
Mathematics Education in the Early Years: building bridges

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ABSTRACT Aligned with the enhanced international commitment to early childhood education, recognition of the importance of providing young children with opportunities to develop mathematical understandings and skills is increasing. While there is much research about effective mathematics pedagogy in the school sector, less research activity is evident within the early childhood sector. Focused on people, relationships and the learning environment, this article draws on a synthesis of research on effective pedagogical practices to describe effective learning communities that can enhance the development of young children's mathematical identities and competencies. Concerned that the wider synthesis noted limited cross-sector collaboration within the mathematics education community, this article aims to act as a bridge for researchers currently working within the preschool and school sectors. The authors argue that understandings of effective pedagogies that enhance young children's mathematics learning will benefit from more cross-sector research studies.

Introduction

The development of mathematical competencies begins at birth. Young children of diverse socio-economic and cultural contexts are immersed in a world of mathematics from the time they come into the world. 'In the early months of life, [babies] are busy learning about mathematics as part of the explorations necessary to the process of becoming members of the community in which they live' (Pound, 1999, p. 3). Numerous research studies document very young children's potential to engage with mathematical skills and understandings. These include enumeration, simple arithmetic, representation, problem solving, measurement and spatial skills, geometric knowledge and logic in a range of circumstances (Hughes, 1986; Peters, 1992; Diezmann & Yelland, 2000; Kilpatrick et al, 2001; Perry & Dockett, 2002; Ginsburg & Golbeck, 2004; Sophian, 2004; Zur & Gelman, 2004; Mulligan et al, 2006). However, despite knowing about this, we do not have a clear understanding of how to help young children learn mathematics. Gifford (2004, p. 100) makes this point in a review of mathematics pedagogy for the early years: we simply 'do not know much about systematically helping children to learn'.

Whilst there is wide-scale acceptance that access to effective mathematics teaching makes a positive difference to the life chances of learners within the school sector, endorsement of the importance of such access for young children within preschool settings is less visible. From a search of the 10-year period (1997-2006) of the *Journal for Research in Mathematics Education*, we found only three research articles that concerned preschool children (see Kato et al, 2002; Sophian, 2002; Anderson et al, 2004). Mathematics education researchers identifying closely with the early years sector confirm the paucity of research in the prior-to-school years (Ginsburg & Golbeck, 2004; Perry & Dockett, 2004; Fox, 2007).

Within New Zealand, finding out about the sort of pedagogies that support the development of competencies and identities of young children is a central goal of the Iterative Best Evidence Synthesis (BES) Programme. This programme was established by the Ministry of Education to deepen understanding from the research literature of what works in education for diverse learners. Adding to the existing best evidence synthesis on early years (Farquhar, 2003) and quality teaching best evidence synthesis (Alton-Lee, 2003), the Ministry of Education commissioned the report

Effective Pedagogy in Pāngarau/Mathematics: best evidence synthesis iteration (BES) (Anthony & Walshaw, 2007). As writers of the mathematics BES, our role was to determine what the literature says about quality mathematics education for diverse learners.

What we found in the early years mathematics education research literature is, we believe, worth sharing for two important reasons. First, our literature search made us acutely aware of how disconnected the available research literature concerning preschool mathematics is from internationally recognised mathematics education journals and conference proceedings. This concern is reinforced by our findings that few of the researchers in the prior-to-school context appear to be engaging in research with a mathematics education focus and, conversely, few mathematics education researchers situate their research within preschool contexts. Second, despite apparent similarities regarding the characteristics of effective pedagogical practices between the sectors, we were struck by the sometimes apparent climate of distrust or disinterest that exists amongst educators from the preschool and school sectors. To bridge the learners' transition between sectors, and further support the goal of providing effective lifelong education in mathematics, we argue strongly that researchers and educators need to develop an increased awareness of effective pedagogical practices within the preschool years. To this end, this article provides an overview of what we have learned from the BES about effective mathematics pedagogical practices for preschool children. It is hoped that the article will act as a stimulus to bridging conversations and partnerships between researchers and educators working in and across a range of education settings.

We first describe the theoretical framing and the method we used to access our data. We then look at what we found out about how teachers and significant adults set about providing mathematics learning experiences for young children. Focused on people, relationships and the learning environment, this article draws on research findings to describe how teachers and caregivers create effective learning communities that enhance the development of young children's mathematical identities, dispositions and competencies.

