing are mediated by teachers to reduce the complexity of everyday experiences, respectfully and "without losing sight of the rich and dynamic totality of their lives" (González et al. 2005, p. 21). For example, the teacher may represent football scores in terms of patterns which in turn may link to other everyday experiences but the use of scores, the reasons for variations, and the creation of variations reduces complexity without loss of connection to everyday life. In this way, mathematics is modelling everyday experiences that have meaning and context for Aboriginal students.

Physical space of the learning environment is important to encourage the cultural learning and learning from Elders. The Tree of Life program for boys is held in outside places and centred on the didgeridoo and cultural knowledge sharing (Rick Powell, personal communication). The Mathematics in Indigenous Contexts held at Gilgandra, Warren and Coonabarabran also involved excursions to outside community places with Elders (NSW Board of Studies Aboriginal Education Unit et al. 2003–2005). In both Sweden and PNG the Indigenous curricula begins outdoors and incorporates all subject areas within the spiritual approach to learning. For example, activities for creating material culture might require estimating size, counting, measuring, recognising shapes, and problem solving. Understanding nature would likewise require pattern recognition, experiments and mathematical concepts like volume, time, and ways of measuring. Bush programs that are outside in nature and related to the curriculum provide culturally inclusive curriculum and pedagogies. This was evident in the shared stories from Sweden and Papua New Guinea (Ylva, Patricia Paraides, Kay) that illustrated measurement in a cultural context. Education should start with trees, animals, dirt and wood as well as local designs and these can be linked to mathematics and literacy. The *tekotahitanga* website for implementing culture in practice in schools in New Zealand is another example of practice that links the place and culture to school education.

Social justice requires inclusive pedagogies recognisant of community voices (Apple 2004). The community must be involved in leading and decision-making in partnerships that address educational issues. Discussion of their perspectives is needed so others involved in education recognise their views. An appropriate and fulfilling education requires transformative alignment with community cultural patterns and perspectives based on systemic willingness to listen to households so that stereotyping and homogenising assumptions are avoided. For example, in the Funds of Knowledge projects in the USA, teachers asked households about family

history and contacts with others in the region, formal and informal labour, routine activities, and perceptions of their roles as parents and caretakers, their own and their children's schooling, and language used in schooling. The interviews informed professional pedagogic discussions and decision-making (González et al. 2005). In these borderlands, education affords the child his or her own developmental "transit where space and time cross to produce complex figures of difference and identity, past and present, inside and outside, inclusion and exclusion" (Bhabha 1995, p. 1). The teacher's role was to facilitate these border crossings (Jegede and Aikenhead 1999).

The Funds of Knowledge projects explored ways of representing cultural resources and maintaining wellbeing. The practices, strategies, and knowledges of the households are mediated by teachers to reduce the complexity of everyday experiences, respectfully and "without losing site of the rich and dynamic totality of their lives" (González et al. 2005, p. 21). For example, the teacher may represent basket weaving in terms of patterns which in turn may link to other everyday experiences but the use of baskets, the reasons for variations, and the creation of variations reduces complexity without loss of connection with everyday life. Pedagogical changes occurred as teachers adapted procedures, artifacts, discourses and reasoning as a result of their communication with the community households. They were inquirers with questions, and they accepted that funds of knowledge are fluid and negotiated through discussions among participants. These same processes became the meta language and processes of their own teaching with the students actively involved in developing their knowledge. Teachers became risk-takers, supportive, and non-judgemental. A hybridity of this fund of knowledge developed as two-way or both-ways education (Civil and Andrade 2002; Stanton 1994)with equity of purpose, worldviews and pedagogies for teachers and community families.

These approaches may overcome some of the concerns of McKinley (1999) that the teaching might be superficial or even offend, that it should not lower expectations of high achievement, that it not be examples of the current curriculum or just for engagement, and that it meet the desires and needs of the community for self-determination and a cohesive epistemology. Another premise for these projects was that culture is not frozen in time as portrayed by special cultural days. Instead learning is a lived, cooperative experience that reflects the children's cultural backgrounds and promotes interracial understanding. This cooperative learning was not just in the classroom between children but between the teachers, parents and communities (see also Pinxten et al. 1983).

