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EARLY CHILDHOOD MATHEMATICS EDUCATION

Key words: contexts of mathematics learning; young Indigenous mathematics learners; mathematics and starting school; early childhood mathematics educators; assessment of early mathematics learning; content of early childhood mathematics education.

INTRODUCTION

During the review period, there has been unprecedented political interest in early childhood education in Australasia (taken to be education of and for children aged between 0 and 8 years old). In New Zealand a review of the implementation of the respected prior-to-school curriculum framework *Te Whāriki* (Ministry of Education [MoE], 1996) has been recommended. For schools, the *New Zealand Curriculum* (MoE, 2007) was introduced in 2007. In Australia, the *Early Years Learning Framework for Australia* (Department of Education, Employment and Workforce Relations [DEEWR], 2009) was implemented from 2010 and Phase 1 of the implementation of the *Australian Curriculum* (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2010), including mathematics, has begun.

All of this interest in early childhood has provided some stimulus for early childhood mathematics education research in Australasia, building on the substantial work that was reported in the previous two MERGA reviews of research (Perry & Dockett, 2004; Perry, Young-Loveridge, Dockett, & Doig, 2008). However, the quantum of early childhood education research emanating from Australasia seems to have diminished since these earlier reviews, perhaps because of a substantial lessening of the work stimulated by the heavily supported systemic numeracy programs in both Australia and New Zealand.

The purpose of this chapter is to critique and celebrate the most significant of the Australasian early childhood mathematics education research that has been published over the review period 2008–2011 and to use this critique to look forward into the next review period with suggestions for future research. The chapter is divided into sections dealing with Australasian research of contexts, pedagogies and content for early childhood mathematics education.

CONTEXTS FOR EARLY CHILDHOOD MATHEMATICS EDUCATION

Much of the recent Australasian research in early childhood mathematics education considered elements of the context in which learning occurs. In this section we

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review research undertaken with Indigenous communities; as children make the transition to school and the connections among contexts that promote young children's mathematical learning.

Successful Approaches to the Mathematics Education of Young Indigenous Children

Successful approaches to the mathematics education of young Indigenous students continue to be a key issue in both New Zealand and Australia. In New Zealand, *Te Poutama Tau* (the Māori-medium component of the *NZ Numeracy Development Projects* [NDP]), underpinned by opportunities to develop the teaching of mathematics (pāngarau) in the medium of Māori, has continued to evolve. The focus of *Te Poutama Tau* is on improving student performance by improving the professional capability of teachers, and supporting the broader aims of Māori-medium schooling in the revitalisation of *te reo Māori*.

In their study of longitudinal patterns of performance of *Te Poutama Tau*, Trinick and Stevenson (2009) reported similar patterns of progress across years 2005–2008 for Years 2 to 8 students. Student progress was affected by a number of variables, including teacher competence, quality of time spent learning, and the quality and availability of support resources. The longitudinal data showed that students who initially performed at a higher stage on *Te Mahere Tau* (*The Number Framework*) maintained that advantage to at least Year 4.

Trinick and Stevenson's (2009) analysis from 2005–2008 suggested that students' ability to articulate their mental strategies was linked to their language proficiency in *te reo Māori* which impacted on their ability to communicate, extract meaning from mathematics statements and convey that meaning in spoken or written discourse. The importance of language proficiency was reiterated in their more comprehensive evaluation of *Te Poutama Tau*, from 2003–2009, where they reported differences in students' strategy components, particularly as students were required to verbalise their mental strategies (Trinick & Stevenson, 2010). Additionally Young-Loveridge (2008) postulated that many of the total immersion teachers were second-language learners themselves, raising some interesting linguistic issues around specialised vocabulary and discourse. With 46% of the New Zealand Year 1 population coming from backgrounds other than European, Peters (2010) suggested the importance of acknowledging research that focused on culturally appropriate pedagogy and assessment practices, and ways of building on valued learning from home. Efforts to achieve this were seen in the evaluation of *Te Poutama Tau*.

Currently 20% of Māori children attend Māori-medium schooling. Extensive analysis of NDP data of those 80% in mainstream education showed that NZ European students started school at higher stages of *The Number Framework* than Māori and Pasifika students. However, the gains from the NDP, as measured by effect sizes, for Māori and Pasifika students are very similar to those for NZ European students (Young-Loveridge, 2008). Furthermore, Young-Loveridge (2009) noted a clear advantage for Māori and Pasifika students attending higher decile schools, rather than lower decile schools, with the average effect size for the difference in gain around one third of a standard deviation.

