

# Developing Mathematics Knowledge Keepers - Issues at the Intersection of Communities of Practice

Dianne E. Siemon  
RMIT University, Bundoora, VIC, AUSTRALIA

Received 17 July 2008; accepted 24 March 2009

This paper discusses some issues that arose in the context of a three-year research project on Indigenous mathematics teacher education in the Northern Territory of Australia<sup>1</sup>. The project was based on the premise that Indigenous student numeracy outcomes are more likely to be improved where students can work on key number ideas and strategies in first language with knowledgeable community members. The research was located at the intersection of three communities of practice involving Indigenous teacher assistants, non-Indigenous teachers, and research team members. While a range of factors variously impacted the project, tensions within and between the communities of practice emerged to challenge the initial design and pose new questions. This paper will describe the research approach and illustrate the need for analyses which accommodate the often “messy relations” between individuals, individuals and communities, and different communities of practice.

*Keywords:* Indigenous Teacher Education, Mathematics Education, Communities of Practice, Number Concepts, Situated Learning

## BACKGROUND

The educational challenges facing remote Indigenous communities in Australia are not unique. Minority groups in many countries experience similar economic and social disadvantage and are disproportionately represented in the lower levels of educational achievement. While the provision of high quality education for increasingly diverse student populations is a challenge in many large cities around the world (Ladson-Billings, 1994), this is exacerbated in isolated Indigenous communities where English may be a fourth or fifth language and the everyday lived experience of children is very different to that of their non-Indigenous peers.

Not surprisingly, international and system-wide data consistently point to low levels of literacy and numeracy achievement of Indigenous students. For example, although Australia’s results on the 2006 *Programme for International Student Assessment* (PISA) were above the OECD average in scientific, reading and mathematical literacy, the same cannot be said of the results for Australia’s Indigenous students, which were significantly lower than the results for non-Indigenous students and the OECD average overall (Thomson & De Bortoli, 2008). This discrepancy is particularly marked in the comparison of Indigenous and non-Indigenous students as they move from Year 3 to 5 in the Northern Territory. For example, results from the *Multi-level Assessment Program* (MAP) consistently show that Indigenous students are four times more likely not to satisfy the Year 5 National Numeracy Benchmarks than their non-Indigenous peers.

This is a disappointing and frustrating outcome given the many and varied attempts to find more effective ways to support the teaching and learning of mathematics in remote schools as a means of improving

*Correspondence to: Dianne E. Siemon, Professor of Mathematics Education,  
School of Education, RMIT University,  
PO Box 71, Bundoora 3083, VIC, AUSTRALIA  
E-mail: dianne.siemon@rmit.edu.au*

Indigenous student numeracy outcomes<sup>2</sup>. These have taken the form of more culturally sensitive, community-based approaches to teaching mathematics (e.g., Cooke, 1990; Bucknall, 1995; Marika, 1999), evidence-based advice on ‘what works’ in these settings (e.g., Efthymiades, Roberts & Morony, 2000; Frigo & Simpson, 2001; Mathews, Howard & Perry, 2003; Perso, 2003; Commonwealth of Australia, 2005), considerably more and better quality pre-service and in-service teacher education (e.g., Howard, Perry, Lowe, Ziems & McKnight, 2003; Mellor & Corrigan, 2004); and increased efforts to involve more Indigenous people in community-based teacher training programs (e.g., Lamb, Arizmendi, Stewart-Dore & Danaher, 2002; York & Henderson, 2003).

While there is little doubt that the educational outcomes of Indigenous students are impacted by a complex set of socio-economic circumstances (Mellor & Corrigan, 2004; Mathews et al, 2003; Partington, 1998), it is widely recognised that teacher quality is also one of the most important factors affecting student performance more generally (Ball, 1997, Rowe, 2002; Hattie, 2003; Mellor & Corrigan, 2004). Indeed, as Darling-Hammond (2000) notes, “the effects of well-prepared teachers can be stronger than the influences of student background factors, such as poverty, language background and minority status” (p. 35).

For Indigenous students in remote communities, the issue of teacher quality is compounded by the relatively high turn-over of non-Indigenous teachers, the tendency for recently arrived teachers to revisit content that may well have been mastered previously with little regard for the connections between that knowledge and the students’ lived experience, and the lack of consistent access to first language (L1) speakers who can help scaffold students’ mathematics learning beyond simple modeling and rote counting. In addition, where secondary-trained teachers in remote schools are expected to teach a particular group of students across all learning areas, many find themselves teaching upper primary and/or junior secondary mathematics without any formal training in mathematics, mathematics pedagogy and/or teaching English as a second language (Commonwealth of Australia, 2005). These issues are further compounded by the increased demand for verbal reasoning and written communication skills in mathematics as a consequence of curriculum reform initiatives (Rowe, 2002). All of which point to the critical need for well-trained, Indigenous teachers who are unlikely to move from the community and have a strong vested interest in the success of their students.

Although Mellor and Corrigan (2004) question the assumption that Indigenous teachers are more likely to adopt culturally appropriate practices than their non-Indigenous colleagues, they acknowledge the critical importance qualified Indigenous teachers and/or

teacher assistants in remote communities on the grounds that they are more likely to understand the cultural practices, language, and circumstances of students, and have long-standing and on-going relationships within the community. The inherent advantages in this can be seen in the following reflective journal entry of a first-year out Native American teacher (cited in Beaulieu, Figueira & Viri, 2005).

I know what challenges the children have ... I know that these children hold the key to the success of my Tribe’s future... I know that non-Indian teachers have never experienced racism for being Native, and I have. Nor have they experienced lack of effort on the part of their own teachers in encouraging the children to reach for the sky. Things like these make me different from non-Indian teachers and therefore my teaching is different ... I tell them that the language must be learned so that our ancestors aren’t forgotten and our culture stays intact. Their success is my success. This is how I am different from a non-Indian teacher (p. 1)

Important and necessary as this is, cultural connectedness and commitment are not sufficient to support and sustain improved numeracy/mathematics outcomes. Sound subject-matter knowledge appropriate to the level taught and a well-developed capacity to implement effective pedagogical practices are also needed (e.g., Ma, 1999; Australian Association of Mathematics Teachers, 2002). Together with a deep understanding of students as learners of mathematics as noted by Masters (2004).

Highly effective teaching depends on an understanding of individual learners, including their current knowledge and beliefs, misconceptions, incomplete understandings and naïve mental models ... If teachers are to function in this way, then they must have a deep understanding not only of the subject matter they are teaching, but also of the ways in which students typically learn that subject matter (p. 7).

