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Early childhood mathematics education research is burgeoning in Australasia. This chapter highlights and critiques key research in the area that has been published between 2004 and 2007. In particular, it considers specific mathematical topics such as number and numeracy, space and measurement, and structure and patterning; contextual matters such as links among home, school, prior-to-school settings and community, indigenous learners and mathematics learning as children start school; assessment of mathematics learning in early childhood settings and the professional development of early childhood teachers of mathematics. It concludes with some suggestions for fruitful areas of future research.

Key words: assessment, contexts, early childhood, indigenous, number, numeracy, professional development, transition to school

INTRODUCTION

The internationally accepted definition of early childhood refers to the period of a child's life between birth and age 8 years (Bredekamp & Copple, 1997; OECD, 2001). In this chapter, we adhere to this definition by including reference to studies in mathematics education research which refer, exclusively or at least substantially, to children in this age range, their educators or the contexts in which the children learn mathematics.

Since the publication of the previous MERGA Review of Research (Perry, Anthony, & Diezmann, 2004), the impetus and focus of Australasian early childhood mathematics education research has strengthened and broadened. One of the impacts of this has been the involvement of Australasian early childhood mathematics education researchers in national and international reviews of research (for example, Anthony & Walshaw, 2007; Fox, 2007; Mulligan & Vergnaud, 2006; Perry & Dockett, in press; Young-Loveridge & Peters, 2005) and special issues of international journals such as Early Childhood Research Quarterly and Mathematics Education Research Journal. Another perspective on change can be seen in the efforts Australasian mathematics education researchers have made to have their work published not only in mathematics education research journals but also in more generic early childhood research journals. This has broadened the impact of their work.

Another aspect of the broadening of impetus and focus has been the increased diversity of early childhood mathematics education fields in which Australasian researchers are working. While the influence of systemic numeracy programs in
the early years of school can still be seen in the directions of this research, changes in emphasis towards, for example, early algebra development, assessment and mathematics learning in the years prior-to-school have been added to the collective repertoire of Australasian early childhood mathematics education researchers. However, not only has the breadth of early childhood mathematics education research increased. Recognition of key Australasian researchers by international journals and publishers suggests that the quality of their work is also on the march.

The aim of this chapter is to highlight and critique key Australasian early childhood mathematics education research published between 2004 and 2007. The chapter seeks to incorporate what the authors see as the key research directions in the field over the stated period of time. It is divided into subsections covering specific mathematical topics; contextual matters such as links among home, school, prior-to-school setting and community, indigenous learners and mathematics learning as children start school; assessment of mathematics learning in early childhood settings and the professional development of early childhood teachers of mathematics.

NUMBER AND NUMERACY

Systemic numeracy programs (particularly Count Me In Too (CMIT) and Early Numeracy Research Program (ENRP) in Australia and the Early Numeracy Project (ENP) in New Zealand) continue to have major impact both on the mathematics learning of young children and early childhood mathematics education research in New Zealand and Australia (Bobis et al., 2005; Wright, Stanger, Stafford, & Martland, 2005; Young-Loveridge & Peters, 2005).

Analysis of the extensive database collected by ENRP (for example, Clarke, Clarke, & Horne, 2006; Gervasoni, 2004a, 2004b, 2005, 2006; Horne & Levy, 2006) has continued to provide insights into young children’s numeracy development. Clarke, Clarke and Horne (2006) use this database as the foundation of a longitudinal study of children’s mental computation strategies as they move through primary school. They suggest that in spite of the gains younger children make through adopting efficient mental strategies for computation in the first years of school, a significant proportion of them still rely on inefficient counting strategies to solve arithmetical problems mentally in the upper years of primary school.

Horne and Levy (2006) consider the development of place value knowledge in Year 1 children. By analysing data from 200 children, they report that 75% of the children could read and order at least two-digit numbers, 60% could write them on a calculator and 37% could interpret them in terms of a tens structure. The authors were concerned about whether the children who did display knowledge of all four aspects of place value might “have to mark time” in later years as they were already ahead of the grade-based curriculum. They were also concerned about the likely learning trajectories of children who did not display the four aspects of place value knowledge.
The considerable body of work that Gervasoni has built from her involvement in ENRP is concerned with children who are vulnerable in their number learning. Using the notion of on the way growth points (Gervasoni, 2004a, 2004b), vulnerable children from Years 1 (n=576) and 2 (n=679) were identified from the ENRP database. Their vulnerability in the domains of counting, place value, addition and subtraction and multiplication and division was determined and it was found that there was great diversity among the identified vulnerable children in terms of their learning needs:

... children who are vulnerable in aspects of learning school mathematics have diverse learning needs, and this calls for particular customized instructional responses from teachers. It is likely that teachers will need to make individual decisions about the instructional approach for each child, and that there is no 'formula' that will meet all children's instructional needs. Further, the diversity of children's mathematical knowledge in the four domains suggests that knowledge in any one domain is not necessarily prerequisite for knowledge construction in another domain. (Gervasoni, 2004b, p. 253)

After identifying vulnerable children from the entire ENRP cohort, Gervasoni (2005, 2006) chose 42 Year 1 and 60 Year 2 children to undertake a mathematics intervention program. Many of these vulnerable children were unable to use efficient reasoning-based strategies and often relied on count-all to solve addition tasks. Of particular concern was that many of the Year 2 children seemed to have already entrenched these inefficient strategies, making successful intervention quite difficult, or, at least, suggesting that initial intervention at Year 1 might be more profitable for these children than waiting for intervention in Year 2.