We might ask whether it is possible for Indigenous Australians whose languages are now being revived but whose worldview and relationships are embedded in their Indigenous culture to achieve a similar curriculum approach. The logical systems, the language that might dictate the concepts and logic, and the purpose for mathematical thinking has largely been fragmented. The question remains is it possible to recognise Indigenous mathematics in a colonised community. Mellin-Olsen's (1987) critique of Pinxten's approach is that his semantic cognitive anthropological approach fails to take mathematics education as a sociopolitical activity. It is not just that mathematical achievement might position students in society but also that a sociopolitical perspective takes account of students' beliefs about mathematics, their valuing of mathematics, and themselves as being able to

make a difference in society. It provides opportunity for self-determination. When Gutstein (2007a) gave students mathematics related to the issues facing their barrio in their USA city, the students were empowered to realise that mathematics was relevant and that they were able to have a say about political issues. Knijnik (2002) illustrated a similar positioning around the landless movement in Brazil, and Andersson (2010) reported on the impact of projects related to social issues in mathematics classes for social-science students in Sweden. She showed an increase in engagement especially when the students saw the impact of their posters in which they had used mathematics to present social issues to others.

These studies have emphasised the sense of agency that such student projects generated. By sense of agency we mean the sense that they themselves can use mathematics to make a difference. This difference relates not only to themselves as mathematical thinkers but also themselves being able to use mathematics to make decisions affecting their personal lives, to make a difference in terms of the values of the community, and to impact on sociopolitical issues in their community. This sense results from their self-valuing and identification, their sense of pride in their ability to understand and use mathematics, and their sense of their democratic role in society. Each was a result of reflection on a transition between mathematics as perceived in terms of the school mathematics but mathematics being related to out-of-school situations (Andersson 2010).

De Abreu (2002) used the term "valorisation" to distinguish when certain values tended to occur commonly within a group such as the carrying out of farm mathematics with a non-school technique. Competing valorisations in cultural and school activities require mediating. The mediating tool may be physical or in the mind such as numeracy systems which are reflected in the language. There is no easy consonance between one knowledge and another and it is necessary to consider how the knowledges are mediated by experiences. Establishing meaning depends on the ecocultural background of students (Chinn 2007; Gruenewald and Smith 2008; Mellin-Olsen 1987), no matter how colonised it might be. Each student may value one of their knowledges more than another in general or in a specific situation. One may be recognised as mathematical and the other not. In fact, Gorgorió et al. (2002) and Owens (2006, 2008; Owens and Kaleva, 2008a, 2008b) both initially asked villagers about how they carried out certain activities, to show or describe the activity rather than to ask what mathematics they used. In several studies, value-ladened culturally mediated tools would lead participants to falter when having to explain their practices (de Abreu 2002). In PNG, the use of the phrase "centimetre-metre" was a TokPisin way of saying "small unit and a big unit made up of the smaller units". Language, as indicated by the above examples, is linked to power issues in mathematics education (Gutstein 2007b; Walkerdine 1988). Language in ecocultural mathematical contexts "leads us to the statement that there are more than a single and unique rationality, a single and unique mathematics, and a single and unique set of rules by which individuals and cultures deal with space, time and quantification processes, which in the western civilization is associated with the notion of mathematics" (Knijnik and Wanderer 2010, p. 353).

Connections and transitions between students' cultural knowledge and their school education are to be encouraged and established with evenness and consistency (de Abreu 2002; Esmonde and Saxe 2004; Valsiner 2000). Any

dissonance is associated with a negative shattering of value as an agent who can affect their own lives and society's development (Presmeg 2002). Mathematics education can either lead to dissonance or strengthen students' knowledges through making connections between knowledges. Whether it is dissonance or synergy, there is an impact on the students' sense of agency and hence their mathematical thinking.