However, given that the Indigenous community members most likely to contribute to schooling at the present time are also the ones who invariably take on a whole host of other community-based roles and responsibilities, the possibility of them being able to spend the time to acquire this sort of deep knowledge for teaching across each area of the school curriculum is increasingly unlikely. This suggests that it might be reasonable to explore the possibility of improving Indigenous student numeracy outcomes by means of an alternative, community-based approach to Indigenous teacher education exclusively focused on developing pedagogical content knowledge for teaching mathematics. Such an approach is consistent with the community-based notion of collective rather than individual knowledge, and the generally accepted view that not everyone needs to be knowledgeable about all aspects of community practice (Christie & Grotorex,

2004). This makes the task of contributing to schooling more manageable, and increases the likelihood of involving more Indigenous community members in the life and work of the school.

This discipline-specific, community-based approach to Indigenous teacher education was supported by the experience and findings of the *Supporting Indigenous Students' Achievement in Numeracy* project (SISAN) which was conducted by the author in collaboration with the Northern Territory Department of Employment, Education and Training (NT DEET) in 2003-4. The SISAN project was aimed at researching the impact of authentic (rich) assessment tasks on the numeracy outcomes of middle years' Indigenous students in a targeted group of remote schools. Although the rich tasks helped identify 'what works' in this context and highlighted important areas of learning need more generally (e.g., number sense and mathematical reasoning), the literacy demands of these tasks limited the extent to which they could be used to inform starting points for teaching. As a consequence, a small number of more focused tasks known as Probe Tasks were introduced<sup>3</sup> which provided a broader range of response modes and allowed teachers to identify learning needs more specifically. Participating teachers typically reported that as student responses to these tasks were more readily observed, interpreted, and matched to expected levels of performance, they felt more confident about responding to student learning needs, and as a result, more likely to positively impact student numeracy learning. This was particularly the case for the Indigenous teacher assistants and secondary-trained teachers with little/no mathematics background, suggesting that the Probe Tasks and their associated advice offered a useful means of building remote teachers' pedagogical content knowledge for teaching mathematics (Commonwealth of Australia, 2005).

### ***Mathematics knowledge keepers***

A conversation with two respected community elders at Milingimbi, an island off the coast of Arnhem Land in the Northern Territory, prompted the current research project. Both had completed their teacher training in the days when it was relatively easy to undertake periods of formal study at the Batchelor Institute for Indigenous Tertiary Education (BIITE). Now grandmothers, with considerable community responsibilities outside of school, they lamented the fact that there were very few Indigenous people to take their place, pointing to the demands on those that might be interested in teaching and the problems associated with being away from the community for extended periods of time. Given that most non-Indigenous teachers transferred or left the school after one or two years and tended to base their

teaching on the age/grade level of students and/or information that might be gleaned from a written test in English, I asked them to consider what would make a difference to remote Indigenous student numeracy outcomes in the longer term. They talked about their experience in the project and their confidence in using the Probe Tasks to identify specific learning needs in first language and direct observation of student behaviour. It occurred to me during the course of this conversation that one way of addressing the issues identified was to build local capacity to support student numeracy learning and the transfer of control over 'who does what, when' to those most likely to stay in the community. I asked them how they would feel about taking on this role more formally, that is, monitoring key aspects of student learning in mathematics in L1 and providing advice to non-Indigenous teachers about what was known and possible starting points for teaching. They both expressed their interest and enthusiasm in doing this, with one responding: "Yes that would be good ... [then, after some time and with a glint in her eye] that means we could choose who to tell" (M, February, 2004). We talked about what this would mean from a community perspective where knowledge was distributed and individuals were valued on the basis of the particular knowledge and skills they maintained and nurtured on behalf of the community. This led to the notion of 'knowledge keepers for mathematics' or 'mathematics knowledge keepers' as a means of supporting sustainable improvements in Indigenous student numeracy outcomes.

### **The Project**

Teaching informed by quality assessment data has long been recognised as an effective means of improving learning outcomes (eg, Ball, 1993; Black and Wiliam, 1998; Masters, 2004). It is also evident that where teachers are supported to identify and interpret student learning needs, they are more informed about where to start teaching, and better able to scaffold their students' mathematical learning (Clarke, 2001). However, this approach presents a challenge in remote schools where the language of instruction is not the language of the community and typical assessment tasks rarely, if ever, provide an accurate assessment of student thinking.

As indicated above, the *Building Community Capital to Support Sustainable Numeracy Education in Remote Locations* (BCC) project was established to explore an alternative, community-based model of Indigenous teacher education aimed at building local capacity to support sustainable approaches to mathematics learning in the middle years of schooling with a view to addressing the persistently low levels of remote Indigenous student achievement in mathematics beyond Year 3. It was

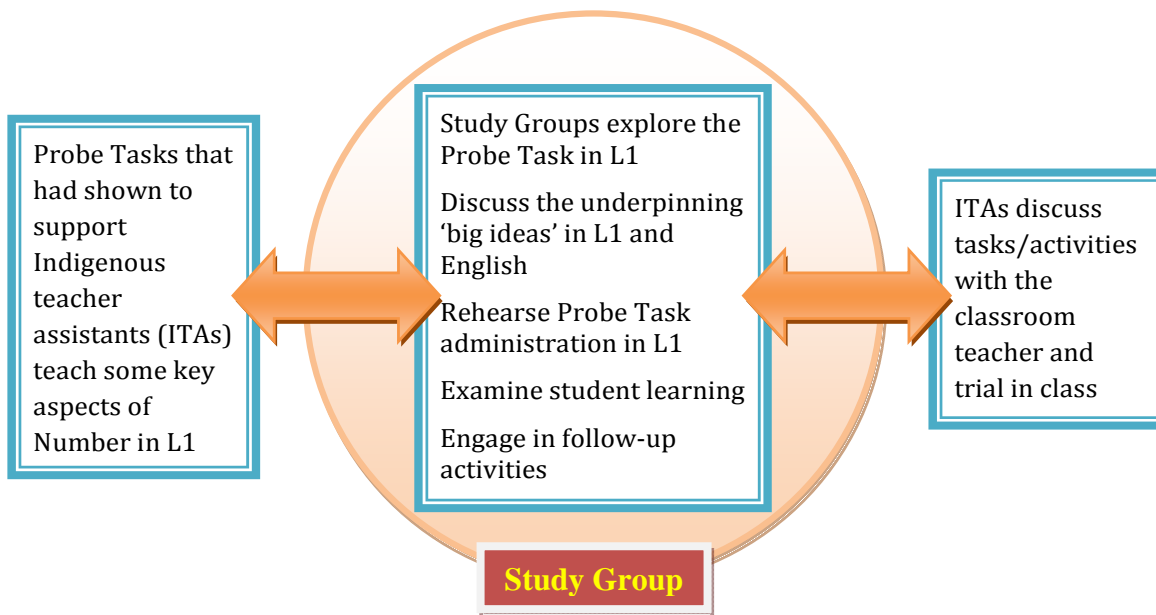


Figure 1. Schematic representation of study design

conjectured that the Probe Tasks could be used to engage volunteer Indigenous Teacher Assistants in a deeper examination of their own and their students' understanding of the 'big ideas' in Number and that by working with classroom teachers and research team members on strategies to enhance students' understanding, they would be more likely to take on the role of 'mathematics knowledge keepers'. As a consequence, the BCC project was designed to explore the following questions.