Recent years have also seen the development and implementation of several large-scale Australian longitudinal studies of Indigenous children's engagement with mathematics. The four year *Make It Count* project aimed "to provide better mathematical outcomes for Indigenous children" (Hurst, Armstrong, & Young, 2011, p. 373) by developing "an evidence base of practices that improve Indigenous students' learning in mathematics and numeracy" (Australian Association of Mathematics Teachers, 2011). The *Make It Count* project had largely focused on improving teacher capacity for effectively engaging young Indigenous students in mathematics learning. Reporting on the Swan Valley cluster of the *Make It Count* project, Hurst et al. (2011) described initiatives implemented as part of the project and the resultant changes in practice. The first of these initiatives was the provision of professional learning in mathematics teaching for Education Assistants (EAs) and Aboriginal and Islander Education Officers (AIEOs). The second was the concentration of a school's Indigenous cohort within classes taught by teachers identified as culturally sensitive and empathetic towards Indigenous children (Hurst et al., 2011). These teachers "often spent a lot of time talking to their Indigenous children, dealing with social and emotional issues during their recess breaks or planning time and putting 'school stuff' to one side" (p. 378). Evidence from interviews with principals, teachers, EAs and AIEOs, and teacher questionnaires undertaken during the study suggested that:

> The mathematics professional learning for EAs and AIEOs contributed to the development of professional learning communities. As well, it is apparent that effective teachers of Indigenous children have particular qualities and use particular strategies that develop and enhance supportive and empathetic teacher-student relationships, and which will hopefully lead to improved numeracy outcomes for Indigenous children. (p. 381)

The *Bridging the Numeracy Gap in Low SES and Indigenous Communities* project (Gervasoni, Hart, Crosswell, Hodges, & Parish, 2011) emerged from the work undertaken in the *Early Numeracy Research Project* (ENRP) (Clarke, Clarke, & Cheeseman, 2006). The ENRP explored the numeracy abilities and experiences of young children in both prior-to-school and early school contexts.

The *Bridging the Numeracy Gap* project sought to build capacity and improve mathematics learning outcomes for children in low-socioeconomic status and Indigenous communities. The project involved 42 school communities across Victoria and Western Australia, including four schools in the Kimberley (Gervasoni, Hart et al., 2011). One aspect of the project explored the role of Aboriginal Teaching Assistants (ATAs) in the provision of high quality mathematics learning experiences for children, concluding that as "often the only permanent members of school staff, [they] play an essential role in building community connectedness and relationships between teachers and families" (p. 313). Acknowledging the importance of community connection to the provision of meaningful and relevant mathematics experiences for young children, Gervasoni, Hart et al. called for school communities to “draw upon the expertise of ATAs, invest in their professional learning, and acknowledge their critical role in building community connectedness and advocacy for Aboriginal students and their families” (p. 313).

The *Young Australian Indigenous Students Literacy and Numeracy* (YAILN) study investigated teaching and learning activities that support Indigenous children as they enter school (Warren, Young, & de Vries, 2008a, 2008b). The YAILN study involved collaboration between researchers, 120 children attending Prep (non-compulsory first year of school) and their teachers at five schools in North Queensland. The multi-tiered design consisted of four data gathering activities: (a) pre- and post-tests; (b) student portfolios; (c) classroom observations; and (d) teacher interviews. Results outlined several strategies for supporting the mathematical learning of young Indigenous students. In particular, the role of pre-Prep (two years prior to Year 1) was noted in promoting understanding of mathematics concepts and understandings. The authors concluded that “the students who had participated in pre-Prep not only possessed a better understanding of numbers to 5 but also the associated mathematical language used to access this understanding” (Warren et al., 2008a, p. 552). Results also suggested that direct teaching together with play-based opportunities generated contexts that promoted young Indigenous students’ early mathematics learning.

The *Maths in the Kimberley* (MitK) project (Jorgensen, 2010; Niesche, Grootenboer, Jorgensen, & Sullivan, 2010) also investigated effective mathematics pedagogy for Indigenous students. While recognising the critical role of teachers in educational reform, this project trialled an innovative mathematics pedagogical model in six remote Indigenous communities in the Kimberley region, Western Australia. Extensive data, including questionnaires, classroom observations, interviews and student testing, were used to evaluate the model and its impact. Results have highlighted the importance of home language use in the classroom. As well, Jorgensen (2010, p. 743) has questioned the appropriateness of group work, suggesting that it may indeed be a “domain of Western/modern education” not necessarily suited in Indigenous contexts.

Another component of the MitK project explored the ways in which teachers in remote schools could connect the mathematical concepts they were teaching to the experiences of the students (Sullivan, Grootenboer, & Jorgensen, 2011). Giving the example of using coins in number operation tasks, Sullivan et al. highlighted the importance of incorporating contexts which are familiar to students to effectively engage young Indigenous students in learning mathematics.

As with the YAILN study, the MitK study emphasised the importance of allowing children to discuss their mathematical reasoning in their home language (Niesche et al., 2010). However, the MitK researchers were met with concerns from teachers about “not knowing what the students were talking about and whether they would remain on task” (Jorgensen, 2010, p. 742). Despite an initial reaction from the MitK research team “that ‘loss of control’ was not a good reason for absolving the use of home language” (Jorgensen, 2010, p. 742), they acknowledged that the flow-over of community issues and resultant loss of control presented a challenge for educators of Indigenous children. A key insight from the MitK project was the need to confront assumptions around good mathematics pedagogy for young Indigenous students (Jorgensen, 2010).

As the initial stage of the *Representations, Oral Language and Engagement in Mathematics* (RoleM) longitudinal study, McDonald, Warren, and de Vries (2011) investigated the nature of oral language and representations in the mathematics education of young Indigenous students. They found that an English as a second language (ESL) approach was employed by the majority of teachers in schools with high proportions of Indigenous students. They cautioned that this approach may result in interactions becoming linguistic exercises rather than a means to develop mathematical concepts. McDonald et al. suggested that teachers of young Indigenous students attended to a combination of oral language communication and rich mathematical representations.