A good start for Indigenous students is one in which the history and culture of Aboriginal and Torres Strait Islander communities are included in school, and language is acknowledged. Culturally appropriate ways in schools and lower turnover of staff occur if Indigenous staff are employed permitting non-Aboriginal teachers to see what are appropriate ways (Hockey 2008). Teachers should be aware of the complexity of the cultural and social contexts in which Aboriginal students learn mathematics. A literature review on Aboriginal children's numeracy (Frigo and Simpson 2001) noted teaching strategies should support parents and communities in being involved in their children's learning. They went on to say the content should:

- value Aboriginal students' diverse cultural and linguistic heritages;
- make explicit the difference between Western mathematics and Aboriginal mathematics, and value both equally;
- make explicit the link between community, home and school mathematics;
- provide realistic and real-life classroom contexts for mathematics activities;
- be developed in consultation with local communities and Aboriginal education workers; and
- be open to and encourage modifications of content and pedagogy to reflect particular students' interests and learning needs. (Frigo 1999, cited in Frigo and Simpson 2001).

Frigo (1999)made similar comments about materials and resources used by Indigenous students. By contrast,

> traditional mathematics education aims at transmitting a certain amount of content and uses it in artificial situations presented as problems. The problems are artificially formulated, in such a way that they can only help memorization skills, at best. These techniques and problems are usually boring, uninteresting, obsolete, and unrelated to the modern reality of students (Orey and Rosa 2006, p. 73)

Mathematics related to culture may restore a sense of pleasure and a sense of belonging in the classroom so students will be more motivated and engaged (Osterman 2000). Discussing and sharing ideas especially about relevant community activities and problems and using cultural and language resources will engage students in mathematics learning (Howard 2001). Teachers and educational systems need to listen to and take direction from Indigenous people to appreciate and come to know the contexts in which Indigenous students are living and learning (Hickling-Hudson and Ahlquist 2003). Community partnerships need to be reflected in mathematics teaching, and change has to be a whole school and community effort (Howard et al. 2003; Matthews et al. 2005).

The child as a member of the family is at the centre of the learning framework surrounded by schools, community, and finally systems. This means that various

people in certain kinship relationships will have certain roles but also that the curriculum permits the child to draw upon home knowledge. To do this successfully, there needs to be a decolonisation of the curriculum. Examples from overseas provided above and from NZ, Sweden and PNG illustrated the strength of Indigenous mathematical ways of thinking. Recognising these strengths is important since numeracy empowers people but without an appropriate decolonised curriculum it disempowers Indigenous students.

Ylva (Jannok Nutti 2008) explained that Sámi culture differed across place, family and time (with three main dialects and many subdialects) but it had been handed down through generations and concerned both practical and theoretical knowledge especially about local conditions and nature, psychological and spiritual conditions, social relations, and cultural and social institutions (Averill et al. 2009; Bergstrøm 2001, cited in Jannok Nutti 2008; Nelson 2005). There is a national Swedish curriculum but in Sámi schools they also teach Sámi language and other cultural practices. Ylva made reference to a number of frameworks such as Bishop's (Bishop 1988) mathematical activities of counting, locating, measuring, designing, playing and explaining and studies that had provided Mathematics in Context such as the Yup'ik curriculum in Alaska (Lipka and Adams 2004; Lipka et al. 1998)and Sámi schools in Norway (evaluated by Hirvonen 2004). The importance is to reclaim, reformulate and reconstitute Indigenous cultures and languages (Tuhiwai Smith 2005). Some would see this as forming a bridge between cultural knowledges (Battiste 2000; Gerdes 1998; Swedish Sámi project).

Ylva gave several examples of Sámi mathematics and its use in schools. One father shared his knowledge with the children about grouse trapping. It was a practical experience in and outside school with measurement in a cultural way. A herder must measure snow depth so the reindeer can dig down to the food beneath the snow. The way of approximating the number of reindeer in a herd, counting ear markings and inscribing numbers on a stick is discussed in schools. Position and the location of reindeer are decided by the wind, rivers and landscape. Measurements are made by using the body both in herding and in handicraft and distance is measured by time, sound and sight. There are eight Sámi seasons depending on light and activities.