Gervasoni's work has been extended to incorporate using the numeracy development of primary school children to inform the professional development of teachers in the Ballarat Diocese of the Catholic education system (Gervasoni, Hadden, & Turkenburg, 2007). Data have confirmed earlier findings highlighting the diverse mathematical learning needs of young children.

New Zealand's Numeracy Development Project (NDP) is a collective term encompassing the four individual projects catering for students at different points in their schooling (Early Numeracy Project (ENP) for students in Years 0-3, Advanced Numeracy Project (ANP) for students in Years 4-6, Intermediate Numeracy Project (INP) for students in Years 7-8, and Secondary Numeracy Project (SNP) for students in Years 9-10). Initially each of the individual projects comprising the NDP was evaluated annually (for example, Higgins, 2004; Irwin, 2004; Thomas & Tagg, 2004). However, since 2005, the quantitative data sent by primary school teachers to a secure website (i.e., ENP, ANP, & INP data) have been analysed by one researcher (Young-Loveridge, 2005).

Thomas and Tagg (2004) reported on data from more than 31,000 students in Years 0-3 (5 to 8-year-olds) in English-medium schools. While 20% of students at the end of Years 0-1 were able to use counting on or back to solve addition and subtraction problems, by the same time in Year 2 this had increased to 58%.
Fifteen percent of Year 2 students were able to use part-whole strategies to solve simple addition and subtraction problems and this increased to 41% by the end of Year 3. Students' proficiency with strategies varied as a function of ethnicity and socio-economic status (as reflected in the decile ranking of the school: decile 1 – schools serving the lowest 10% of the population in terms of income and education, decile 10 serving communities with the highest levels of education and income). The Asian and European cohorts had the greatest proportion of students using higher-level strategies (e.g., 26% and 22% using simple part-whole strategies, respectively), while Māori and Pasifika cohorts had the least students at this stage (13% and 8%, respectively). Similarly, 24% of students in high-decile schools were using part-whole strategies compared with only 13% of those in low-decile schools. Age was a factor as older students tended to make greater progress on the number framework central to NDP than younger students. Gender was an issue at higher stages on the framework, where boys made slightly greater progress than girls. As well, in the higher stages of the framework, European and Māori students made greater progress than Pasifika students.

Young-Loveridge (2004b) reported on an analysis of data collected from more than 200,000 students between 2001 and 2003. Her analysis showed that while all students benefited from participating in NDP, regardless of ethnicity, gender and socio-economic status, the relative differences between subgroups were virtually identical at the end of the project, and, if anything, there was a slight widening of the various ‘gaps’. European and Asian students tended to make greater progress on the framework than did Māori or Pasifika students. At lower stages on the framework, girls made slightly better progress than boys. Students at higher decile schools started the project at higher framework stages than those at low- and medium-decile schools, and made larger gains over the course of the projects. Ethnicity, gender, and socio-economic status had a combined effect on students' performance and progress, with being a female Māori or Pasifika student attending a low-decile school more disadvantageous than any one of those factors on its own.

The New Zealand Ministry of Education has introduced many Schooling Improvement Projects – “planned interventions designed to raise overall academic achievement of targeted students. … A priority group of students in New Zealand targeted for involvement in schooling improvement are Māori (New Zealand’s indigenous people) and Pasifika in origin” (Annan, 2007, p. 116), many of whom are students at low-decile schools. NDP clearly has a Schooling Improvement Project perspective. For example, Young-Loveridge (2005) noticed that students at low-decile schools in 2004 who began NDP at lower stages on the framework made greater progress than comparable students from medium- and high-decile schools. Effect sizes (calculated by comparing younger students after the project with slightly older students before they began the project) were almost half a standard deviation for multiplication/division and proportion/ratio, and about a quarter of a standard deviation for addition/subtraction.

Heirdsfield and her colleagues (Heirdsfield, 2005; Heirdsfield & Cooper, 2004a, 2004b; Heirdsfield, Dole, & Beswick, 2006; Heirdsfield & Lamb, 2005, 2006a, 2006b) have used extensive small-scale case studies to explore the development of
mental addition and subtraction strategies in young children as an alternative to what is felt to be the too early introduction of written algorithms. Through the introduction of mental computational practices and teacher development around these practices, strong advances have been made not only in the accuracy of young children's calculations but also in the sophistication and flexibility of their methods (Heirdsfield & Lamb, 2005).

The diversity of mental computation skills, approaches and needs among young learners has also been explored by Heirdsfield and her colleagues (Heirdsfield & Cooper, 2004a; Heirdsfield et al., 2006; Heirdsfield & Lamb, 2006a). As in Gervasoni's (Gervasoni, 2005; Gervasoni et al., 2007) work, a wide diversity in skills and knowledge was described as was the reliance on inefficient counting strategies by many 'at risk' mathematics learners.