The reviewed research contributes much to the interrogation of appropriate pedagogies and approaches for teaching and learning mathematics in Indigenous contexts. On the basis that much of this research considered school contexts, there is room for greater research focus on the mathematical knowledge and experiences of children in their prior-to-school contexts, including educational, family and community settings.

Mathematics as Part of the Transition to School

A range of research has considered the mathematical knowledge and understanding of young children as they start school. Consistent themes in this research include the importance of recognising and valuing learning that has occurred before children start school and the role of early childhood education in promoting mathematical learning.

MacDonald (2010b; 2011; MacDonald & Lowrie, 2011) conducted a three-year longitudinal study of young children's understandings of measurement at the start of school, concluding that these understandings resulted from children's informal engagements in a variety of contexts, prior to the commencement of formal schooling. Using a series of drawing tasks, MacDonald (2011) elicited children's understandings about measurement, and the contexts—prior-to-school and out-of-school—that influenced these. Conclusions from the research included recommendations about the value of mathematical drawing activities for assessing and extending children's understandings; recognition of the measurement learning that occurs in prior-to-school contexts; and reconsideration of the measurement curricula for children in the first year of school.

The participants in the *Competent Children* project, funded by the New Zealand MoE and the New Zealand Council for Educational Research, are now young adults. The project has gathered information on the development of 500 children in the Wellington region of New Zealand, from 1993 onwards. A report from this study (Wylie, Hodgen, Hipkins, & Vaughan, 2008) confirmed earlier results, that high quality interactions in the early childhood years continued to have positive benefits for cognitive outcomes (including literacy, numeracy and logical problem solving) and attitudinal competencies, to age 16.

In a description of the mathematical learning contexts of four New Zealand early childhood settings, Davies and Walker (2008) identified strengths in the child-directed focus of learning, integration of curriculum areas, play-based pedagogies and teacher commitment to extending children's existing understandings. Detailed narrative assessment addressed children's dispositions, while at the same time providing evidence of specific mathematics concepts being developed. However, no specific policies or approaches were in place to share this deep knowledge with schools. This proved to be problematic for families, who expected that the wealth of documentation from the early childhood setting, as well as their own knowledge, would be accessed by school teachers.

A further, year-long study (Davies, 2009) investigated existing transition practices, particularly around mathematics learning and teaching, between early childhood services and primary schools in a small town in New Zealand. The study considered five key aspects: (a) structural provisions for mathematics; (b) assessments of children's mathematical understanding; (c) transfer of information between sectors; (d) processes and provisions for transition; and (e) parental perceptions and expectations. Although they had been prepared by prior-to-school educators, portfolios of narrative assessments were not used by the new entrant teachers. In completing her investigation on the mathematical practices as children moved into two primary schools, Davies (2011) reiterated that the connections between early childhood and the school setting were very tenuous. Limited evidence was found of the New Zealand curriculum's suggestion that "children's learning builds upon and makes connections with early childhood learning and experiences" (MoE, 2007, p. 41). Recommendations from the Davies (2009, 2011) study noted that focusing on dispositions and key competencies could well initiate closer links and promoted reform of transition practices to ensure that "schools can design their curriculum so that students find the transitions positive and have a clear sense of continuity and direction" (MoE, 2007, p. 41).

The role of teacher beliefs about mathematics and how children learn mathematics was the focus of a small study of five New Zealand teachers (Sherley, Clark, & Higgins, 2008). Results highlighted the general lack of attention that teachers paid to the knowledge and skills that children had when they started school. There were also marked differences between what teachers said they believed when compared with what they actually did in the classroom: the stated constructivist practices were inconsistent with the transmission approaches noted in classroom interactions. The interplay of beliefs and practices was demonstrated as four of the teachers disregarded the stated curriculum in favour of practice based on their own beliefs.

Connections among Contexts in Early Childhood Mathematics

Children's development of mathematical ideas almost always begins with a connection between the idea and a relevant experience in their lives. Indeed, facilitating such connections is a key role of early childhood educators. Sawyer's (2008) analysis of two Year 1/2 teachers and their efforts to help students make mathematical connections—both between the children and their worlds and within mathematics—outlined some possible strategies to achieve such connections.

In their study of Year 2 and Year 3 students' performance on map tasks, Lowrie, Diezmann, and Logan (2011) explored connections between children's lived experiences (in terms of geographic locality) and their ability to decode maps. They found some difference between the performance of metropolitan and non-metropolitan students on a coordinate-map and a landmark-map task. They suggest that this may be the result of difference in exposure to map systems, thus highlighting the connection between the mapping tasks and the children's lived experiences in out-of-school contexts.

The use of picture books to stimulate mathematics learning has been investigated by van den Heuvel-Panhuizen, van den Boogaard, and Doig (2009). They provided examples of picture books that were not blatantly mathematical and suggested that these books could be used as scaffolds to mathematical learning. Recommendations were made as to how this might happen and what role the adult might play in the story reading and mathematical development.