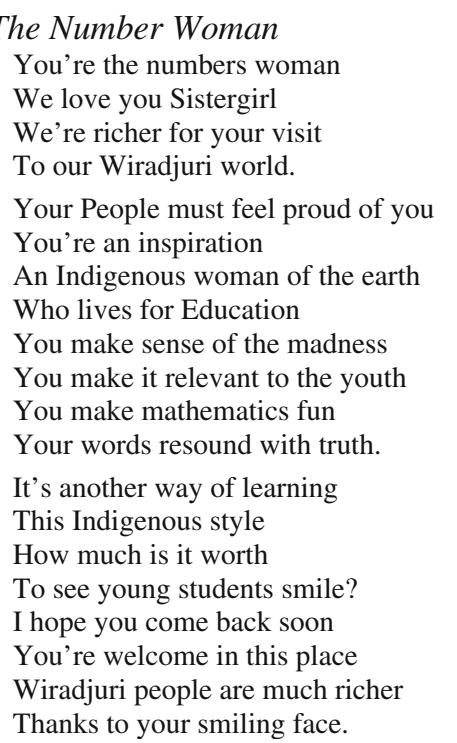
Ylva's ethnographic study had recorded Sámi mathematics involved in cultural contexts and some of this was now being used in school experiences. The plan was whole community action research to provide for education for everyday life, to provide for the right of a history, and of a future with traditional Sámi knowledge as a base for mathematical understanding. Ylva, with the Sámi Education Board, would like to see a Sámi mathematics curriculum that is Sámi centred, child-centred and not a mere translation of the Swedish curriculum and textbooks. It should be noted that for some Sámi like Ylva, they had not learnt their language as a child, a significant point given that many Aboriginal people in NSW also did not learn much of their language as children. Nevertheless, the cultural understandings have continued. A comparison can be made with children in PNG towns for whom TokPisin is their first language. These students will have their first schooling in this language at elementary schools. Sweden creates a bilingual experience for children by ensuring at least one of the teachers in the school speaks the language of the child's home. This may be Sámi Lulé, Sámi North or Swedish.

A similar study was undertaken by Patricia Paraides, a Tolai from Papua New Guinea. This country has a Reform education that involves vernacular education in the early years. Studies found that schools were not connecting back to their communities so that children could build on knowledge from their culture to become part of the global community. This prompted Patricia's research. She presented just one of the many mathematical ways of thinking from PNG, a land with over 850 languages and 19 Provinces (Glen Lean Ethnomathematics Centre University of Goroka 2003; Matang 2008; Matang and Owens 2006; Owens 2001; Owens and Kaleva 2008a; b). Patricia recorded and shared with us how her language and cultural activities reflected the Tolai cultural ways of thinking mathematically. Tolai counting varies depending on the activity. In gathering taro tubers, two are tied, then four, then one set of six which then has the value of one whereas banana bunches, coconuts, and wild fowl eggs are counted as one set of four, two then three sets of four (12 as a unit). Peanuts are counted in sets of ten or twos but there is no fixed number strung together for small fish. In Tinatatuna, the Tolai language, groups of 12 coconut are called *a pakaruati* (one lot of 10) and then 10 or 20 of these lots. Actions like stacking occurred as they counted. People are counting in groups as opposed to individual objects and this is communicated through Indigenous oral discourse. Tolai currency is shell money, *tabu*. Five shells is the lowest value. Stringed together shells are measured against lengths of parts of the arm can be used such as finger to mid-upper arm straight, same but hanging, hanging to mid-chest, hanging between outstretched arms. Each has a precise name. Some lengths of 10 and 12 are used together with multiples of these groups. More importantly, each length and distribution of shell money is significant to an occasion. Lengths of shell money in a circle are grouped in tens and in tens of tens.

Patricia's (2003) research had shown that students performed better in numeracy and literacy if they began school in their vernacular or home language. This is supported by Matang's (2008) research on another language group, Kâte, and his more recent research on a number of other languages (personal communication). In his study of Kâte, a Papuan language from the hinterland of the Huon Peninsula of Morobe Province, PNG, he found students performed better if taught in elementary school in their vernacular home language rather than in a school with TokPisin (PNG creole) or English.