The nature of numeracy in the early childhood years has been explored by a number of researchers (Howell & Kemp, 2005; Killdeer & Yelland, 2005; Wood & Frid, 2005; Young-Loveridge, 2004a). Using a modified Delphi procedure with a small group of Australasian academics published in early mathematics or in the study and development of number sense, Howell and Kemp sought consensus on the skills comprising number sense as children start school. In the first round of the procedure, 24 of the 25 skills listed were rated by the 'experts' in the range 'strongly agree' to 'strongly disagree', suggesting that there was little agreement. In Round 2 of the procedure, there was still a lot of disagreement. The authors conclude that:

... it is essential to establish exactly which skills reflect number sense and whether or not these skills can be effectively taught. The lack of genuine consensus reached in the present study raises questions about the emphasis currently being placed on number sense within curriculum documents. Without a clear definition of number sense it may be that current assessment and teaching practices are premature in their claim to reflect number sense. (Howell & Kemp, 2005, p. 568)

Wood and Frid (2005) examined numeracy teaching and learning practices in a multiage (pre-primary to Year 2) classroom. Through extensive observation, including video and audio records, over almost 5 months, Wood and Frid (2005, p. 96) noted that "the key numeracy teaching and learning practices that emerged as themes in this case study of a multiage early childhood classroom were: teacher planning, teacher 'assisted performance', peer sharing and tutoring, and peer regulation". Further, they noted that the multiage grouping of the students did not, of itself, support learning. "Rather, effective learning was dependent upon the teacher's capacities to develop productive discussion among children, as well as implement developmentally appropriate curricula that addressed the needs of the different children" (Wood & Frid, 2005, p. 80).

In New Zealand, before the introduction of a system-wide initiative in numeracy, Young-Loveridge (2004a) explored the effectiveness of a program designed to improve the number skills of 5-year-olds from low-decile schools by using number books and games with pairs of children guided by an expert teacher.
The numeracy levels of children who participated in the program increased significantly and showed an effect size of almost two standard deviations. Fifteen months after the program ceased the effect size had reduced to half a standard deviation but the advantage for the children who had participated in the program remained statistically significant.

By filming 10 Prep grade children from a Melbourne school for a day in their school lives, Killdeer, and Yelland (2005) have been able to analyse the children’s school activities in terms of the mathematics skills and knowledge that they used and the ways in which they used these. The “Prep children were observed applying their numeracy skills in a range of activities throughout the school day” (Killdeer & Yelland, 2005, p. 117). Beyond the diversity of the nature of these numeracy experiences is the realization that, inter alia, “ICT provides meaningful contexts in which young children’s numeracy explorations are possible and they can support children to ‘form strong, valid mathematical ideas’ (Clements, 2002, p. 165) as well as improve the children’s ICT literacy and skills” (Killdeer & Yelland, 2005, p. 120). Not only do ICT enhance the possibilities for children learning expected numeracy ideas, they also provide opportunities to learn different mathematical ideas and to apply these in their lives.

**SPACE AND MEASUREMENT**

Clarke (2004) outlined the importance of the ENRP framework of growth points within the space or geometry area through linking it to the work of van Hiele (1986) and the database of ENRP outcomes from both children and teachers. She showed exploration, investigation and instruction based upon experiences informed by the framework could result in a significant growth in children’s understanding of geometric ideas. Clarke (2004) also emphasized the need to ensure that children explore the properties of a range of shapes rather than spending most of their geometry learning time “naming large numbers of formal geometric shapes” (p. 124). The importance of children investigating shapes in their environment and discussing why certain shapes are used for certain functions was also emphasized. Just as has been the case in working with number, the ENRP framework of growth points for geometric learning has facilitated the analysis of children’s learning and provided guidance for the teaching of geometric concepts.

Curry and Outhred (2005) considered pedagogical links among the measurement of length, area, and volume. As part of the development of the *Count Me Into Measurement* program, they designed and implemented a 45-minute clinical interview to 96 Year 1-4 students in Sydney schools. The interview was designed to assess students’ knowledge of the measurement of length, area and two aspects of volume – filling and packing. Important findings included the following:

... students were able to measure volume by filling as well as they did length, using a similar unit iteration procedure; measurement of length was not a prerequisite for measurement of area, partly because both seem to be affected by a general tendency towards precision in recording the unit iteration; and understanding of the unit structure for area provides the foundation for
understanding measurement of volume by packing. (Curry & Outhred, 2005, p. 271)

The consequences of these findings for the teaching of length, area and measurement are significant. The differences in understandings of the two aspects of volume measurement suggest that packing be introduced to students much later than filling which, on the basis of this study, could be introduced at the same time as length. These findings indicate that there may need to be consideration of curriculum changes in the order of introduction of certain measurement concepts.

A cross-cultural study by Irwin, Vistro-Yu, and Ell (2004) also considered young children’s measurement of length. Through interviews with 48 children aged 8 and 9 years from the Philippines and 43 children of the same age from New Zealand, the authors have been able to make cross-cultural comparisons as well as investigate the relationships between the children’s informal and formal measurement experiences. Using a specifically constructed interview schedule consisting of five tasks, Irwin et al. illustrated the importance of prior experiences on children’s measurement of length, with a striking example from the Filipino children of the impact of their rounding of monetary transactions to include only whole numbers on their tendency to round their measurement of a length to the whole number of centimetres. Other differences in the student’s performance on the measurement tasks may be related to differences in curricula. For example, students from both countries achieved equally on tasks requiring the use of a standard measuring tool but Filipino children were not as successful as the New Zealand children on tasks requiring visualisation. The authors emphasise the importance of informal measurement experiences and lament the lack of these experiences in both countries. While agreeing with Irwin et al. concerning the importance of informal experiences as children learn about various measurement concepts, Curry and Outhred (2005) suggest that the choice of particular informal units that reflect the property being measured is critical as is the order in which experiences are encountered.