*What processes are involved in building community capital to support more sustainable and better targeted approaches to the teaching and learning of mathematics in remote communities?*

*To what extent can deep pedagogical content knowledge for teaching mathematics be developed through the use of Probe Tasks and participation in Study Groups?*

*What impact, if any, does the alternative model of Indigenous teacher education have on Indigenous student numeracy achievement?*

*To what extent can the alternative model be documented in a form that is recognized and valued by all stakeholders, including the possibility of formal accreditation?*

Two relatively recent research approaches informed the design of the study, design experiments (e.g., Brown, 1992, Cobb, Confrey, di Sessa, Lehrer & Shauble, 2003) and multi-tiered teaching experiments (Lesh & Kelly, 2000; English, 2003). Both of which accommodate a situated view of learning and acknowledge multiple elements in the process. In this instance, the design brings together a multi-disciplinary research team with expertise in mathematics education, Indigenous teacher education, the socio-cultural practices and languages of

Yolngu people, and the policies and practices of the Northern Territory Department of Employment, Education and Training<sup>4</sup>. The project is a design experiment to the extent that it has both a "pragmatic bent ... and a theoretical orientation" (Cobb, Confrey et al, 2003, p.9). The pragmatic bent is that it is focused on a particular but evolving approach to Indigenous teacher education. The theoretical orientation is evident in the intent to develop domain specific theories about the nature of the learning involved and how it came about in the context of the social settings in which it is located. The project also shares some of the features of a multi-tiered teaching experiment in that it "involves participants at different levels of development who work interdependently towards the common goal of finding meaning in, and learning from, their respective experiences" (English, 2003, p.242). The participants included volunteer Indigenous Teacher Assistants (ITAs), the classroom teachers with whom they worked, and members of the research team supported by school based linguists and/or curriculum leaders. A study group organisation was used to explore the Probe Tasks in L1, negotiate and rehearse their use with students, reflect on student thinking, and plan appropriate follow-up activities. Two Study Groups per school term were planned for the duration of the project. Figure 1 provides a schematic representation of the study design.

### *Theoretical underpinnings*

The alternative approach to Indigenous teacher education evolved from the need to support more sustainable and better targeted approaches to the

teaching and learning of mathematics in remote locations. By supporting and working with Indigenous educators and/or interested community members to become recognized 'mathematics knowledge keeper(s)' with a special regard for how best to communicate and share that knowledge with other community members, it was envisaged that the ITAs would ultimately take on a school/community leadership role in this area. For example, providing advice and direction to recently arrived non-Indigenous teachers about individual student learning and taking responsibility for decisions about where, and how to start teaching mathematics most effectively. The model has its origins in the Cognitively Guided Instruction (CGI) approach to teacher professional learning which is premised on the view that teacher's instructional decisions are shaped by their knowledge and beliefs and observations of student behaviour in response to learning opportunities (Carpenter & Fennema, 1991).

While it is acknowledged that design experiment methodology typically leaves open the issue of underpinning theory to optimize the emergence of new theory, it was felt that the particular goals and circumstances of the BCC project warranted a theoretical framing to help ensure that the very different backgrounds and perspectives of all those involved were respected in the process. As a consequence, the research was conceptually framed by a sociocultural, interactionist view of learning and development that acknowledges the importance of discourse in the shared construction of meaning both within and between different communities of practice (Clarke D, 2001; Lerman, 1998; Wenger, 1998). This approach has its origins in a situative perspective that views learning and development in terms of transformation where "the central question becomes how people participate in sociocultural activity and how their participation changes from relatively peripheral, observing and carrying out secondary roles, to sometimes being responsible for managing activities" (Rogoff, 1985, p.157).

More recently, and with specific reference to understanding student learning in classroom settings, learning has been conceptualised "as changes in participation in socially organised activities, and individuals' use of knowledge as an aspect of their participation in social practices" (Borko, 2004, p.4). The roots of this approach and indeed, the communities of practice metaphor (Lave & Wenger, 1991; Wenger, 1998) can be traced to cultural-historical activity theory (e.g., Cole & Engeström, 1993; Roth & Lee, 2007) which uses the notion of activity systems to model the complex interactions between the individual (subject) and the object of their activity as mediated within communities bound together by social rules and characterised by divisions in labour. As a consequence,

Wenger (1998) views learning as social participation, where participation refers

not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to those communities. (p.4)

A community of practice "is characterized by the shared manner in which its members act and how they interpret events" (Pawlowski, Robey, & Raven, 2000, p.331). According to Wheeler and Faris (2007), communities of practice involve people with common interest – often in a common vocation or profession – who engage in processes to share and/or acquire relevant knowledge, skills, attitudes and values, i.e., learning that informs and improves their practice. (p.1)

Wenger (1998) characterized a community of practice in terms of three dimensions of practice: a joint enterprise (what is it about), mutual engagement (how does it function), and a shared repertoire (what capability is produced). Three communities of practice are acknowledged for the purposes of the research. These will be referred to here as the Yolngu, school community, the school mathematics community, and the emergent study group community.

### *Three Communities of Practice*

The Yolngu school community includes those members of the local Indigenous community associated with the work of the main school or homeland in some way (i.e., as assistant teachers, teachers, School Councillors and/or interested others). The joint enterprise of this community is to support Indigenous student engagement in schooling. They have shared, culturally-bound ways of engaging with each other and learned ways of acting and interacting in the school context.

The school mathematics community includes all those that by virtue of their responsibilities are concerned in some way with school mathematics (e.g., classroom teachers, the school mathematics coordinator, the assistant principal responsible for curriculum). These people may undertake different tasks, and have different levels of knowledge, confidence and commitment but they contribute in some way to the joint enterprise of ensuring students are able to demonstrate increasing levels of competence in relation to school mathematics. They share general norms of participation in the school community and have shared standards by which they justifying their decisions in relation to the teaching and learning of mathematics.

The emergent study group community involves a shifting subset of the members of the two communities described above and visiting members of the research

**Table 1. The Beginning Place-Value Task*****Beginning Place-Value Probe Task***

You will need:

- 26 large kidney beans or counters in a suitable jar or container
- 7 bundles of ten icy-pole sticks and 22 loose icy-pole sticks
- paper and pen/pencil

**Empty container of beans or counters** in front of student, ask them to count the collection as quickly as possible and write down the number. Note how the count is organised.

If not 26, ask, “Are you sure about that? How could you check?”

Once student has recorded 26, circle the 6 in 26 and ask, “Does this (pointing to the 6) have anything to do with how many you have there (pointing to the collection)?” Note student’s response.

Circle the 2 in 26 and repeat the question. Note student’s response.

**Place bundles and sticks in front of the student.** Make sure student understands that they are bundles of tens and ones. Ask the student to make 34 using the materials. If they ask if they can unbundle a ten, say, “No, Is there any way you could use these (pointing to the bundles of ten) to make 34?” Note student’s response.