Mode of Inquiry and Theoretical Framing

The report *Effective Pedagogy in Pāngarau/Mathematics: best evidence synthesis iteration (BES)* (Anthony & Walshaw, 2007) aimed to identify, evaluate, analyse and synthesise evidence of quality teaching of mathematics. Taking into account the histories, cultures, languages and practices within New Zealand and comparable international contexts, the synthesis drew on research studies that make explicit links between pedagogical practices and learner outcomes. In addition to a focus on the development of mathematical proficiency, we included a range of other outcomes that relate to affect, behaviour, communication and participation. The outcomes include:

- a sense of cultural identity and citizenship;
- a sense of belonging;
- contribution;
- well-being;
- exploration; and
- commonly held values, such as respect for others, tolerance, fairness, caring, diligence, non-racist behaviour and generosity.

In highlighting these outcomes we note the strong links between these and the principles that form the foundational practice in early childhood contexts, as outlined in the New Zealand early childhood curriculum document *Te Whāriki* (Ministry of Education, 1996). Our task was to determine what the literature says about quality mathematics teaching for diverse learners. The intent was to access a number of measures that derived from the 'what', 'why', 'how' and 'under what conditions' questions concerning pedagogical approaches that facilitate positive outcomes for all learners. Whilst our focus was initially on the New Zealand literature, we drew heavily on relevant work reported in other English-speaking countries. We searched both print and electronic indices, endeavouring to make our search as broad as possible within the limits of manageability. Specifically, the search covered scholarly work in:

- key mathematics education literature including all major mathematics education journals (for example, *Journal for Research in Mathematics Education*, *Educational Studies in Mathematics*,

Journal of Mathematics Teacher Education, For the Learning of Mathematics and Journal of Mathematical Behavior), international conference proceedings (for example, International Group for the Psychology of Mathematics Education [PME], International Congress on Mathematical Education [ICME] and Mathematics Education Research Group of Australasia [MERGA] publications) and international handbooks of mathematics education (for example, English, 2002);

- relevant Australasian-based studies, reports and thesis databases;
- education journals (for example, *American Educational Research Journal*, *British Educational Research Journal*, *Cognition and Instruction* and *Learning and Instruction*);
- sector-defined journals and texts (for example, *Australian Journal of Early Childhood*, *Contemporary Issues in Early Childhood*, *Early Childhood Research Quarterly*, *The Elementary School Journal* and *International Journal of Early Years Education*);
- specialist journals and projects, especially those located within the wider education field (for example, *Journal of Learning Disabilities*); and
- landmark international studies including the Trends in International Mathematics and Science Study (TIMSS), the Programme for International Student Assessment (PISA) and the Leverhulme projects in the United Kingdom.

This search strategy led us to a large body of literature that served as a starting point for identifying effective pedagogical practices that link with student outcomes. However, as noted in the introduction of this article, it was evident that research studies concerning early childhood mathematics education were, for the most part, located in dedicated early childhood journals, theses, reports and texts, rather than mathematics education sources. Most notably, in the BES chapter that focuses on early years mathematics education, only 27% of the research citations are drawn from mathematics education journals, conferences, reports and texts. The sources of research evidence are largely located within publications that are intended for the early years audience (54%) and educationalists in general (19%).

In selecting which studies to include, we noted that many studies offered detailed explanations of learning outcomes yet failed to make explicit the links between teaching practices and outcomes. Others provided detailed explanations of pedagogical practice yet made unsubstantiated claims about, or provided only inferential evidence for, how those practices connected with learner outcomes. Thus, assessments about the quality of research depended on the nature of the knowledge claims made, and the degree of explanatory coherence between those claims and the evidence provided for the context in question. Using research reports of empirical studies – from very small single-site settings to large-scale longitudinal experimental studies – our focus was on those studies that were able to provide rigorous explanations for a close association between a pedagogical practice and particular outcomes. In searching for those studies that made connections between pedagogy and desirable outcomes, we were careful to demonstrate a

willingness to consider all forms of research evidence regardless of methodological paradigms and ideological rectitude, and [a] concern in finding contextually effective appropriate and locally powerful examples of ‘what works’ ... with particular populations, in particular settings, to particular educational ends. (Luke & Hogan, 2006, p. 174)