STRUCTURE AND PATTERNING

A group of researchers based at Macquarie University has implemented the Australian Pattern and Structure Mathematics Awareness Program (PASMAP) with the broad aim of describing “general characteristics of structural development and how pattern and structure are integral to [mathematical] concept development” (Mulligan, Mitchelmore, & Prescott, 2006, p. 4-209). Through interventions with both prior-to-school and school learners, PASMAP has developed a framework of broad stages of structural development (Mulligan, Mitchelmore, & Prescott, 2005) and an individual interview assessment instrument – Pattern and Structure Assessment (PASA) – which is very highly correlated with these stages (Mulligan, Mitchelmore, & Prescott, 2006). Through both intervention and longitudinal studies (Mulligan, 2007; Mulligan, Mitchelmore, & Prescott, 2006; Mulligan, Prescott, Papic, & Mitchelmore, 2006), the relevance of pattern and structure to young children’s mathematical development has been indicated:
It is not conclusive from our data whether the awareness and appropriate use of pattern and structure is a good predictor, or a consequence of, successful acquisition of basic mathematical concepts and skills. ... Our findings support our initial hypothesis that the more a child’s internal representational system has developed structurally, the more coherent, well-organised, and stable in its structural aspects will be their external representations, and the more mathematically competent the child will be. (Mulligan, Mitchelmore, & Prescott, 2006, pp. 4-213-4-214)

Two researchers have investigated patterning in prior-to-school settings both for its own sake and as a possible pre-cursor to the development of algebraic reasoning (Fox, 2005, 2006; Papic & Mulligan, 2005, 2007; Waters, 2004). Based in the research of PASMAP, Papic and Mulligan (2005, 2007) have investigated the development of patterning skills in two groups of children (total n=53) in two ‘matched’ preschools. One of the groups of children participated in a six month intervention promoting these patterning skills while the other group acted as a non-intervention control. Individual interviews were used to assess the children’s patterning skills on eight separate tasks both before and after the instructional intervention. On the pre-intervention assessment, the children in the non-intervention group were more successful than the intervention group on all but one of the tasks. However, after the intervention, the intervention group was more successful than the other group on all the tasks. Further assessment after a year of schooling has shown that this trend has been maintained (Papic & Mulligan, 2007).

In her initial investigation of patterning in early childhood settings, Waters (2004) observed patterning experiences in two settings in Brisbane. While she saw patterning experiences – both teacher- and child-initiated – in both settings, she also observed a number of instances where the possibility of discussion about patterns was missed by the teachers. She concludes that there is a need to enhance prior-to-school teachers’ knowledge of patterning and skills in both planning for patterning experiences and eliciting discussion about patterning from young children. In follow-up analyses of her data, Fox (previously publishing as Waters) considers both child-initiated (Fox, 2005) and teacher-initiated (Fox, 2006) patterning experiences in the two settings. She concludes that “child-initiated experiences can be powerful learning opportunities with the potential to develop children’s knowledge of mathematical patterning in meaningful contexts” but “teachers need to have knowledge of mathematical patterning and be capable of capitalizing on children’s interests” (Fox, 2005, p. 2-319). The need for teachers to develop strong understandings about mathematical patterning and its importance in later mathematical learning, especially in algebra, is emphasized by both Fox (2006) and Papic and Mulligan (2007).

This work on patterning, structure and early algebra is a significant ‘new’ field for Australasian early childhood mathematics education researchers and one in which both output and conceptual framing are significant. It fits well with the work of English (2004, 2005, 2006, 2007; English & Watters, 2005) and Warren (2005a, 2005b, 2006) with slightly older children.
The *Catch the future* project was designed to help raise literacy and numeracy outcomes for children living in low socio-economic families in an area south-east of Melbourne (Clarke & Robbins, 2004; Fleer & Robbins, 2005; Kennedy & Ridgeway, 2005; Kennedy, Ridgeway, & Sunman, 2006). Families in the *Catch the future* project were invited to use disposable cameras to photograph their preschool child undertaking literacy and numeracy activities outside of their early childhood setting. These photographs were discussed with the families and the different responses of people to the literacy and numeracy experiences illustrated were noted through three lenses that were originally formulated by Rogoff (1998):

- what everyone could see in the photographs about literacy and numeracy (personal lens);
- what only the family could see in the photographs as literacy and numeracy (interpersonal lens); and
- what literacy and numeracy practices were so much part of everyone’s everyday life that you could no longer see them (institutional/cultural lens) (Clarke & Robbins, 2004).

The analysis of the photographs from 52 families revealed “the extensive numeracy enactments occurring within many families in lower socio-economic circumstances” (Clarke & Robbins, 2004, p. 180) and the high value that families put on these enactments. “The challenge for preschool and early years teachers is to connect and build upon this rich base of mathematical experiences in ways that acknowledge and support the family’s role” (Clarke & Robbins, 2004, p. 181).

Fourteen early childhood educators from the centres attended by the families in the project had the opportunity to be involved in professional development activities designed to build pathways for learning literacy and numeracy between homes and early childhood settings. Initially, these teachers seemed to hold a deficit view about the families’ knowledge and understanding of literacy and numeracy but, after viewing the photographs taken by the families and listening to the accompanying comments (Fleer & Robbins, 2005), the educators’ views seemed to change although there still seemed to be a reluctance to work with families to build pathways in literacy and numeracy. This theme is taken up by Kennedy et al. (2006) who suggest pathways to literacy and numeracy which link home and early childhood centre experiences through play, using computers, family routines and reading and writing texts.