In recognition of the importance placed on this dialogue with other Indigenous cultural groups, one of the Wiradjuri authors wrote a poem for Patricia from PNG (Fig. 1). Dialogue is significant in developing a mathematical curriculum that is cognisant that mathematics is itself varied and a cultural phenomenon (Ferreira 2010).

Several local examples of mathematics linked to culture and community were shared. For Wiradjuri, counting every item might be a sign of disrespect and lack of trust so students are not encouraged to count. Wiradjuri counting is based on five (*marra* – hand) rather than ten as in European school mathematics. "Riverbank" mathematics includes knowing seasons from the bush, building shelters, checking angles and understanding aerodynamics in throwing boomerangs. It covers boats and floating and the size required for the task and the tree needed for that task (there are several trees with scars from which canoes and other objects like coolamons were made). The size and recognition of shapes and patterns in paw prints can tell a lot



The Number Woman

You're the numbers woman
We love you Sistergirl
We're richer for your visit
To our Wiradjuri world.

Your People must feel proud of you
You're an inspiration
An Indigenous woman of the earth
Who lives for Education
You make sense of the madness
You make it relevant to the youth
You make mathematics fun
Your words resound with truth.

It's another way of learning
This Indigenous style
How much is it worth
To see young students smile?
I hope you come back soon
You're welcome in this place
Wiradjuri people are much richer
Thanks to your smiling face.

Fig. 1 The number woman by Frank Doolan (Riverbank Frank) 2008

about the animals' movements. Navigation relied on stars, sun, and moon which is often not discussed but observed and distances needed discussion beyond the "long way" and the "little bit long way" description. Even ratio is needed if a kangaroo motif is to be put on a shield or other object and also in deciding how many kangaroos to get for the family since animals are not taken unnecessarily. An emu egg is equal to 12 chicken eggs providing an example of ratio. These brief suggestions provided mainly by Riverbank Frank and confirmed and expanded by others give an idea of how the Aboriginal authors saw connections between Aboriginal knowledge and school mathematics.

Other examples were provided including a recent project involving boys in bike repair and in developing a small hill area with native plants outside the classroom. These activities were carried out with plenty of cultural knowledge stories including the cultural uses of the plants. Community groups discussed bank accounts. In one of the schools, simple readers were prepared and used to integrate mathematics into a reading recovery type program. The uniqueness of each culture, the use of mathematical knowledge in most practical activities, and the fact that western mathematics is limited in assisting with recognising differences (Battiste 2000) means most educational recognition of culture in curriculum is tokenistic and does not represent a true Wiradjuri curriculum.

Conversations also revolved around teacher education both as preparation for teaching and as a place of learning per se. Many of the following comments are also applicable within school and early childhood settings. Active partnerships and the

use of Indigenous languages, contexts, beliefs, protocols and values is critical for Indigenous education. Education is an activity that requires collaboration like paddling a canoe (Averill et al. 2009). Partnerships ensured access to deep cultural knowledge and expertise as well as integrity and cultural authority in developing the Maori curriculum. To prepare teachers for Maori schooling, a culturally responsive education was provided with protocols, pedagogies, assessment and personnel. In Averill et al's (2009) study some of the more overt aspects like protocols, storytelling, and having a Maori lecturer were recognised by the preservice teachers but others like a philosophical statement at the beginning of the course, use of review and metaphor as strategies were not recognised (Averill et al. 2009). The authors suggested aspects of Maori culture should stay in context, to keep its integrity and prestige, and to weave in mathematics rather than the culture being added on to the mathematics. Weaving mathematics into activity is similar to the ideas of early childhood education (Macmillan 2009). The use of weaving (e.g., a *tukutuku* panel) was a metaphor by which students recalled the course content and pedagogy to develop their understanding of the implications of the Treaty of Waitangi (partnership, protection, participation) in their own teaching. Interestingly, some aspects of teaching like use of review, linking new to existing knowledge and cooperative group work were not considered by students to be culturally responsive education although they are valued by western schooling but also by the Maori culture. The implication of that is the need for bicultural aspects to be highlighted as Maori pedagogies and not just western quality teaching pedagogies. Furthermore, the teachers were able to identify activities of other cultural groups that linked to mathematics. However, metaphorical use of cultural activity may be inappropriately appropriated when it has not been generated and accepted by the community in the way it is used. Importantly, a system of mentoring was more appropriate for learning than a standard lecture-tutorial perspective.