In a completely different 'connection', Jorgensen and Grootenboer (2011) investigated the mathematics learning opportunities afforded by swimming lessons for under-fives. From careful observation, they concluded that the swimming school environment could help expose very young children to mathematical vocabulary through everyday discourses, such as swimming lessons.

Parents, and the home learning environment they help create, influence children's mathematics development. While attempts to assist parents to help in their children's mathematical development are not new, they are relatively sparse in this review period. Muir (2009) reported a study designed to investigate parents' perceptions of mathematics through an intervention in which the parents became actively involved in their children's mathematics development. Collaborative support from teachers and clear understandings of the purpose for certain strategies and activities were identified as critical to the effectiveness of this program.

A strong point made by both Sawyer (2008) and Jorgensen and Grootenboer (2011) was that equity issues needed to be considered when connections in mathematics education are being advocated. For example, swimming lessons were out of the financial reach of many families, meaning that access was limited to those who could afford them. While this is not a reason for not having the experiences available, it should ring alarm bells. There is much mathematics in children's worlds and early childhood mathematics educators need to ensure that all children have access to it.

PEDAGOGIES FOR EARLY CHILDHOOD MATHEMATICS EDUCATION

Many issues influence the teaching and learning of mathematics in early childhood. These include pedagogical issues—such as the approaches used to promote and assess mathematical learning—as well as issues related to the confidence and competence of the educators engaged in this endeavour. In this section, we review research exploring the use of technology and play in the mathematics education of young children; assessment in the early childhood years; and the importance of early childhood teacher education and professional development.

Technology in the Mathematics Education of Young Children

Despite the currency of issues surrounding the use of technology in young children's learning (Robbins, Jane, & Bartlett, 2011; Sweeney & Geer, 2010; Yelland, 2011), there appears to have been relatively few research reports published in the area of early childhood mathematics education and technologies during the review period. This reiterates the work of Highfield and Goodwin (2008) who reported few articles addressing early childhood mathematics education and technology in five of the leading international mathematics education research journals over the previous five years. It also reinforced the claim made in the early childhood education chapters of the two previous MERGA research reviews (Perry & Dockett, 2004; Perry et al., 2008).

Highfield (2010a; 2010b; Highfield & Mulligan, 2009) and Goodwin (2008a, 2008b) have continued in their work in the area, with Goodwin particularly studying the links between interactive multimedia and the representations of fraction concepts by children in the first three years of primary school. Her detailed intervention study in two first-year-of-school classes used a range of multimedia tools including interactive whiteboards and personal computers. While the study was small in scale, preliminary analysis of students' fraction representations using the SOLO taxonomy led to the conclusion that "multimedia tools afforded the intervention students the opportunity to engage with advanced mathematical ideas that exceed current teaching practices and syllabus requirements" (Goodwin, 2008b, p. 115).

Highfield has continued her work on robotic (techno) toys with children in preschool and the first years of school and has developed some innovative tasks, particularly in the area of problem solving. These included play experiences with the techno toys followed by mathematical problem solving tasks that involved the children in 'programming' the toy. Highfield suggested that using a multi-faceted approach through dynamic tasks "can promote rich mathematical thinking and sustained engagement" for young children (2010b, p. 27) and that techno toys can assist young children develop meaningful mathematical understandings and social skills (Highfield, 2010a).

Yelland and Kilderry (2010) reported a three-year study that considered how young children became numerate in contexts that were rich in information and communication technologies. The study was designed to ascertain the range and nature of tasks with which children engaged in their first three years of school and which contributed to their becoming numerate. It was undertaken in two Melbourne schools with 11 teachers and the children in their classes. Yelland and Kilderry (2010) developed a *Mathematical Tasks Continuum* from data generated in the first year of the study to explore the complexity of tasks across the four variables: (a) using mathematical concepts and processes; (b) applying mathematical knowledge; (c) opportunities for exploration; and (d) learning outcomes. One conclusion from the study was that most of the mathematics tasks met by young children within the mathematics curriculum were unidimensional – "characterised by simple sequences of activity that often have a single outcome, minimal opportunities for exploration and where mathematical concepts and processes are introduced via structured tasks" (Yelland & Kilderry, 2010, p. 97). On the other hand, other curriculum areas were more likely to use mathematical tasks that were multidimensional—"open-ended, integrated investigations that not only built on basic or introductory mathematical skills and concepts, but also provided students with multiple opportunities for exploration" (Yelland & Kilderry, 2010, p. 97). Often, these multidimensional tasks could be facilitated using appropriate technology as a stimulus and context in which the more complex learning about numeracy could flourish.

An interesting juxtaposition of older and newer technologies has been investigated by researchers from Western Australia. The advent of 'virtual manipulatives' or virtual representations of concrete materials such as pattern blocks or MAB via interactive white boards or as pictures in NAPLAN tests has reopened questions about the role of such manipulatives in mathematics learning. Swan and Marshall (2010) used virtual and physical manipulatives in a revision of an older study (Perry & Howard, 1997). While there were some key differences in the results of the two studies, particularly around the perceived need of the teacher respondents for professional development, Swan and Marshall (2010) confirmed conclusions from the earlier study, warning that while there were good reasons for using manipulatives in mathematics learning, their use did not guarantee success: the major benefit of the manipulatives comes from the discussion that goes on around them and explicit linking by the teacher to the mathematics they represent.