Many of the findings arising from *Catch the future* have also been noted by Goos and her colleagues in a national project designed to explore the links between home, school and community that support young children’s numeracy development (Goos et al., 2004; Goos & Jolly, 2004). Through a mixed-mode methodology including seven detailed case studies, critical changes required to build long-term and meaningful relationships among educators, families and communities that support children’s numeracy development were identified. These included:
forging parental and community involvement in mathematics education development and change;
recognizing social, cultural and gender differences and relations of power in building partnerships;
enhancing communication between teachers and parents;
improving teachers', parents', and communities' understanding of the nature of numeracy and numeracy learning; and
understanding the nature of partnerships and participant roles (derived from Goos, 2004, p. 20).

One of these case studies is exemplified more fully in Lowrie (2005) through a detailed description of the establishment of a numeracy culture in an environment serviced by distance education. Echoing the findings from Catch the future, Goos and Jolly (2004, p. 285) note that "even though some schools endeavour to help parents recognize numeracy learning opportunities in the home environment, we suspect that the rich variety of numeracy events embedded in home and family contexts remains invisible to most parents and teachers". There is a clear need for continuing work in this area.

EARLY CHILDHOOD MATHEMATICS AND INDIGENOUS CHILDREN

In Papua New Guinea, education reform has encouraged the use of local vernaculars in teaching mathematics in elementary schools (Matang, 2005; Vagi & Green, 2004). Many parents are concerned about this move as they believe that the way ahead for their children is through English or Tok-Pisin medium schooling. In a study of 52 children in three schools, two of which use the local vernacular as the medium of instruction and one which uses mainly Tok-Pisin and some English, Matang (2005) implemented a modified version of the Schedule of Early Number Assessment from Count Me In Too. He found that students from the vernacular-medium schools showed no significant difference in their responses to the English-medium numeracy assessment tasks from those shown by students from the Tok-Pisin/English-medium school. Hence, "those children learning early number knowledge in Kâte language using its counting system are not in any way disadvantaged in learning the formal English arithmetic strategies normally taught in schools when compared to [the] children not taught in Kâte" (Matang, 2005, pp. 509-510).

The issue of contextualization of mathematical experiences for indigenous children has received a lot of attention in recent years (Cronin & Yelland, 2004; Macmillan, 2004; Warego, 2005). McMillan's paper describes a project that offered access to numeracy knowledge for preschool Koori children in an urban regional area of New South Wales. The children were given numeracy kits to play with at their early childhood centre, and to take home to play with their families. While the materials and suggested activities in the kits were not specifically related to the Koori culture of the children and their families, the children responded well to the kits. Further,
Being able to take the kit home meant that the families of the children could support them in their play, they could develop a better understanding of their children’s numeracy potential, and they could perceive a tangible connection between centre and home. (Macmillan, 2004, p. 36)

Watego (2005) also discusses the issue of contextualization of numeracy experiences in preschools and what it means for Aboriginal people. Her initial analysis of the contextualisation observed in one inner-city preschool raises many issues around what is meant by contextualization and how it might be enacted in such a setting. She argues that while this setting implements a play-based curriculum for its children, the subtle differences resulting from an awareness and understanding of Aboriginal ways of knowing, and the incorporation of “specific language, meanings and behaviours” result in distinctly Aboriginal activities that help empower the children “by building the base of confidence and identity that is necessary” (Watego, 2005, p. 773).

Cronin and Yelland (2004) investigated teaching practices designed to enhance numeracy learning outcomes for young Aboriginal students through case studies of four teachers working in the preschool to Year 3 classes of a school with 100% Aboriginal enrolment in a rural community in Queensland. It was found that “a ‘special approach’ was not required [for the Aboriginal students] but rather effective pedagogy as for all students. Teachers of Aboriginal students need to be culturally sensitive just as all teachers should” (Cronin & Yelland, 2004, p. 106). However, because the potential for teacher and students to connect may be lessened in the context of an Aboriginal community:

the professional teacher, who is more interested in student learning outcomes, will develop an interest in the child’s cultural and social context – and consider it in their planning of learning experiences. In fact, it is argued here that if a teacher is not prepared to engage with the student’s social and cultural context, then there is little relevance engaging with the syllabus either. It is further argued that those who are not prepared to engage with the student’s social and cultural context will severely disadvantage outcomes for Indigenous students. (Cronin & Yelland, 2004, p. 108)

Taken together, the papers of Cronin and Yelland (2004), Macmillan (2004), Matang (2005), and Watego (2005) clearly establish the pre-eminence of context and culture when considering the mathematics education of young indigenous children.

In New Zealand, the emphasis on cultural and linguistic appropriateness is reflected in the provision of Te Poutama Tau the Māori-medium equivalent of the NDP. The challenge for Te Poutama Tau has been to focus on Māori pedagogy and patterns of discourse that are authentic to the culture and the syntax of the language, at the same time as retaining the integrity of key aspects of the NDP such as the number framework and the diagnostic interview. These patterns of discourse include such aspects as the ways that language is used to talk about mathematics (including the ways teachers give instructions), how various concepts are explained, and the scaffolding of interaction in ways that lead to understanding.
The goal of *Te Poutama Tau* is to advance the teaching and learning of mathematics while taking cognisance of linguistic concerns, such as ensuring that the authenticity of the language is maintained and items of vocabulary are simple, concise and enhance understanding. It is important that throughout the pāngarau/mathematics curriculum, Māori pedagogy and tikanga (customs), Māori language, and Māori contexts are used and a student’s Māori identity is reinforced (Christensen, 2004). The guiding principles for *Te Poutama Tau* evaluation research include a unique Māori worldview, culturally safe research practices, challenges to existing power relationships, accountability to and mediation by a Māori supervisory group/whanau (*Te Ropu Whaiti*), and concern by the researcher to make a contribution to Māori development and advancement. It is important to recognise that *Te Poutama Tau* is not just a version of the NDP in the language of Māori; it is part of a much greater goal, which is the maintenance and revitalisation of the Māori language (te reo Māori) (Trinick & Stephenson, 2006). As such it emphasises the importance of cultural understanding and language in ways that are reinforced by the studies discussed earlier from Papua New Guinea and Australia.