Our inclusion of many different kinds of evidence – evidence that takes into account human volition, programme variability, cultural diversity and multiple perspectives – affirms our aim to seek out those pedagogical practices that were effective for particular learners, in particular settings and to particular mathematical educational ends. In doing so, we make no claim to linear causal explanations between pedagogy and student outcomes; the sheer complexity of the teaching–learning relation ‘precludes the possibility of identifying clear-cut cause–effect relationships’ (Sfard, 2005, p. 407). Our synthesis of this range of studies conceptualises teaching as nested within an evolving network of systems. The system itself functions like an ecology in which the activities of the learners and the teacher, as well as the early years/school community, the home, the processes involving the mandated curriculum and education at large, are constituted mutually through their interactions with each other.

The way we dealt with meaning construction in the BES was informed by Deleuze’s (2001) ideas on process, emerging relationships and interconnections that parallel, in some important

respects, current applications of complexity science in mathematics classrooms. In particular, it has many synergies with the work of Davis & Simmt (2003), in which learning environments are read as adaptive as well as self-organising complex systems. Within the early childhood sector, influences of sociocultural theorists such as Vygotsky (1986) and Rogoff (1990) support a model of shared learning – shared in the sense that there is valuing of children’s control alongside a significant role for the adult. The idea of teaching and learning as a complex context-dependent process also draws inspiration from the work of post-Vygotskian activity theorists such as Davydov & Radzikhovskii (1985) and Lave & Wenger’s (1991) well-known social practice theory. Both propose a close relationship between conceptual development and social processes.

Attending to the theorising of the larger synthesis document, we have in this article structured the discussion of effective pedagogical practices within early childhood settings according to two key organisers: mathematical experiences and activities, and communities of practice. We conclude with a discussion outlining current issues around the transition from early childhood to school in relation to mathematics pedagogy and curriculum.

Access to Mathematical Experiences

As our starting point, the research clearly identifies that young children can be powerful mathematics learners. As discussed above, studies identify a range of mathematical skills and understandings that are appropriate for young children to explore and develop. Moreover, those studies collectively provide evidence that very young children can demonstrate a wide range of mathematical thinking practices, including making connections, argumentation, number sense, mental computation, algebraic reasoning, spatial and geometric reasoning, and data and probability sense (Perry & Dockett, 2007).

Mathematical Learning Experiences and Activities

For young children, opportunities to learn arise from both naturally occurring, informal experiences and from planned activities. Typically occurring everyday activities provide the stimulus for much of children’s informal mathematical development. Infants, for example, learn about time and pattern through the use of rhymes and song, and develop spatial skills and awareness as they move around their environment. Likewise, the everyday activities of sharing, cooking, playing games, completing puzzles, counting, estimating distances and making music provide rich opportunities for young children to practise and develop mathematical competencies. Interacting with information and communication technologies (ICTs) provides a contemporary example of everyday experiences that can be linked to mathematical activity. For example, using digital scales or programmable toys (for example, Roamer) can help the development of estimating skills (Pound, 2006). Computer software (for example, Building Blocks) can also support ‘finding the mathematics in, and developing mathematics from, children’s activity’ (Clements, 2002, p. 168).

Play – a key component of children’s experience – provides a rich source of spontaneous mathematical activity, language and thought (Irwin & Ginsburg, 2001; Davies, 2002; Ginsburg & Golbeck, 2004). In spontaneous play, ‘the practice of the community creates the potential curriculum’ (Macmillan, 2004, p. 37). For example, in the following episode, the child makes a connection with a home experience and uses mathematical positioning language when describing a snail’s movements:

I’m patting him. He didn’t like it [as the snail slid off the celery]. I’m putting him on the carrot. He’s trying to get off. One of these snails was on my garbage bin at home. He’s going to fall off it in a minute. He’s going down. He can get down. (Macmillan, 2004, p. 37)

Whilst spontaneous play is potentially rich in mathematics, unstructured play, by itself, is unlikely to provide sufficient support for young children’s mathematical development. Observational studies suggest that children’s involvement in mathematical activities appears to be moderated by their own interest and prior knowledge. For example, a study by Tudge & Doucet (2004) of everyday mathematical activities engaged in by three year olds showed that there was considerable variation in children’s engagement. Their study found no evidence to support parents’ expectations

that their children would more likely be engaged in mathematical activities in formal centres than at home.