Other culturally appropriate examples within teacher education were discussed. In a mathematics education course at Balob Teachers College (PNG), the students made traditional objects like bilums (string bags) and discussed the mathematics involved in making the bag (Kay). Story boards (a traditional artefact from an area of the Sepik) have also been seen as a metaphor for teaching and learning (Primary and Secondary Teacher Education Project). At the University of Goroka, high school teacher education students selected a village activity and linked it to the curriculum and to Bishop's mathematical activities like counting, designing, measuring, playing, locating, and explaining (Bishop 1988). In Dubbo, student teachers are encouraged to learn Wiradjuri language and to participate, in these classes, in culturally appropriate teaching practices in which listening, speaking and song, interwoven with stories, are used. Each of these examples illustrate ways in which teachers can be sensitised to thinking about culture and mathematics.

Strategies for education cover not only the content but the approaches as shown in the Sámi teacher education project. Teachers are to show competence in subject knowledge, educational knowledge, cultural knowledge and cultural interactions. Places for education in the Dubbo community were the river bank and camp fire circle, a place to come back to for learning. Education enhances the blending of cultural self, respect, and home with school and includes the way of speaking. Aboriginal English and the underlying Wiradjuri language and concepts support

student's cultural identity and self-respect but further work is need to build on this language knowledge for expressing mathematical concepts in Standard Australian English. Discussion covered the importance of teacher education out in the bush, to talk of different wood, plants, leaf shapes and lengths, describing and making cultural artefacts involving mathematical language and explaining dance and relationship.

Several examples were used to illustrate how students can be engaged in the classroom. When one teacher had drawn parallel lines on the board and talked about equal angles, the student did not even open his book. Teachers need to recognise students' defensive behaviour. The tutor suggested to the student to draw a football field on his page and show the various sections with lines. "Now they are parallel lines." The tutor continued to talk about kicking and passing balls and at what angles. This engaged the student. When the teacher talked about percentages, the tutor talked about the percentage of students on and off the field when there was a penalty, and the percentage of players on different sections of the field. Another story was about playing with cards to engage students in probability ideas. The practical approach was necessary to develop basic mathematical concepts and for the students to develop a love of mathematics. When students go on excursions, they should not just enjoy and learn about culture but write in their journal about the process, and include the mathematics involved in, for example, bike repairs or making didjeridoos or whatever they are involved in. An appropriate way of learning is for questions to be asked and for students to go and find information. Teaching needs to be interactive and not just telling students what to do. Furthermore, peers can co-teach. Quality teaching for Indigenous students is also quality teaching for all students.

Commitment of the community provides a structure for utilising the roles of family members of students at the centre of education. The strength of learning in an Indigenous way will emphasise sitting and listening and taking time to take in the intention of the conversation. This may not be a direct way of interacting in linear time. Another strength of community learning is that of life skills and being smart in difficult situations. There are ways of supporting this in schools. For example, teachers and schools and systems should recognise Aboriginal English and recognise the self-sufficiency and individual talents that the students have. There needs to be removal of barriers between classrooms so that support networks are still in place from the home environment and caring/sharing responsibilities are maintained. Community tutors provide an opportunity for whole of school awareness of community. There needs to be ways of all teachers and other staff to become aware of community and when not aware to have the attitude that the community has a role in the students' lives and must be respected. There will be continuity and sustainability if the relationships, trust, respect, responsibility and commitment are present when community, home, school, language and culture are drawn together into the metaphoric educational circle.