Play and Mathematics

While the mathematical content of young children's play has been established in national and international research (Ginsburg, 2006; Perry & Dockett, 2008), there have been few research reports relating to this area during the review period. In one study, Lee (2010) confirmed that the outdoor play of toddlers incorporated a wide range of mathematics and that toddlers were indeed competent and confident mathematics learners. Despite this, she cautioned that both integrated, play-based curriculum and adult input are required to make the most of these experiences.

The trend in recent years seems to be away from research exploring specific areas of play and mathematics, such as block play, to greater interrogation of what constitutes play and the connection between learning and play (de Vries, Thomas, & Warren, 2010; Hunting, 2010; Perry & Dockett, 2010, 2011). This research emphasised the importance of educators themselves having a sound understanding of mathematics, as well as the confidence to use it, as they engage with children.

Professional Development of Early Childhood Teachers

It is well known that the quality of teacher knowledge—both pedagogical and content—is positively correlated with children's mathematical learning outcomes. There is also evidence that some early childhood teachers do not have a strong grasp on mathematics and, in particular, do not understand the future trajectories for the mathematics developed by children in the prior-to-school years: "This not only makes it difficult for them to provide necessary scaffolding for young learners but it may also even lead to negative attitudes about the subject—attitudes that may be transferred to the children in their care" (Perry & Dockett, 2008, p. 97). This situation has ramifications for both initial teacher education and ongoing professional development of early childhood educators.

In New Zealand, Sherley et al. (2008) identified the importance of support for teachers to recognise children's prior knowledge and understandings, and to explore the interactions of beliefs and practices in teaching mathematics. As well, Johnston, Thomas, and Ward (2010) suggested that professional development with first-years-of-school teachers encouraged them to acknowledge children's existing knowledge and strategies, rather than emphasising the pedagogical importance of strategy over knowledge. They reported that practising known strategies assisted students to develop new number knowledge and facilitated the development of increasingly sophisticated strategies for solving number problems.

In a major study, *Mathematical Thinking of Preschool Children in Rural and Regional Australia* sponsored by the National Centre of Science, ICT, and Mathematics Education in Rural and Regional Australia (SiMERR), 12 early childhood mathematics education researchers from ten universities in Australia and New Zealand investigated the conceptions and views of preschool practitioners with respect to young children's mathematical thinking and development (Hunting et al., 2008; Perry, 2009/2010). Drawing on extensive interviews with 64 early childhood educators in three Australian states, the project gathered data, inter alia, on the mathematical knowledge of the preschool educators (Bobis, Papic, & Mulligan, 2009/2010) and on the support they felt they needed to facilitate the mathematics development of the children in their care (Pearn, Hunting, & Robbins, 2009/2010).

Bobis et al. (2009/2010) used videorecords and still photography to capture evidence of mathematical activities involving preschool children and their educators. They reported that the two practitioners in their study did display sound knowledge of relevant mathematics but were less able to extend the children's mathematical thinking and development. There were many potentially rich mathematical episodes that were missed by the practitioners. The authors called for the development of professional resources and professional development opportunities for early childhood educators.

Pearn et al. (2009/2010) reported on the stated needs of the 64 preschool educators in professional development in mathematics. In particular, the following two research questions were addressed:

– Where do you get information about suitable mathematical activities? and
– What kind of assistance would you find useful?

The most important source of information about mathematical activities was other people, particularly other early childhood educators. While university early childhood staff and consultants were mentioned, they were not seen as important sources of such information. Other sources were the media, particularly the internet, and, only occasionally, professional publications and meetings such as scheduled professional development opportunities. In terms of assistance that would be useful, there were again three main categories: (a) personal support, (b) resources, and (c) training. Networking with colleagues was the most frequently elicited personal support followed by the institution of a mentoring system. Overall, the need for people and resources (mainly time, although in more remote areas, also money for travel) to support professional development were seen as the key needs of those interviewed.

As part of her team's extensive work on the development of early algebra concepts, Warren (2008/2009) undertook a project designed to develop and implement a professional development model that supported teacher learning in this mathematical domain. The *Transformative Teaching in the Early Years Mathematics* (TTEYM) model is based on the principle that learning is cyclical and consists of four components: (a) knowing person; (b) collaborative planning; (c) collaborative implementation; and (d) collaborative sharing. Data generated at the conclusion of two cycles of implementation and 18 months after the completion of the project suggested that "TTEYM proved effective in assisting teachers to implement new curriculum that contained unfamiliar mathematics content knowledge and pedagogy ... its effectiveness was independent of the content knowledge being introduced" (Warren (2008/2009, p. 44). The TTEYM model deserves further investigation in other mathematical areas.

Perry (2011) has reported on the professional development aspects of his ongoing *Early Years Numeracy Pilot Project* which used an inquiry model of professional learning linked to the intensive development of numeracy leaders from preschool and the first years of school. Using interview and journal data, Perry (2011) chronicled the growth of four numeracy leaders as they led colleagues through the project. With particular reference to the artefacts of the project, the numeracy leaders showed that the intensive and extensive professional development that they experienced through the project had changed their skills, confidence and competence in leading change among their early childhood colleagues.