Remove all materials.

**Tip out container of 26 beans** and ask student to count these again and record the number. Then ask student to place beans in groups of 4 ... Once this is completed, point to the 26 that has been recorded and circle the 6. Ask: “Does this have anything to do with how many beans you have? Repeat with the 2. Note the student’s responses.

team. The members of this community are engaged in the joint enterprise of supporting Indigenous participants become mathematics knowledge keepers with the knowledge, skills and dispositions to ultimately take on a specialised role within the school and the wider community. This emergent community has a developing set of shared techniques, norms, and ways of operating based on the use of the Probe Tasks to identify and better understand student learning and targeted teaching activities to address those needs.

The use of study groups both as a space where different communities of practice can meet to negotiate shared meaning around mutually accessible cultural objects, and as a research tool to explore the processes involved in building community capital, builds on the work of Wenger (1998), Borko (2004), and Cobb, McClain et al (2003). The idea of using the Probe Tasks for this purpose was prompted by their demonstrated accessibility to Indigenous education workers in the context of the SISAN project (Commonwealth of Australia, 2005). Their conceptualisation as *boundary objects* (Wenger, 1998), around which shared understandings of key ideas in western mathematics might be negotiated and explored from different perspectives, including community numeracy practices and languages, was suggested by the experience of Christie and Greatorex (2004) in working with the notion of social capital at the interface of two communities of practice. The nature and role of the Probe Tasks as boundary objects are discussed in more detail below.

***The Probe Tasks***

In addition to their hypothesized role as boundary objects, the Probe Tasks were chosen as the focal point of the study group deliberations on the grounds that learning is enhanced when teachers pay attention to the knowledge and beliefs that learners bring to the learning tasks, use this knowledge as a starting point for new instruction, and monitor students’ changing conceptions as instruction proceeds (Bransford, Brown & Cocking, 2000, p.11)

The tasks were drawn from the research literature and/or our experience in working with ‘at risk’ middle years’ students (e.g., Siemon & Virgona, 2002). They were specifically chosen or designed to examine Year K to 6 student’s understanding of key number-related ideas and/or strategies on the grounds that differences in students capacity to work with number accounts for most of the difference in mathematics achievement in the middle years of schooling. The tasks support a range of student responses and generally require students to manipulate concrete materials and/or provide non-written responses to visual prompts (i.e., they are performance-based). They are also relatively short and easy to administer individually within the context of the classroom (i.e., they do not require withdrawal).

The original Probe Tasks focussed on subitising (recognising numbers to 5 and beyond without counting), counting (including part-part-whole understanding), place-value, partitioning, addition, and multiplication. They were prepared at three different

**Table 2. An excerpt from the Beginning Place-Value Task Advice****Beginning Place-Value Advice****Kidney Beans:**

Student responses to this task indicate the meanings they attach to 2-digit numerals. A version of this task was originally employed by Ross (1989) who identified five stages in the development of a sound understanding of place-value, each of which appears in some form in the advice below.

<b>Observed Response:</b>	<b>Interpretation/suggested teaching response</b>
Little/no response	<i>May not understand task</i> <ul style="list-style-type: none"> <li>• Check part-part-whole knowledge for numbers to 10 and capacity to recognise and use 2, 5 and 10 as composite units to count large collections</li> </ul>
Response given but not indicative of strong place-value knowledge, eg, refers to 6 ones or physical arrangement such as “2 groups of 3” for circled 6, and “twenty” for circled 2.	<i>Suggests 26 is understood in terms of ones, or 20 (ones) and 6 ones, may not trust the count of 10 or see 2 as a count of tens</i> <ul style="list-style-type: none"> <li>• Check extent to which child trusts the count for 10 by counting large collections (see Consolidating Counting Probe Task Advice above), play Trading Games</li> <li>• Practice making, naming and recording tens and ones, emphasising the count of tens in the tens place and the count of ones in the ones place.</li> </ul>
Says 6 ones and 2 tens fairly quickly	<i>Appears to understand the basis on which 2-digit numbers are recorded</i> <ul style="list-style-type: none"> <li>• Consolidate 2-digit place-value by comparing 2 numbers (materials, words and symbols), ordering/sequencing (by ordering 5 or more 2-digit numbers or placing in sequence on a rope from 0 to 100), counting forwards and backwards in place-value parts starting anywhere (eg, 27, 37, 47 (clap), 46, 45, 44, 43, ...), and by renaming (eg, 45 is 4 tens and 5 ones or 45 ones)</li> <li>• Consider introducing 3-digit place-value (see Booker, 2003 for further details)</li> </ul>

**Bundling Sticks:**

Student responses to this task indicate their understanding of place-value and the extent to which they trust the count of 10, that is, can treat 10 as a countable unit. ...

levels of understanding to support the identification of learning needs across Years K to 6. An example of one of these tasks is presented in table 2. The levels were referred to as beginning, consolidating, and establishing to avoid Year level identification. The task shown in Figure 2 was adapted from a task reported by Ross (1989) and an item in the *Early Numeracy Interview* (Victorian Department of Education, Employment and Training, 2001) which was very similar to the one used by Ross originally.

Given the positive response to the use of the Probe Tasks in the context of the SISAN Project, a Probe Task Manual<sup>5</sup> was prepared to document the advice provided in the field. The advice was organized in the form of a table that matched an observed response (left hand column) to a possible interpretation (in italics) and one or more suggested teaching responses (dot points) in the right hand column. The advice was prepared on the basis of the relevant research literature and student responses derived from mainstream classrooms and a small sample of Indigenous students from remote communities who were observed or interviewed for this purpose. An excerpt of the advice associated with the Beginning Place-Value Task is shown in table 2 below.

The Probe Task Manual that was prepared after the SISAN project was completed was aimed at supporting

classroom teachers in remote schools more generally to use the tasks to identify specific learning needs and choose developmentally appropriate activities to address those needs. Given that this form of the advice had not been ‘road-tested’, it was decided that relevant aspects would be provided on a task-by-task basis for use in the study groups with the classroom teachers. This was done on the basis of the reported efficacy of using hypothetical learning trajectories to support teacher learning (Simon, 1995) and Fennema, Carpenter, Franke, Levi, Jacobs and Empson’s (1996) observation that

There may be many ways in which teachers can come to create their own psychological models of children’s thinking that are useful ... However, starting with an explicit, robust, research-based model of children’s thinking, ... enabled almost all teachers to gain knowledge, change their beliefs about teaching and learning and improve their mathematics teaching and their students’ mathematical learning (p.433).

Where possible it was also decided to video student responses to the Probe Tasks to further support the work of the study groups.