Aboriginal Education Officers (AEOs) need to work with teachers in classrooms and to assist in the professional development of teachers. Their role should not be stagnant and there should be pathways for AEOs. More recently a few more goals for students are being negotiated with parents and the child in Personalised Learning Programs. As in other countries like Sweden, it often requires the presence of an intermediary who is employed by the school. Recognition was given to preservice

teacher education provided by the community at the after-school tutoring at the community centre. Not only did this provide an opportunity for achievement for children in literacy and numeracy but it was a beginning of understanding for the preservice teachers learning from and in the community.

In Coonabarabran (as mentioned above), the mathematics teacher (Harry Langes) worked with the Indigenous staff and community to develop a unit on mapping with the students visiting the area of town where many Indigenous families live. This site is of cultural significance for the Indigenous students. The Indigenous students showed a sense of ownership and engagement with the mathematics. The project provided an opportunity for the non-Indigenous students to learn incidentally and informally more of the Indigenous Australian culture of their fellow students. The teacher for many years also provided mathematics classes for parents so that they had a greater sense of partnership with the children. In another town, teachers engaged students by improving their teaching strategies for the Space strand of mathematics. This approach of making and investigating engaged the students more. At the same time the principal was going out to meetings in the community and community members were coming into the school and sharing with teachers how they felt about school and the reasons for this. Similar stories from people known to teachers were considered as a critical turning point in empathy and understanding by teachers in the bidialectal approach to teaching (Owens 2004). In other schools, teachers implemented *Outback Maths* which was a way of relating mathematics to other subjects and to the students' environment through a series of lessons on topics like The River or The Town's Show (Lewis, personal communication; Nelson 2005). These projects become sustainable because of the involvement of the community.

Prior to the forum (2008) National Testing (NAPLAN) placed students into six levels of achievement and the results at one local primary school indicated Indigenous students were reaching Band 6, the highest band, and were overall above the state average for Indigenous students but the principal of the school noted that there was still room for improvement. This reflects what was reported by Laughlin and Ella (2004) across New South Wales[1] that some Indigenous students were reaching higher bands but there was a larger than the overall average number of students in lower bands. At another school it was noted that students were poor in the area of Space and Geometry in mathematics butit is frequently found that students' performance in this strand of the syllabus is lower than in other strands indicating that teachers need time to develop a curriculum approach that is investigative, and relevant to the place and culture. In this area of the curriculum the school symbolism often fails to reflect cultural background and experience. This could be altered through dialogue with community and an ecocultural perspective that permits "imagination (that) takes shape between subjective urges and the pressures exerted by the socio-cultural environment. It draws on symbolization processes that are contextualized in place and time" (Ferreira 2010, p. 376).

[1] New South Wales is a state of Australia having the largest population. Sydney is its capital, situated 400 km away from our city. In Australia, education is a state matter but there are now national assessments and curriculum statements. The results of these assessments are noted with a strong realisation of their limitations.

More Indigenous parents were in communication with the schools largely as a result of the Aboriginal Education Consultative Committee (AECC) encouraging this and principals now going out into the community for meetings and to visit families. Another principal noted the main reason for improvements in testing and attendance was change of teachers' attitudes. Teachers had been provided with a process called 8-ways (Yunkaporta and McGinty 2009) to assist in cultural competence. Teachers were beginning to identify quiet, capable achievers and provide extension experiences for students such as travel and leadership. However, some Indigenous parents were young and needed education themselves in Indigenous community roles. High achievements were expected not only in school-decided goals but also in cultural ways.