While professional development of early childhood educators has received some mention here, there is very little to report on researching initial teacher education specifically in early childhood mathematics. This is an area of much needed research.

Approaches to Assessment in Early Childhood Mathematics

Over several years, Howell and Kemp (2009, 2010) have explored number sense and its assessment among young children. Drawing on an earlier Australian Delphi study, an international study was undertaken to establish some consensus among early mathematics researchers about the elements of number sense (Howell & Kemp, 2009) and its assessment (Howell & Kemp, 2010). Assessment of counting, number principles and number magnitude on standardised measures, as well as receptive vocabulary, identified a broad range of number skills among children prior to starting school. The majority of the children demonstrated counting skills to at least 10 and an intuitive understanding of number magnitude, but without sound understanding of counting principles. These studies provided the basis for an ongoing research agenda investigating potential causal links between number sense and later mathematical performance.

The nature of assessment, rather than its specific content, has long been a contentious issue in early childhood education, with Meisels (2007, p. 35) describing young children as "unreliable test takers", affected by the nature of the test taking environments as much as the tests themselves. He argued further that the common practice of assessment at school entry assumes that children have had similar prior-to-school experiences and would be entering similar educational contexts. This view positions assessment at school entry as formative and diagnostic, rather than summative; that is, the start of an appropriate learning and teaching program, rather than a predictor of future success. A similar argument is offered by Young-Loveridge (2011) in her overview of assessment practice in New Zealand. While recognising the potential value of recently introduced National Standards, Young-Loveridge promoted the continued use of diverse opportunities for assessment of these standards. These included the individual diagnostic interview, with its associated advantages of limited demands on children's reading or writing ability, and opportunities for teachers to convey clear instructions and engage in diagnosis throughout the interview, as well as higher levels of child engagement and opportunities to build on teacher-child relationships. This was also evident in the smaller effect size when using interviews over written tests with children from minority groups (Young-Loveridge, 2008).

In a context where school-entry assessments are increasingly popular, there remains limited research addressing issues of the assessment of mathematics in the early childhood years across Australia and New Zealand. School entry assessments vary considerably, but each has a focus on numeracy. Most assessments are conducted once only. An exception is the *Performance Indicators in Primary School* (PIPS) which was used to assess what children had learnt over their first year of school (Wildy & Styles, 2008). With the current emphasis on national and international testing, there is much potential for the downward-push of testing regimes. Research focusing on the nature and role of mathematics assessment in early childhood will inform future trends for testing and assessment.

New Zealand's *Numeracy Development Projects* (NDP) continue to be analysed, resulting in regular reports of student data across all school years and research projects focused on various aspects of the NDP (MoE, 2008a, 2008b, 2009, 2010a). Analysis of data specific to the early school years identified benefits for children after a year engaging in NDP (Young-Loveridge, 2009).

Within the *New Zealand Number Framework* (MoE, 2006) a distinction was made between strategy and knowledge with importance placed on making progress in both, as "strong knowledge is essential for students to broaden their strategies across a full range of numbers, and knowledge is often an essential prerequisite for the development of more advanced strategies" (p. 2). Johnston et al. (2010) reported data from 3742 students (including 2117 from Years 0 to 3) over three consecutive years from 2006–2008. Results supported the notion that students require an initial body of knowledge to solve number problems using strategy and that this body of knowledge is accumulated rapidly during their first three years at school. These conclusions are supported by a comprehensive analysis of the NDP data undertaken by Young-Loveridge (2010). She concluded that student achievement in the early years of school fell some way short of the Ministry's numeracy expectations (MoE, 2007) and the mathematics standards (MoE, 2010b). For example, just over half (57%) of the students were able to count on (stage 4) by the end of Year 2. Results showed students appear to progress through the early (lower) stages on the *New Zealand Number Framework* far more quickly and easily than they progress through the later (upper) stages, thus reinforcing some of the findings by Johnston et al. (2010). Young-Loveridge (2009) postulated that students in the early years of school used counting strategies for longer than is desirable or necessary. She suggested that introducing ideas about the composition of numbers as wholes made of different parts may be of benefit.

Mathematics teaching and learning in the early childhood years is influenced by many factors. In recent years, attention has been directed towards the professional development of teachers, and away from areas such as the role of play in teaching and learning mathematics. In a context where standards and assessment are becoming increasingly important—both for teachers and children—there is great potential to examine the impact and implications of these.

CONTENT FOR EARLY CHILDHOOD MATHEMATICS EDUCATION

Three areas of content have dominated Australasian research over the review period: (a) number; (b) algebra; and (c) measurement. Important work has also been completed in the areas of data and modelling but very little has been addressed in geometry.