Concerned that purposeful opportunities to engage in mathematical activities may be limited, researchers (for example, Hunting & Pearn, 2003; Haynes et al, 2007) recommend that early childhood educators develop a more mathematical orientation within their centres. Various studies report increasing mathematical focus within centres through the introduction of target activities and instruction involving games (Davies, 2002), weekly themes/projects (Sophian, 2004), problem-solving adventure stories (Casey et al, 2004), imaginative kits (Macmillan, 2004), books (Young-Loveridge et al, 1995), technology (Sarama & Clements, 2004; Clements & Sarama, 2007) and mathematics displays (Haynes et al, 2007).

Other projects have sought to identify how *specific* mathematical competencies can best be taught. Griffin (2004) reports on the pre-K–2 mathematics programme Number Worlds, developed to teach conceptual structure for number. The programme builds upon children's current knowledge through the provision of multilevel activities to utilise activities that follow a natural developmental progression, and to teach computational fluency as well as understanding. Activities include contextual problems using multiple representations of number: a group of objects, a dot-set pattern, a position on a line, a position on a scale and a point on a dial. Evaluations found that the children in the study made significant gains in conceptual knowledge of number and in number sense when compared with matched control groups.

Starkey et al's (2004) intervention programme targeted children from economically disadvantaged families. The introduced activities included computer-based mathematics activities. In addition, the intervention strategy incorporated teacher professional development and a parent/child education programme. Parents and children in the intervention group attended a series of three mathematics classes where home-based activities were presented and strategies for dyadic engagement discussed. The significant socio-economic status-related gap in mathematical knowledge found at the beginning of the pre-kindergarten year was decreased following the intervention year.

Sophian (2004) reports on another successful intervention designed to address the perceived disadvantage – in terms of levels of mathematical knowledge – of children from low-income families. Implementation of an experimental mathematics curriculum included teacher supports and home activities that corresponded to activities presented in the centres. Unlike many interventions that focus on number, this curriculum intervention focused on learning to reason about quantity as it applies to enumeration, measurement and the identification of relations among geometric shapes. Measurement activities involved measuring the same quantity using different units, an approach not typically found in other preschool curricula. For example, children made a row of prints of their own hand on strips of cloth and then used their strip to measure various objects. These types of measurement activities have also been found to be beneficial to children's learning in early grades. Longitudinal studies of young school children in the Measure Up programme have found that these measurement-type activities promote students' understanding of algebraic reasoning (Slovin & Venenciano, 2008).

Focusing on children's interests and play situations, Australian researchers Papic & Mulligan (2005) developed an intervention programme built on children's existing ideas about pattern. Evaluations reported a sustained positive impact on the mathematical development of the intervention children (who represented a range of ability), both during the 6-month period of the study and 12 months later at the end of the first year of formal schooling. It was noted that 'the development of pattern as a unit of repeat promoted other mathematical processes such as multiplicative thinking and transformation skills' (Papic & Mulligan, 2007, p. 599).

In a study involving computer software as a curricular programme, rather than as a tool, Clements & Sarama (2007) reported that young children's use of Building Blocks resulted in significant learning gains in spatial, geometric, and numeric competencies and concepts. The 'average achievement gains of the experimental group approached the sought-after 2-sigma effect of individual tutoring' (p. 136). The success of Building Blocks was attributed to the use of 'activities-through-trajectories' (Sarama & Clements, 2004, p. 188) – on and off the computer – that connect children's informal knowledge to more formal mathematics. Like other studies (for example, Perry & Dockett, 2005; Yelland, 2005), the potential of ICT appeared to be mediated by

teacher knowledge and confidence. Teachers who understood the learning trajectories were more effective in teaching and encouraging ‘informal, incidental mathematics at an appropriate and deep level’ (Sarama & Clements, 2004, p. 188).

Identifying Children’s Interests and Mathematical Understandings

In addition to concerns about participation in mathematical experiences within early childhood settings, Young-Loveridge et al (1995) question the extent to which individual children access *appropriate* mathematical activities that match their current understandings. Their observations of centres in New Zealand noted that many of the mathematics activities were suited to children with average numeracy levels; activities more appropriate for novices and experts were noticeably missing. Likewise, in a study in the United Kingdom, Siraj-Blatchford & Sylva (2004) noted that in the majority of centres, opportunities for sustained, shared cognitive engagement were missed and the cognitive challenge involved in teacher–child interactions was frequently less than optimal.