**MATHEMATICS LEARNING AS CHILDREN BEGIN SCHOOL**

Issues around continuity and change as children move from prior-to-school contexts to school contexts have been well-researched over the last 10 years (see, for example, Dockett & Perry, 2007). On both sides of the Tasman, this general interest has been exemplified by studies in relationships between mathematics education in prior-to-school and the first years of school. The work of Papic and Mulligan (2005, 2007) and the developing project in indigenous communities reported by Warren, Young, and de Vries (2007) are examples.

In New Zealand, two studies have particular relevance to this section of the review. Peters’ (2004) doctoral study focused on children’s general transition to school, with mathematics learning one of the many aspects explored. Her findings underline the complexity of children’s learning, including an appreciation of the different ‘cultures’ of home, early childhood centre, and school, negotiated by children as they learn to take on the role of school pupils. Peters argues that instead of eliminating the differences between settings, teachers in both early childhood centres and schools should support children to ensure that they can capitalise on the developmental possibilities of coping with change. The lack of flexibility and the focus on performance in schools seemed to exert strong pressure on children to conform to expectations and in the process gain status in the classroom. The Peters’ study has important implications for early childhood teachers who want to foster communities of inquiry within their classrooms, and want mathematics learning to occur as part of a collaborative, shared process among members of such a community.

Belcher (2006) looked at the way that five new entrant (5-year-old) children and their parents experienced and interpreted the transition from an early childhood education centre to primary school in terms of numeracy learning. Belcher used participant observation in the classroom and unstructured interviews to gather data
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on the perspectives and experiences of the children and their parents. Parents were unaware of the differences in philosophy among the teachers in their child’s early childhood centre and those in the primary school, and the impact of those differences on their child’s learning experiences in the two settings. A greater need for communication between the two sectors, as well as between teachers and parents, was identified (Belcher, 2006).

In Australia, ENRP has considered various aspects of children’s prior-to-school numeracy abilities and their consequences for teachers in the first year of school (Clarke, Clarke, & Cheeseman, 2006) and beyond (Horne, 2005). Through the application of their First Years of School Mathematics Interview and, where appropriate, the full ENRP Interview, with over 1400 students, Clarke, Clarke, and Cheeseman have provided a very detailed picture of the mathematics knowledge and skills of Victorian children as they commence school, and at the end of their first year of school. Traditional expectations about the mathematics children bring to the first year of school are questioned.

Clearly most Prep children arrive at school with considerable skills and understandings in areas that have been traditional mathematics content for that age. As acknowledged by many ENRP Prep teachers, this means that expectations could be raised considerably in terms of what can be achieved in that first year. (Clarke, Clarke, & Cheeseman, 2006, p. 97)

In spite of the strength of their findings in terms of the overall strengths of young children as they start school, Clarke, Clarke, and Cheeseman (2006) make the point that there is a danger of losing the individual in such considerations of the typical and that the “mathematical thinking of the child should be the starting point” (Clarke, Clarke, & Cheeseman, 2006, p. 99) in the development of learning activities.

Project Good Start (Thomson, Rowe, Underwood, & Peck, 2005) investigated practices in prior-to-school settings that seemed to benefit children most in their first year of school. More than 1300 children in 80 early childhood settings across Australia were tested twice in their year before school using Who am I (de Lemos & Doig, 1999) and I can do maths (Doig & de Lemos, 2000). In their first year of school, 1620 children in 44 schools, including 282 children from the prior-to-school cohort, were assessed with I can do maths. Apart from these quantitative measures, surveys of pre-school and school teachers’ attitudes and practices in numeracy were conducted. Parents were involved in focus groups, and site visits were made to the pre-schools involved in every state and territory.

The main findings of the prior-to-school phase of the study were that effective numeracy programs involved teachers who:

- were interested in numeracy, and had high expectations of their children;
- have formal and explicit plans for numeracy learning;
- provide numeracy-focused materials;
- use and develop mathematical language;
- have the ability to engage children in mathematical activity; and
- conduct regular assessment and feedback on children’s abilities and progress.
The findings for the children in the prior-to-school settings were that:
- there were no sex differences in achievement;
- indigenous children performed less well than non-indigenous children; and
- children from higher SES achieved better than children from lower SES levels.

Overall findings from Project Good Start were that:
- an effective practice for numeracy development was regular formative and summative assessment, combined with feedback to children and parents;
- high expectations by parents were a strong influence on achievement;
- nearly half of the first year of school teachers had not had the opportunity to engage in quality professional development in numeracy in the previous two years;
- the mean achievement of indigenous students was lower than that of non-indigenous students;
- about a third of the indigenous group achieved above the median of non-indigenous students;
- many children had highly developed numeracy skills in the year before school;
- lower SES level children gained from a pre-school experience, reducing the ‘gap’ in numeracy between them and higher level SES children;
- many pre-school and school teachers were unaware of the achievements of children, mainly due to the lack of assessment of children’s numeracy skills and understandings; and
- much of the transition to school information sent on to schools was neither consistent nor valued by FYS teachers.