Number

Recent number research has challenged assumptions relating to children's understanding of multi-digit numbers, mathematisation and subitising. As part of the *Bridging the Numeracy Gap* project, Gervasoni and her colleagues (Gervasoni, Parish, Hadden et al., 2011; Gervasoni, Parish, Bevan et al. 2011) extended the *Early Numeracy Interview* (ENI) and growth points developed during the ENRP (Clarke et al., 2002) to explore the understandings of 2-digit and 3-digit numbers of children in Grades 2 to 4. Five additional tasks were included: (a) bundling; (b) 2-digit number line; (c) 3-digit number line; (d) 10 more; and (e) 10 less. Analysis of the performance of approximately 2,000 Grade 1 to Grade 4 students from the *Bridging the Numeracy Gap* cohort of 42 low-socioeconomic status communities across Victoria and Western Australia indicated that:

> These tasks distinguished students who were assessed as understanding 2-digit and 3-digit numbers respectively, but who in fact could not reliably identify numerals on a number line or state the total of a collection reduced or increased by ten. These additional tasks assist teachers to identify students who need further experience with multi-digit numbers to construct full conceptual understanding, and highlight the importance of teachers focusing instruction on interpreting quantities and developing a mental number line, and not simply reading, writing and ordering numerals. (Gervasoni, Parish, Hadden et al., 2011, pp. 321–322)

From the *Numeracy Intervention Research Project*, Ellemor-Collins and Wright (2008, 2009, 2011), stressed the importance of mathematical sophistication (mathematisation) in students' development of arithmetical knowledge. They proposed a framework of ten dimensions of mathematisation for arithmetic instruction and showed how this framework could be used by teachers. The framework has the potential to synthesise the important aspects of mathematisation for learning arithmetic.

Warren, de Vries, and Cole (2009) explored the conjecture that young Indigenous students possess an innate ability to subitise, superior to their non-Indigenous counterparts. Reporting on the results of a series of subitising tasks, Warren et al. concluded that, contrary to previous findings (Treacy & Frid, 2008; Willis, 2000), there was no significant difference between the Indigenous and non-Indigenous students' ability to subitise. From this, Warren et al. (2009) recommended intervention in the first year of school in order to increase both Indigenous and non-Indigenous children's ability to subitise.

Algebra

In the previous MERGA review, Perry et al. (2008) identified work on patterning, structure and early algebra as a significant 'new' field for Australasian early childhood mathematics education researchers. A significant Australian program of research in this area has been the *Pattern and Structure Mathematical Awareness Program* (PASMAP) (Mulligan & Mitchelmore, 2009). PASMAP, incorporating the *Pattern and Structure Assessment* (PASA), and *Early Mathematical Patterning Assessment* (EMPA) (Papic, Mulligan, & Mitchelmore, 2011) has made substantial contributions to educators' understandings of young children's development of patterning skills, spatial structuring, and multiplicative reasoning. Mulligan and colleagues have recently undertaken a comprehensive evaluation of PASMAP and PASA (Mulligan, English, Mitchelmore, Welsby, & Crevensten, 2011), exploring the effectiveness of PASMAP for children's mathematical development in a two-year longitudinal study. Comparing PASMAP with standard programs implemented by teachers of the first year of school in two Sydney and two Brisbane schools, Mulligan et al. (2011) noted that while students engaged with PASMAP demonstrated some advantages, students who had not engaged with the program were capable of demonstrating similar learning outcomes. They recommended that "further analysis of the impact of PASMAP on structural development must consider individual teacher effect and school-based approaches to evaluate the program's scope and depth of achievement" (Mulligan et al., 2011, p. 555).

Warren and Miller (2010a; 2010b), have explored understandings of patterning among young Indigenous children across tasks requiring children to copy, continue, complete and create repeating patterns. They noted that children found it easier to copy patterns than they did to continue and complete patterns. Children whose strategy for copying a pattern involved working from left to right performed at higher levels across all tasks, leading to the conclusion that "how a child copies a pattern provides insights into their ability to see the structure of the pattern as a whole" (Warren & Miller, 2010b, p. 600). Furthermore, they hypothesised "that 'seeing structure' of repeating patterns requires the identification of two components, identifying the rhythm of the pattern, and breaking this rhythm into the repeating component" (Warren & Miller, 2010b, p. 600).

In a related study, Warren, Miller, and Cooper (2011) considered how children aged 5 to 9 years grasped and expressed generalisations. As one aspect of the larger study, they examined Year 1 students' ability to identify function rules. Connecting this work to their other work on patterning, they hypothesised that the act of grasping generalisations entailed an understanding of the function or pattern, and translation of this to a process that efficiently reached accurate answers.

Measurement

Research encompassing children's understandings of mass and length has been identified for this review. Cheeseman, McDonough, and Clarke (2011) renewed explorations of ENRP data about young children's understandings of mass. They reported that by the end of the first year of school:

> Most students were able to compare masses, and three-fifths were able to use an informal unit to quantify a mass. By the end of Grade 1, virtually all students were able to compare masses, and 69% were able to quantify masses and were ready to move towards using standard units. By the end of Grade 2, over 40% were using standard units successfully, and the rest were ready to move towards that goal. (p. 178)

On the basis of these results, Cheeseman et al. (2011) have identified targets for the teaching of mass for children in the first three years of school, reflecting children's increasing understanding and the move towards standard units to quantify mass. Advice for teachers has emphasised the value of children's engagement in rich, hands-on experiences with mass measurement in the early years of schooling.