To date, the tasks have proved useful as boundary objects in that the two established communities of practice can engage with the tasks and what they reveal



about student learning at some level and they have undoubtedly been responsible for motivating and establishing the emergent community of practice. For instance, there was evidence early on of an ITA confidently demonstrating the Subitisation and Sequencing Probe Tasks to participating classroom teachers (Study Group video, 28 August 2006) and the study group initiated and organized a Community Maths Day in November 2006. However, a number of quite challenging issues have emerged as a result of using the tasks in this way. These include the relationship of key underpinning ideas (e.g., place-value) to Yolngu ways of representing value and order in the world (e.g., the kinship system), the assumptions inherent in mandated school mathematics curriculum about learning sequences and pedagogical practices; and classroom teachers' views about their role in relation to the ITAs with whom they work. These will be discussed in more detail below along with a number of other issues that served to challenge the original design.

### ***Participants and study group organisation***

Expressions of interest in participating in the project were elicited from remote schools by NT DEET in March 2006. Initially it was thought that we would work in two remote schools but given the logistics of this (difficulties and expense of travel in remote locations, particularly in the wet season), a decision was made to work with a relatively large school site and one of its associated homeland schools. Briefing meetings were held with the leadership and teaching staff of the main school in June and plans were made for implementing the project in the second half of 2006. Given the complexities involved in setting up the study group at the main site and negotiating ways of working, it was agreed that work would not start in the homeland school until the beginning of the school year in February 2007.

In recognition of the fact that English is a second language for the vast majority of students in remote schools, NT DEET supports a trained teacher and an Indigenous assistant teacher for each K-7 classroom. Schools may vary in the extent to which they adopt a 'both ways' approach to curriculum and/or a bilingual program. In this case, both schools are recognised as bilingual schools and provide regular (usually daily) opportunities for students to engage with Yolngu language and community-based cultural practices. Qualified Indigenous teachers and ITAs take on this role, negotiating the curriculum and contributing to the preparation of appropriate resources.

As the project was aimed at exploring an alternative approach to Indigenous teacher education, expressions of interest in project participation were invited from all those Yolngu associated with the school in whatever

capacity. Indigenous School Council members were also approached with a view to securing the participation of interested community members. In the event, six of the ITAs, who were also undertaking an Indigenous Education Worker's Certificate Course offered on-site by a staff member supported in part by BIITE, agreed to participate in the project. This had an unforeseen consequence in that it 'locked in' those classroom teachers who were working with the ITAs at the time into the study group meetings. This ultimately led to some issues within the study group community itself which will be elaborated below. A comparable but smaller number of participants are involved in another Study Group at the associated homeland site.

At the outset, the study groups were designed to meet in school time for approximately 6 hours (3 sessions) every 3 to 4 weeks per term over 8 to 10 school terms (2 to 2.5 school years). The initial two and half hour session involves the Yolngu teacher assistants and at least two members of the research team, one of whom is a fluent Yolngu speaker. Whenever possible the school linguist also participates in this session. This is followed by a second session involving everyone in the first session together with the respective classroom teachers and at least one other member of the school mathematics community (usually the mathematics coordinator and/or the assistant principal in charge of curriculum). The third session, generally held on the following day, involves those who participated in the first session.

The purpose of the first session is to provide a supportive environment in which the Indigenous participants can reflect on their experiences of using the Probe Tasks and/or the targeted teaching activities in L1 (Yolngu Matha) using video and/or reports of student responses. The second session is designed as a sharing phase in which student responses and/or teaching experiences are shared in English and discussed with a view to building a shared understanding of what is involved (e.g., key ideas, strategies, implied learning need) and what might be done next (e.g., appropriate follow-up activities, questions). New Probe Tasks and/or targeted teaching activities may also be modelled and discussed at this time. The final session is designed as a planning phase in which participants 'unpack' any new Probe Tasks /activities using L1 to explore meanings and representations, engage in suggested targeted teaching activities, and discuss/explore alternatives with a view to deciding on an agreed course of action and how it might be supported.

### **Discussion of Issues**

At the time of writing this paper, we are still in the final stages of translating the videotapes and collating the



records associated with the operation of the Study Groups so my intent here is not to report findings but to outline, from my perspective, a number of issues that emerged to challenge the initial design and question our original assumptions. As observed by Cobb, McClain et al (2003), it was some time before the issues within and at the edges of the communities of practice emerged. In the initial stages, we also experienced the phenomenon noted by Grossman, Wineburg, and Woolworth (cited in Cobb, McClain et al, 2003) of “pseudo agreements that serve to mask differences in viewpoints” (p.17). While this had the effect of lulling us into a false sense of security at the time, in retrospect it was understandable given the time needed to establish agreed ways of operating and build a sufficient level of trust and confidence to support more robust forms of interaction. In what follows, I will briefly describe the issues as they emerged from my perspective. In doing this, it needs to be recognized that this is a work in progress and that many of issues described are issues because they simultaneously both afford and constrain how we organise, advance, and make sense of the work of the project. The issues are highly interrelated and their presentation as a list (not in any order) is purely a device to help clarify my thinking<sup>6</sup>. Apart from my purposes here (contributing to an emerging group of researcher’s understandings of the communities of practice metaphor and how this might be used to advance our separate fields and build bridges between them), the primary motivation for preparing this paper is to support the on-going work of the research team and study groups. Subsequent retrospective analyses from the different standpoints of all those involved may well challenge this tentative, personal, and preliminary view to offer a more informed and considered account of what we are doing and seeing.

### ***Tension between ‘starting small’ and ‘thinking big’***

In teasing out aspects of the initial design with school leadership and NT DEET representatives at the beginning of the project, a decision was made to ‘start small’. That is, after an orientation session to inform all those about the nature of the project and negotiate ways of working, it was agreed that rather than ‘roll out’ all the Probe Tasks at once and dip into these as relevant for particular classroom contexts, we would all start with the same Probe Task (in this case, the Subitizing task) as our priority was to generate a shared understanding of purpose and to maximize interaction by focusing on a common object. This was embraced by the members of the school mathematics community, accepted by the Yolngu school community, and clearly afforded the practices of the study group community at the time. However, once this community was more comfortable with what we were doing and why, the

pseudo agreement to proceed in this way that existed at the outset was challenged. The members of the school mathematics community, particularly those charged with responsibility for mathematics more generally, were keen to explore how the Probe Tasks related to the NT Mathematics Curriculum Framework and the work that had been done locally on translating a widely used interview tool into Yolngu Matha (L1). They were also focussed on preparing/sourcing an extended range of ‘activities’. At more or less the same time, and after we had started to make connections with the Indigenous community more generally, the members of the Yolngu school community were keen to explore the ‘big ideas of Western mathematics’ in relation to ‘Yolngu mathematics’ (e.g., see Cooke, 1990; Bucknall, 1995; and Marika, 1999).