Conclusion

Unlike education driven by high stakes testing of a globalised, centralised curriculum, this paper exemplifies how Elders in the community legitimise mathematics education permitting localised, place-based, ecocultural education, involving the Elders and Indigenous knowledge rather than generalised externally imposed mathematics. This approach indicates pathways to go forward with an integrating cyclical structure from home to school to home. This approach emphasises language, identity, colonisation, spirituality, kinship, survival, caring and sharing, boundaries, and defined roles and responsibilities. Education becomes holistic and within the environment as understood by the family. Past connections include survival struggles and present connections include heroes including parents and Elders who are significant role models to their children. For these Indigenous knowledges, understandings, stories and connections to be part of the curriculum, a foundation is laid through teacher professional development so teachers appreciate the culture, develop trust, and maintain commitment to change. Knowledge of colonising processes lie alongside important teacher competencies: decolonising, cognitive, cultural, communicative, creative, critical, social and didactic competencies (Johansson 2008). At the same time, parents learn and a critical mass promotes change involving the interrelations of a society's policies and attitudes, community, families, and school. Differences are recognised and mediated through dialogue (Ferreira 2010). The rights of the Indigenous child are embedded in the rights of first occupancy and hence in discourse that conceptualises education as beginning in the home and community. Giving voice to Indigenous community in education, constrains neo-liberal educational policies such as national testing and curriculum dominated by the colonising content and education system. There is less thought of democracy being by majority or even power rule but rather seeing democracy as being emancipatory and culturally embedded education (O'Sullivan 2011). Education that focuses on continuity for Indigenous students counters the colonising restrictions in the natural relationship of Indigenous people and their land (JannokNutti, 2008).

Critical education perspectives consider the impact of educational curricula, policies and implementation in terms of social justice. In particular, we have considered how Indigenous communities can have a lead role in mathematics

education. An ecocultural perspective has been developed from considering place as a space in which Indigenous voices are leading the implementation of mathematics education. It is appropriate that the voices of the Indigenous community with their connection to the land are heard in the education of their children. Working together recognised the role of the Elders in each of the supports for the children and what they bring to school. The Elders have a role in the family, the school and the community.

However, drawing this perspective into mathematics education has built on Indigenous projects from other countries in which studies of ethnomathematics—the mathematics of the cultural group—has formed the basis of the school mathematics. This was shared during the forum by Sámi and Tolai (PNG) representatives but also through the sharing of literature on other projects in PNG, USA, NZ, and other parts of Australia. Examples were provided of how teachers could work with communities to develop education that was embedded in cultural perspectives, knowledge, values and approaches. Important was a development of ownership and identity with the mathematics.

Teacher education is seen as a way of bridging the gap to ensure not only competence in terms of curriculum, classroom learning, policies and perspectives but also in terms of culture. Personal contacts and outdoor spaces are keys to this connection for education. While several practical mathematics activities are suggested, it is noted that teachers' thinking, community, and curriculum have to be decolonised if there is to be true dialogue, understanding, and a renaissance of Aboriginal mathematical thinking along with the language. In particular Aboriginal children's development prior to school of taking initiative to solve problems with the support of family is critical for the school to foster. This risk-taking is also needed by teachers to permit pedagogical changes in discourse, procedures, and reasoning that reflects those of the community. Along with these changes, comes a change in power relationships in which the community and Elders are funds of knowledge in a two-way approach to education. Developing this approach to mathematics education requires a whole of community action research plan that permits alternatives in approaches, culturally embedded experiences, and cultural authority. It is a gradual approach requiring mentoring of teachers and students by community. Community in classrooms and teachers in outside spaces provides for these opportunities.

The dialogue presented in this paper involved an extended yarning across Indigenous nations. It provided a sense of respect in Indigenous knowledges and visions of these knowledges from overseas colonised nations. The study also shows how talking and exploring are important in recognising Indigenous knowledges. Part of this exploration is hard to document as it is learned in nature, in being in the place. It also relies on relationships, trust, and time. This study is an illustration of the process of establishing context and its links to curriculum. It is timely to remember that children begin school with knowledges and come from families with knowledges that many teachers have not experienced. The teacher who questions and listens and learns establishes an educational inquiry with the community. There are knowledges we have not shared as they belong to this place and this community and these children. However, we trust we have presented horizons and the open space that we envision for a curriculum, not bounded by western culture. Like the

river and water that flows and gives life, and the ecosystems of nature that are intertwined and reliant on the health of each part, so mathematics education needs continuity in Indigenous contexts.

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