The prior-to-school years also offer many opportunities for children to generate understandings of mass and to use measurement attributes to make comparisons between objects. MacDonald (2010a) examined children's drawings of 'heavy' and 'light' objects, proposing that children developed theories about mass, based on their experiences, which informed their perceptions of, and decisions about, mass measurement. In further tasks, children's drawings indicated their competence in comparing similar and different objects, and at the most sophisticated level, comparison between more than two objects. Additionally, children were able to use appropriate measurement language in both a dichotomous and comparative manner.

In the same study, MacDonald and Lowrie (2011) explored children's understandings of length at the beginning and the end of the first year at school. Children's drawings of a ruler at each of these points indicated good understandings of length at the start of school, with these becoming more contextualised and sophisticated as the year progressed. McDonough and Sullivan (2011) also reported on the development of length understandings in early schooling, using ENRP data to identify key targets for the learning of length in the first three years of school. They suggested that learning to compare, learning to use a unit iteratively, and measuring using formal units were the most appropriate targets for children learning length measurement.

From her study of the home measurement experiences of a 6 to 7 year old girl over a 20 week period, Meaney (2009) questioned expectations that most interactions involved length. Rather, she reported regular discussions of time, particularly in the context of the child often being late for school. In this case, time, rather than length, was suggested as the context for introducing formal units of measurement. The recognition of context as an important factor in learning suggests that early school curriculum requires connection between home and school contexts.

Statistics and Probability

The paucity of statistical and probabilistic learning in early childhood is reflected in English's (2011) call for "a renewed focus on statistical reasoning in the beginning school years, with opportunities for children to engage in data modelling" (p. 226). The value of work in this area is reflected in English's (2010; 2011) use of data modelling to explore young children's abilities to identify diverse and complex attributes, sort and classify data, and create and interpret data representations. This work also emphasised the influence of task context on children's responses to data modelling activities, suggesting that task context appeared to "present both support and obstacles in the children's reasoning" (English, 2011, p. 231).

Building on her extensive opus in this field, Watson and colleagues (Watson, Skalicky, Fitzallen, & Wright, 2009) explored the practical application of statistics while modelling a manufacturing process in Years 1 and 3 classrooms. They not only showed that the children were capable of dealing with the data modelling involved in the activity but also that it exposed them to many other mathematical topics, technology and real life situations in which data were used.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The above analysis shows that there has been much significant research in early childhood mathematics education in Australasia over the 2008–2011 period, and that this should be celebrated. The focus of this research has changed from that evident in earlier years, possibly reflecting political as well as educational agendas. The burgeoning work around the mathematics education of Indigenous children in both New Zealand and Australia, for example, is a response to both political and social justice priorities in these countries. Much of the work in specific content areas has at least 'one eye on' the new curriculum agendas. The area of mathematics learning as children move between educational sectors continues to attract attention. However, there are some contextual challenges remaining, particularly around collaborative work across these educational sectors.

Anthony and Walshaw (2009) noted there was limited cross-sector collaboration within the mathematics education community. They argued that understanding of effective pedagogies to enhance young children's mathematics learning would benefit from cross-sector research and recommended a research focus that bridged the early years divide to ensure a harmonisation of mathematics teaching across the early years.

Davies (2009; Davies & Walker, 2008) reiterated the call from Anthony and Walshaw and suggests that a future focus on dispositions and key competencies could well initiate closer links, resulting in early years of school programs aligning more closely with those from early childhood settings. Changes in both educational sectors will impact on the learning and teaching within those contexts. For example, what are considered appropriate pedagogies in the prior-to-school years seems to be changing, particularly around the way in which play now seems to be valued only if there is consequent learning, rather than as a worthwhile experience in its own right. While it is important that in mathematics education research, we forefront mathematics learning, it would also seem important to remember that there are other reasons why children might be encouraged to play.

Previous review chapters on early childhood mathematics education research in Australasia have concluded with some suggestions for future research. From the current analysis, the following would seem to be the key areas for consideration beyond 2011:

– continue the extensive work on Indigenous children's mathematics learning by consolidating findings; addressing the role of Indigenous knowledges and pedagogies in the learning of 'school' mathematics; and investigating the mathematics learning of Indigenous students in urban settings, prior-to-school, family and community contexts;

- continue to investigate ways in which there can be greater continuity of mathematics learning and teaching across the prior-to-school to school transition;
- build on the continuing investigations in mathematical content areas in early childhood and consider less-researched areas such as geometry and statistics and probability;
- consider the ramifications of new or revised curricula and standards in Australia and New Zealand on early childhood mathematics education, with particular reference to the impact of school curricula and practices on prior-to-school mathematics education;
- investigate the impact of school entry assessment on mathematics learning and teaching in the first years of school and in prior-to-school settings;
- address the needs and concerns of culturally and linguistically diverse children and families in early childhood mathematics education;
- research the use of ICT as mainstream pedagogies in early childhood mathematics education;
- develop and evaluate programs of initial teacher education and professional learning for practising educators that address their needs in early childhood mathematics education, particularly in rural and remote regions; and
- continue to investigate the role of families and communities in the mathematical learning of young children.

This chapter has shown that there is much to celebrate about the early childhood mathematics education research that has been undertaken in Australasia between 2008 and 2011. However, much more quality research in this field is needed, both to extend the areas of strength and to address the identified gaps. Perhaps this chapter will assist future researchers as they work to improve the mathematical wellbeing of young children and their families, communities and educators.

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