This has resulted in a change to the design in that we are now working towards a ‘big picture’ and a form of representation that links the ideas implicit in the Probe Tasks to the learning sequences of the NT Curriculum Framework and, where possible, to Yolngu knowledge systems. For example, the relationship between place-value and the *rulu* system<sup>7</sup> used to ‘count’ turtle eggs (Marika, 1999). This decision will support the on-going work of the study group but it may also operate as a constraint if it reduces and reifies the ideas to the point where the meanings and representations become taken for granted and thereby less likely to be critically examined. One of the theoretical considerations that has arisen out of these deliberations concerns the ‘fiveness of five’ (Christie, 2007), an on-going and developing conversation about the relationship between individual and collective knowing and the nature of mathematics as a cultural practice.

### ***Passive resistance***

At the outset, as a consequence of the formation of the study groups, some of the classroom teachers felt ‘dragooned’ into the enterprise. With little shared experience to build on, and the expectations associated with assessment and reporting at the time (last term of the school year, 2006), it was inevitable that some of the classroom teachers involved displayed little interest in participating in the study group at the main school.

Interestingly, although the same method of participation is still being used and there has been a considerable turn-over of non-Indigenous staff in the intervening time, it appears that this is much less of an issue than it was. There are some plausible explanations for this. With time the study groups have become an established part of the ‘school furniture’, two senior members of staff are actively and visibly involved in the project, visiting research team members, particularly the two doctoral students, are well known and warmly welcomed in the school, and the school community as a

whole is arguably more aware of the aims of the project and the benefits that it brings (increased resources, a greater awareness and increased focus on the 'big ideas' in number). However, it could also be argued that this shift has come about as a result of a change in the design which re-assigned the project officer support provided by NT DEET to a school-based, support team who work one-on-one with individual classroom teachers and their teacher assistants to plan the use of the Probes and the follow-up activities.

### ***Level of support***

This is a related but more general issue to the one described above. While we recognised the diversity in the school mathematics community, we underestimated the level of support that was (and is) needed to enlist classroom teachers' participation in the study group community both as reflective practitioners and as mentors for the ITA with whom they work. For instance, when non-Indigenous classroom teachers apply and are appointed to a remote school, little is said in the process about their role in relation to the ITAs that they are expected to work with in their classroom. As a consequence, perceptions of the assistant teachers' role may vary from someone who is simply there to translate, maintain class control, and mediate disputes, to someone who is recognised as a valued colleague whose knowledge of local language and culture can be drawn upon to add value and relevance to classroom learning activities.

In addition, a number of the classroom teachers were at different places in their own knowledge and confidence for teaching mathematics compared to the mathematics coordinator and the assistant principal who had many more years experience at the school and were charged with the responsibility of supporting mathematics teaching and learning more generally. Understandably, given the manner in which the classroom teachers came to be involved in the study group at the host school, their understanding of the 'joint enterprise' and their levels of commitment to the work of the project also varied. This contributed to the decision to provide the one-on-one support to classroom teachers and assistant teachers referred to above. But it also prompted new questions that might be addressed in the context of the project. For example, the pragmatic: Is there a role for more rigorous and selective process for recruiting remote classroom teachers as advocated by Haberman (cited in Sleeter, 2001) who identified seven main attributes that enable teachers to teach effectively in culturally diverse urban schools:

persistence, willingness to work with authority on behalf of children or youth, ability to see practical application of principles and research, willingness to

take responsibility for the learning of at-risk children, a professional orientation to teaching, ability to persist within an irrational bureaucracy, and expectation of making mistakes and learning from them. (p.215)

A number of theoretical questions are also prompted by these considerations: How do complex, personal histories interact to mediate the participation of individuals in social practices? How might the communities of practice metaphor account for the "complex and often messy relationships between individuals and between individuals and communities, which contribute to shaping the very social practices in which learning is situated in these models" (Linehan & McCarthy, 2001, p.129)? Does confidence have a role in mathematics teacher learning within a community of practice as suggested by Graven (2004)?

### ***Confusion between the Probe Tasks and follow-up activities***

As the study group has evolved, and as it became clear that we needed to provide additional support for the classroom teachers, some confusion arose in relation to the distinction between the Probe Tasks and the targeted follow-up activities that were aimed at addressing the specific learning needs identified by the Probe Tasks. In part, this arose as a result of the extra activities provided by some members of the school mathematics community to support the classroom teachers (referred to above). In some instances, the relationship between these and the learning needs identified by the Probe Tasks was unclear. In other instances, the literacy demands of the activities limited their potential to address the learning needs.

Another source of confusion was that Probe Task advice advocated the use of similar materials in many of the follow-up activities. For example, the advice associated with the Subitising Probe Task advocated the use of an expanded range of subitisation cards. Although these were printed, laminated and made available to classroom teachers, there have been instances where either the teacher or the ITA have used the subitisation cards from the Probe Task kit for the purposes of a whole class activity (Classroom Video, November 2006). This is not particularly important, but it has the potential to diminish the value of the Probe Tasks as an assessment tool in the longer term. On the other hand, the fact that classroom teachers and assistant teachers have appropriated certain aspects of the Probe Tasks as teaching activities (e.g., the subitisation cards, open number lines, and ordering number activities using rope, pegs, and cards) can also be viewed as evidence of the affordances offered by the Probe Tasks and their efficacy as boundary objects in stimulating discussion and building a shared repertoire of teaching strategies. It is interesting that, in the first

instance, this issue was identified and responded to by those members of the study group community charged with responsibility for mathematics more generally (the mathematics coordinator and the project officer from NT DEET). Their individual representations of the relationship of the Probe Tasks to the activities and the NT Mathematics Curriculum in the form of two quite different tables (Project artefacts, February 2007) reflected their different roles within the study group at the time and their respective understanding of the joint enterprise, but it also afforded a productive discussion among the study group community more widely which led to the decision to prepare a poster that would connect the Probe Tasks and activities to the 'big ideas' referred to earlier.

### *Division of Labor*

Role diversity is to be expected in communities of practice but a tension arises when, with the very best of intentions (e.g., increasing tool accessibility, elaborate the 'big ideas'), the activity of one or more individuals in a community of practice serves to 'fill the participatory space' leaving little or no room for more marginalized members of the community to transform the nature of their participation. An example of this is when those members who justifiably view themselves as participants in a broader community of mathematics educators, prepared a number of tools, resources aimed at 'making the task of maintaining student responses easier' for the Indigenous participants (Project artefacts, March 2007). Another example is when, in the context of an interactive discussion of the 'big ideas', I failed to leave sufficient silences for others to grapple with the ideas and offer their suggestions (Study Group Video, July 2007).

Acting with the best of intentions but in a way which limits participation, is also evident among Indigenous members of the study group community who have been observed in the context of conducting a Probe Task interview to shift from a focus on probing students' understanding to directly telling and/or modelling to ensure that the student is not shamed and experiences a measure of success (Classroom videos, June, 2007, February 2008).

This points to the need to engage more openly and reflectively on how and why we act in certain ways and the impact of this on other members of the community. While this prompts the same sort of questions that were raised under the issue of level of support above, it also raises the more general question of how identity and agency operate within activity systems to marginalise and/or position community members in ways which restrict or enhance their participation in the social practices of the community?