Perry and Dockett (2004a, 2005) have taken the approach of small case studies to illustrate similar points to those of Clarke, Clarke, and Cheeseman (2006). Their story of Harry and the lamentable approach taken to his school mathematics education reinforces the need for all children to be treated as individuals as they move into school. In spite of meeting, in his first year of school, little mathematics that he was not already capable of completing with ease, Harry did maintain the outward semblance of being interested in the work and, at least, being willing to complete it. However, it seems that the strongest lesson he learned in his Kindergarten mathematics experience is that ‘you do not have to work hard at it’. (Perry & Dockett, 2005, p. 4-71)

Taken together, the studies highlighted in this section have shown that many young children have access to powerful mathematical ideas as they commence school and that, often, this access is not recognised by their teachers. On the other hand, not all children have developed their mathematical ideas to the level expected of beginning school children and these children need to be nurtured from their own individual starting points. In fact, a valuable starting point for teachers in the first year of school would be the recognition of the individual mathematical strengths that each child brings to school and a willingness to build on these strengths.
ASSESSMENT OF EARLY CHILDHOOD MATHEMATICS LEARNING

The key assessment approaches of the systemic numeracy projects mentioned earlier continue to dominate the accepted approaches to assessment of early childhood mathematics learning, particularly in the first years of school (Bobis et al., 2005; Clarke, Clarke, & Cheeseman, 2006; Mulligan, Prescott, Papic, & Mitchelmore, 2006). However, two other emerging approaches deserve mention.

The work of Project Good Start (Thomson et al., 2005) is based on two assessment instruments developed through the Australian Council for Educational Research — *Who am I?* and *I can do maths*. The psychometric credentials of these instruments and a summary of their usefulness in many different contexts are presented in Doig (2005) who concludes that:

The use of these assessment tools by researchers internationally suggest that there exists a need for standardized, early years mathematics assessments. While not all early years professionals need or want such tools for their particular contexts, there are others whose interests lie in mapping children’s mathematical abilities. Quality assessment tools provide a means of achieving a mapping over time, place, or culture. (p. 116)

A different approach to the planning and assessment of mathematics learning in the prior-to-school year has been developed through the *Southern Numeracy Initiative* in South Australia. A group of preschool teachers worked with researchers to develop an extensive numeracy matrix which they now use in the assessment of their children’s mathematics learning (Harley, Perry, & Hentschke, 2006; Perry, Dockett, Harley, & Hentschke, 2006). The approach of narrative assessment pioneered in New Zealand by Carr (2001, 2006) is used in conjunction with the numeracy matrix so that the assessment of young children’s mathematics knowledge and skills is accompanied by the assessment of their learning dispositions such as courage, curiosity, trust, perseverance, confidence and responsibility, all of which have clear applicability to the learning of mathematics. Mathematical thinking can include all of these actions or behaviours indicative of learning dispositions. Hence, even children whose mathematical skills per se might be considered limited from a more traditional skills-based assessment approach, may exhibit many of these behaviours, indicating that they are competent and confident learners. The variety of assessment tools available to early childhood teachers means that choices can be made based on the needs of the children and teachers and the purposes of the assessment.

PROFESSIONAL DEVELOPMENT OF EARLY CHILDHOOD TEACHERS

The relative lack of confidence of many early childhood teachers in their knowledge of mathematics and its pedagogy is a challenge for their professional development in this area. One of the common ramifications of this is that teachers often revert to the ‘safety’ of teaching as they were taught. According to Vagi and Green (2004), such an approach is quite common among the trainers of elementary
school teachers in Papua New Guinea. Elementary schools have been established in each village and community-selected trainee teachers need to undergo teacher preparation. Faced with an innovative community-based curriculum in such schools, including the use of the local vernacular, the training of the elementary teachers is conducted by district-based experienced primary trained teachers. However, many of these experienced teachers remain uncertain of appropriate approaches in the elementary years and tend to revert to traditional teacher-centred approaches.

Professional development was a central component of ENRP and other systemic numeracy projects (Bobis et al., 2005). Through a combination of extensive statewide, regional and local input from ENRP team members, cluster coordinators and participant teachers, well-informed 'professional learning teams' were established at the local level. These teams were key to the success of the project. As well as previously recorded professional learning in terms of the research-based framework of growth points in children's mathematics learning, there is evidence that ENRP teachers grew in their practice and changed their beliefs about mathematics and its learning and teaching (McDonough & Clarke, 2005).

Of particular interest in the professional development model enacted by ENRP is the role of the school early numeracy coordinators. Cheeseman and Clarke (2005) have analysed two forms of open-ended written data from the 36 coordinators to reveal the complexity of the task and the variety of ways in which the coordinators carried out their roles, given variations in expertise, school factors and available time. The early numeracy coordinators were clearly the focal points for much of the project work carried out in each school and “exhibited considerable personal professional growth, provided a substantial amount of mutual support, and contributed to the professional development of their team members, thus increasing the chance of improved student learning outcomes” (Cheeseman & Clarke, 2005, p. 232).

To determine which approach should be taken to the professional development of teachers in a particular context can be a challenge. From her perspective as a District Mathematics Consultant, McPhail (2004) tried three variations on the amount of support afforded 17 teachers who were implementing a sequence of specifically designed lessons on area measurement. The teachers chose their mode of support during the 6-week implementation of the lessons:
- no consultant support;
- fortnightly team meetings with the consultant; or
- release for 30 minutes after each lesson for student interviews, fortnightly team meetings with the consultant, and a 1-day team meeting.