## CONCLUSION

Various attempts have and are being made to improve the educational outcomes of remote Indigenous Australians. There are many reasons for the relative lack of success of these initiatives and programs but two of the most significant are that we fail to recognise the enormous complexity involved in working across cultural and linguistic divides, and we grossly underestimate the resources required to bring together the sort of multi-disciplinary teams that might work collaboratively and interactively over whatever time it takes to address the inherent issues involved.

While very few of the issues referred to here are entirely unexpected, what they point to is the value of conceptualising complex learning sites as activity systems involving multiple communities of practice. Although this represents a tentative and incomplete account of the work of the BCC project, I believe it demonstrates the power of sociocultural theory (e.g., Wenger, 1998; Roth & Lee, 2007) and the value of design experiments (e.g., Lesh, & Kelly, 2000; Cobb, Confrey et al, 2003) in accommodating significant shifts in circumstances and modifying design elements. It also demonstrates the need for analytical approaches which enable us to disentangle the complex relations and interactions involved and reconsider underpinning theories. For example, framing cultural objects at the intersection of the communities of practice as boundary objects is helpful but it is the reframing of issues at the intersection of communities of practice as *boundary encounters*, and *people* at the intersection of communities of practice as brokers (Cobb, McClain et al, 2003, p. 13) that might ultimately prove to be the most valuable shift in our understanding of our collective experience.

In this contribution, I have outlined the design and methodological approach that is being used in the BCC Research Project, which is aimed at investigating an alternative, community-based model of Indigenous teacher education in remote Australia. A range of issues within and between communities of practice have been identified which illustrate the advantages of a design research approach to this type of research. In doing this, both the strengths and some of the limitations of a communities of practice approach have been highlighted.

---

### Notes:

1. *The Building Community Capital to Support Sustainable Numeracy Education in Remote Locations Project (BCC Project) is funded by the Australian Research Council and the Northern Territory Department of Employment, Education and Training. The views expressed are the author's and not necessarily those of the funding bodies.*

2. *The relationship between school mathematics and numeracy remains unresolved. However, for most practical purposes (e.g., the implementation of centrally funded programs to improve numeracy outcomes), the primary responsibility for numeracy education is seen to reside with school mathematics. For the purposes of the BCC project, numeracy education was seen to be best served by focusing on a small number of underpinning mathematical concepts and skills that could be considered in L1. This supports the view that numeracy is a "fundamental component of learning, performance, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of underpinning mathematical concepts and skills, ... mathematical thinking and strategies; general thinking skills; and a grounded appreciation of context"* (Department of Education Training & Youth Affairs, 1997, p. 15, emphasis added).
3. *The Probe Tasks were originally developed for the purposes of primary pre-service teacher education at RMIT University (Siemon, 2003). In particular, they were designed to meet the learning needs of graduate entry students who could not be expected to be familiar with the extended numeracy interview protocols used in schools at the beginning of the year.*
4. *Respectively, Professor Dianne Siemon (Project Director), Mr Tom Evison (Deputy Director, Bachelor Institute for Indigenous Tertiary Education), Associate Professor Michael Christie (Charles Darwin University), Ms Debbie Efthymiades (Manager, Curriculum Services, NT DEET), and for the first year of the project Ms Jan McCarthy (Numeracy Project Officer, NT DEET). In addition the project is supporting two full-time doctoral students, Ms Christine Walta whose interest is the identity and agency of the adult Indigenous participants in relation to school mathematics and Ms Kathryn McMahon, an experienced teacher of Indigenous students and Yolngu speaker, who is interested in the role of language and culture in the joint enterprise. I acknowledge their contributions and conversations in the preparation of this paper, although the views expressed are not necessarily representative of the views of the team.*
5. *See Commonwealth of Australia (2005, Appendices)*
6. *I am aware that in labeling the issues in this way, there is a danger in misrepresenting or masking their inherent complexity. The labels serve as markers of a particular impression/viewpoint at the time of writing. The reader is invited to ignore these if they feel they are getting in the way.*
7. *A rulu is the Yolngu word for five turtle eggs arranged in the sand so that four eggs are on the bottom and one is on the top. The use of 'rulu' with the number names for one to four, represented here within the limitations of the Times Roman font (e.g., 'wanggany rulu' meaning 1 five, 'marrma rulu' meaning 2 fives, and so on), suggest a quinary number system, where numbers such as 23 are referred to in terms of the number of fives and the number of ones (e.g., 'dambumirin rulu ga lurrkan' meaning 4 fives and 3).*

## REFERENCES

- Australian Association of Mathematics Teachers. (2002). Standards for excellence in teaching mathematics in Australian Schools. Adelaide: AAMT.
- Ball, D. (1997). What do students know? Facing challenges of distance, context, and desire in trying to hear children. In B. Biddle, T. Good & I. Goodson (Eds.), *International Handbook of Teachers and Teaching* (Vol.2, pp.681-768). Dordrecht: Kluwer Academic.
- Beaulieu, D., Figueira, A. & Viri, D. (2005, November). Indigenous teacher education: Research-based model. Paper presented at the annual meeting of the Australian Association for Research in Education, Parramatta, Australia.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain, *Educational Researcher*, 33(8), 3-15.
- Bransford, J., Brown, A., & Cocking, R. (2000). How people learn: Brain, mind, experience and school. Expanded Edition. Washington: National Research Council.
- Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, 2(2), 141-178.
- Bucknall, G. (1995). Building bridges between aboriginal and western mathematics. *The Aboriginal Child at School*, 23(1), 21-32
- Carpenter, T. & Fennema, E. (1991). Researching cognitively guided instruction. In E. Fennema, T. Carpenter, & S. Lamon (Eds.), *Integrating research on teaching and learning mathematics*. (pp. 1-17). Albany, New York: State University of New York Press.
- Christie, M., & Greatorex, J. (2004). Yolngu life in the Northern Territory of Australia: The significance of community and social capital. *Asia Pacific Journal of Public Administration*, 26(1), 55-69.
- Christie, M. (2007, June). The fiveness of five. Unpublished paper presented to the Extended Research Team Meeting, Darwin.
- Clarke, D. (2001). Perspectives on practice and meaning in mathematics and science classrooms. Dordrecht: Kluwer
- Cobb, P., Confrey, J., di Sessa, A, Lehrer, R., & Schauble, L. (2003). Design experiments in educational research, *Educational Researcher*, 32(1), 9-13.
- Cobb, P., McClain, K, de Silva Lamberg, T., & Dean, C. (2003). Situating teachers' instructional practices in the institutional setting of the school and district, *Educational Researcher*, 32(6), 13-24.
- Cole, M. & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Solomon (Ed.), *Distributed Cognitions – Psychological and educational considerations*. New York, NY: Cambridge University Press
- Commonwealth of Australia. (2005). Supporting Indigenous Student Achievement in Numeracy - NT Strategic Numeracy Research and Development Project 2003-2004. Canberra, ACT: Department of Education Science and Technology
- Cooke, M. (1990). Seeing Yolngu, Seeing Mathematics. Retrieved 22 February 2008 from

- [http://www1.aiatsis.gov.au/exhibitions/e\\_access/mnsc\\_rpt/m0069594/m0069594\\_a.htm](http://www1.aiatsis.gov.au/exhibitions/e_access/mnsc_rpt/m0069594/m0069594_a.htm)
- Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. Education Policy Analysis Archives. <http://epaa.asu.edu/epaa/v8n1>.
- Department of Education, Training and Youth Affairs (DETYA). (1997). Numeracy = Everyone's Business. Adelaide: AAMT
- Efthymiades, D., Roberts, J., & Morony, W. (2000). Numeracy development of Indigenous students: An introduction to research. In Australian Council for Educational Research (Ed.), Improving numeracy learning – Research Conference 2000 Proceedings (pp. 3-5). Melbourne: ACER.
- English, L. (2003). Reconciling theory, research, and practice: A models and modeling perspective. Educational Studies in Mathematics, 54(2&3), 225-248
- Fennema, E., Carpenter, T., Franke, M., Levi, L., Jacobs, V. & Empson, S. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. Journal for Research in Mathematics Education, 27(4), 403-434
- Frigo, T., & Simpson, L. (2001). Research into the numeracy development of Aboriginal students: Implications for NSW K-10 mathematics syllabus. Melbourne: Australian Council for Educational Research.
- Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. American Educational Research Journal, 38(4), 915-945.
- Graven, M. (2004). Investigating mathematics teacher learning within an in-service community of practice: The centrality of confidence, Educational Studies in Mathematics, 57, 177-211.
- Hattie, J. (2003, November). Teachers make a difference: What is the research evidence? Paper presented at the annual conference of the Australian Council for Educational Research, Melbourne, Australia
- Howard, P., Perry, B., Lowe, K., Ziemis, S., & McKnight, A. (2003). Mathematics in Indigenous contexts: A case study. In L. Bragg et al (Eds.), Proceedings of the 26th annual conference of the Mathematics Research Group of Australasia, (pp.436-443). Geelong: MERGA.
- Ladson-Billings, G. (1994). The Dreamkeepers: Successful teachers of African American children. San Francisco, CA: John Wiley
- Lamb, N, Arizmendi, W., Stewart-Dore, N., & Danaher, P. (2002). Beyond Aboriginalism and culturalism in building an indigenous-teacher life-long learning community: Lessons from a Torres Strait Islander distance education program. Paper presented to the International Lifelong Learning Conference, Queensland University
- Lave, J. & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge, MA: Cambridge University Press
- Lerman, S. (1998). Research on socio-cultural perspectives of mathematics teaching and learning. In A. Sierpiska & J. Kilpatrick (Eds.), Mathematics education as a research domain: A search for identity (Vol. 1, pp. 333-350). Dordrecht: Kluwer.
- Lesh, R., & Kelly, A. (2000). Multitiered teaching experiments. In A. Kelly & R. Lesh (Eds.), Handbook of research in mathematics and science education (pp.197-230). Mahwah, NJ: LEA.
- Linehan, C & McCarthy, J. (2001). Reviewing the 'Community of Practice' metaphor: An analysis of control relations in a primary school, Mind, Culture and Activity, 8(2), 129-147.
- Ma, L. (1999). Knowing and teaching elementary mathematics – Teachers' understanding of fundamental mathematics in China and the United States. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
- Marika, R. (1999). The 1998 Wentworth Lecture. Australian Aboriginal Studies, 1(3), 3-9.
- Master, G. (2004 October). Continuity and growth: Key considerations in educational improvement and accountability. Paper presented at the joint Australian College of Educators and Australian Council for Educational Leaders National conference, Perth, Western Australia.
- Mathews, S., Howard, P. & Perry, B. (2003). Working together to enhance Australian Aboriginal students' mathematics learning. In L. Bragg, C. Campbell, G. Herbert, & J. Mousley (Eds.), Proceedings of the 26th Annual Conference of the Mathematics Education Research Group of Australasia (pp.17-28). MERGA: Geelong
- Mellor, S., & Corrigan, M. (2004). The case for change: A review of contemporary research on Indigenous education outcomes. Australian Education Review, 47. Melbourne: ACER.
- Partington, G. (1998). Perspectives on Aboriginal and Torres Strait Islander education. Tuggerah, NSW: Social Science Press.
- Pawloski, S., Robey, D., & Raven, A. (2000). Supporting shared information systems: Boundary objects, communities, and brokering. Proceedings of the 21st international conference on information systems (pp.329-338). Brisbane: Association for Information Systems.
- Perso, T. (2003). Improving Aboriginal Numeracy – A book for education systems, school administrators, teachers, and teacher educators. Perth, WA: MASTEC
- Rogoff, B. (1995). Sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In J. Wertsch, P. del Rio & A. Alvarez (Eds.), Sociocultural Studies of Mind (pp.139-164). New York: CUP
- Ross, S. (1989). Parts, wholes, and place-value: A developmental view. Arithmetic Teacher, 36(6). 47-52.
- Roth, W. & Lee, Y. (2007). 'Vygotsky's neglected legacy': cultural-historical activity theory, Review of Educational Research, 77(2), 186-232.
- Rowe, K. (2002). The importance of teacher quality. Issues Analysis, No. 22, February. Retrieved 12 December, 2007 from <http://www.cis.org.au/IssueAnalysis/ia22/IA22.htm>
- Siemon, D. (2003) Probe Tasks to identify starting points for teaching number. Unpublished course material. Melbourne: RMIT University.
- Siemon, D., & Virgona, J. (2002). Reflections of the Middle Years Numeracy Research Project – Is it a case of too

- much too soon for too many? In M. Pfannkuch et al (Eds.) Mathematics Education in the South Pacific - Proceedings of the 25th annual conference of the Mathematics Education Research Group of Australasia (Vol.2, pp. 617-624). Auckland, NZ: MERGA
- Simon, M (1995) Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, 26(2), 114-145
- Sleeter, C. (2001). Epistemological diversity in research on pre-service teacher preparation for historically underserved children. *Review of Research in Education*, Vol. 25, pp.209-250
- Thomson, S. & De Bortoli, L. (2008). Exploring scientific literacy: how Australia measures up: the PISA 2006 survey of student's scientific, reading, and mathematical literacy skills. Camberwell, Vic: Australian Council for Educational Research
- Victorian Department of Education, Employment and Training. (2001). *Early Numeracy Interview Booklet*. Melbourne: Communications Division, DEET
- Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge, UK: Cambridge University Press.
- Wheeler, L. & Faris, R. (2007). *Defining Learning Communities*, Unpublished discussion paper, RMIT University, September.
- York, F., & Henderson, L. (2003). Making it possible: The evolution of RATEP – A community-based teacher education program for Indigenous peoples. *The Australian Journal of Indigenous Education*, 32, 77-84.