With student learning outcomes as the dependent variable, it was found that some support from the consultant was better than none but that the groups who only met with the consultant on a fortnightly basis obtained better student learning outcomes than the groups who also had opportunities for after lesson interviews and extended team meetings. No claim is made about the generalisability of this finding but it does point to an interesting question about whether there might be
optimal levels of support and even diminishing returns from requiring too much involvement in professional development.

It is well established that early childhood educators' mathematical knowledge and dispositions are key to effective mathematics learning in early childhood settings (Anthony & Walshaw, 2007; Haynes, Cardno, & Craw, 2007; Perry & Dockett, in press). It is also clear that "low levels of content knowledge and the resulting lack of confidence about mathematics limit teachers’ ability to maximise opportunities for engaging children in the mathematical learning embedded within existing activities" (Anthony & Walshaw, 2007, p. 47). This further reinforced in the key finding of the Haynes et al. study:

By far the outstanding finding of the project was the realisation of the importance of teachers' own mathematical knowledge and their personal disposition towards mathematics, leading to improved strategies for providing mathematically stimulating learning opportunities for children. (Haynes et al., 2007, p. 75)

While these findings are not new, they do provide support for continued efforts to improve the professional development of early childhood educators such as those outlined in this section.

CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

After reviewing the Australasian early childhood mathematics education research in the period 2000-2003, Perry and Dockett (2004b) listed what they saw as fruitful areas for future research:

1. approaches to assessment and teaching / learning in numeracy and possible mismatches between these;
2. successful approaches to the mathematics education of young indigenous students;
3. successful approaches to the mathematics education of young children from culturally and linguistically diverse backgrounds;
4. technology in the mathematics education of young children;
5. play in the mathematics education of young children;
6. development of mathematics concepts among children before they start school;
7. continuities and discontinuities of learning in children as they move from prior-to-school to school settings; and
8. recognition of young children as capable learners of mathematics and the results of such recognition in their mathematical outcomes in the first years of school. (Perry & Dockett, 2004b, pp. 119-120)

It is pleasing to see that many of these areas have been featured in the current review. There has been continuing work emanating from the systemic numeracy projects in both Australia and New Zealand and other projects dealing with assessment, the development of mathematics concepts and issues around numeracy at the time children start school. Young indigenous students are being catered for in more meaningful ways in our schools but there is still a long way to go before
they perform, on standardised mathematics assessment instruments, as well as non-
indigenous students.

Little research seems to have been undertaken in the areas of technology and 
early childhood mathematics, even though there continue to be numerous 
computer-based learning programs being made available. While a lot of research 
has been undertaken on the needs of indigenous children in both New Zealand and 
Australia, little seems to have happened with other culturally and linguistically 
diverse groups.

The emergence of pattern, structure and early algebra as a key field of research, 
along with innovative approaches to the assessment of young children’s 
mathematical learning provides fertile ground for further work, as does the ongoing 
need for early childhood educators’ professional development in mathematics 
education.

Clearly, the early childhood mathematics education researchers of Australasia 
have achieved a great deal in the period 2003-2007 both in the consolidation of the 
work done is the systemic numeracy projects and in the development of new areas 
of endeavour. However, much remains to be done in order to further enhance the 
mathematics education of our young children within a range of contexts. We exhort 
our colleagues to continue the work.

REFERENCES

collaboration. In B. Annan, F. Ell, J. Fisher, N. Hawera, J. Higgins, K. C. Irwin, A. Tagg, G. 
Thomas, T. Trinick, J. Ward, & J. Young-Loveridge (Eds.), Findings from the New Zealand 
umeracy development projects 2006 (pp.116-127). Wellington: Ministry of Education.

Ministry of Education.

on transition to primary school numeracy. Unpublished master’s dissertation, Christchurch College 
of Education, Christchurch.

Supporting teachers in the development of young children’s mathematical thinking: Three large 
(Eds.). (1997). Developmentally appropriate practice in early childhood programs (rev. ed.). 
Washington, DC: National Association for the Education of Young Children.

Washington, DC: National Association for the Education of Young Children.


sectors. Set: Research Information for Teachers, 2, 23-27.

Components of the role, highlights and challenges. In P. Clarkson, A. Downton, D. Gronn, M. 
Horne, A. McDonough, R. Pierce, & A. Roche (Eds.), Building connections: Research, theory and 
practice (Proceedings of the 28th annual conference of the Mathematics Education Research Group 


Clarke, B. (2004). A shape is not defined by its shape: Developing young children’s geometric 
CHILDREN'S MATHEMATICAL UNDERSTANDING


Fleer, M., & Robbins, J. (2005). 'There is much more to this literacy and numeracy than you realise ... ': Family enactments of literacy and numeracy versus educators' constructions of learning in home contexts. Journal of Australian Research in Early Childhood, 12(1), 23-41.


CHILDREN'S MATHEMATICAL UNDERSTANDING


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**AFFILIATIONS**

*Bob Perry*
*Murray School of Education, Charles Sturt University, Australia*

*Jenny Young-Loveridge*
*School of Education, University of Waikato, New Zealand*

*Sue Dockett*
*Murray School of Education, Charles Sturt University, Australia*

*Brian Doig*
*School of Education, Deakin University, Australia*