Group and social activities – common practices within early childhood centres – offer a challenge for educators to identify effective ways of combining group work with individual assessment (Sarama & Clements, 2004). Young-Loveridge et al’s (1995) observations of centres found that a number of capable children with a very quiet disposition managed to avoid bringing their expertise to the attention of their teachers. Moreover, children with low levels of expertise but who were outgoing and confident were sometimes assumed by teachers to have much greater proficiency than they actually did have.

Assessment that informs teaching and learning involves noticing, recognising and responding to individual needs. Within early childhood settings this includes a range of innovative practices: systematic observations of children, shared experiences (Fleer, 2002), portfolios (Hedges, 2002), communication between teachers and families (McNaughton, 2002), and the use of learning stories (Carr, 2001). Learning stories, a formative assessment practice, document the alternative strengths of the child. Peters’ (2004b) example (see Figure 1) of an abridged learning story text captures an episode of learning in a New Zealand centre. The story highlights key competencies, learning dispositions and specific mathematical skills of measuring, understanding symbols and communicating mathematical ideas, displayed within the context of a measuring activity.

<i>Tom’s learning story</i>		
Belonging <i>Mana whenua</i>	Taking an interest	Tom held up a long piece of dough he had squeezed from the piping equipment and explained: ‘Look, Rosie – it’s sooo long!’
Well-being <i>Mana atua</i>	Being involved	‘Yes, you’re right Tom – it sure is! Let’s get a ruler and measure it to see how long it really is’, I suggested. Tom placed his dough strip along the tape measure.
Exploration <i>Mana aotūroa</i>	Persisting with difficulty	‘Can you see the numbers, Tom – they tell you how long it is’, I explain. After studying the numbers carefully, Tom announced: ‘19 long!’ ‘Yes, 19 centimetres’, I add.
Communication <i>Mana reo</i>	Expressing an idea or feeling	‘I’ll make another one – but even longer this time. Look, this one is ... 22 centimetres’, he continues.
Contribution <i>Mana tangata</i>	Taking responsibility	‘Wow! Can you make a strip as long as the ruler – 30 centimetres long, Tom?’ After much squeezing and slight adaptation, Tom successfully makes the strip reach from one end to the other. ‘Look – it’s 30 centimetres long now!’
In addition to highlighting the mathematical nature of Tom’s activity (measuring, understanding symbols and mathematical exploration), the learning story portrays Tom’s <i>interest</i> in measuring, sustained <i>involvement</i> in the activities, <i>persistence</i> with difficulty when making the strip as long as the ruler, and verbal <i>expression</i> of his ideas. In terms of key competencies, Tom is involved in logical <i>thinking</i> and adapting ideas, and <i>making meaning</i> in relation to tools, symbols and language for measuring. The learning story is also able to capture Tom’s mathematical discussion with his teacher, and engagement with the wider cultural community of mathematics users.		

Figure 1. Tom’s learning story.

A succession of learning stories is able to demonstrate a child's progress in a range of contexts, the nature of the strategies and dispositions involved, and the degree of increasing mathematical development. Identifying and responding to a child's understandings and interests also requires teachers to understand and respond to the cultural and social perspective of the learner (Hedges, 2002; Macmillan, 2004; Watego, 2005). Children's cultural backgrounds engage them with varied experiences and expectations of mathematical purposes. For example, Ha'angana (1999) provides a description of how the activity of making a *kahoa* ('necklace') supported a young boy's patterning and counting skills.

In attending to children's social viewpoints, researchers have found that young children often have their own purpose for mathematics. Mathematical ideas that are 'genuinely powerful for young children have much more to do with the processes used to interact with and do mathematics than with particular items of mathematical knowledge' (Perry & Dockett, 2002, p. 88). Having a collection of strategies to resolve situations that are relevant to them, such as establishing status or entitlement, creating orderliness, labelling, playing with numbers (just for fun) and exploring quantity to solve a particular problem (for example, measuring, designing, recording, locating and playing games), may on occasions be more pressing than knowing 'correct' mathematical terminology or being able to recite basic addition facts. Recent research demonstrates that young children's natural propensity to problem solve can be applied to mathematical modelling experiences (Fox, 2006).

In summary, in order to address concerns around lack of purposeful opportunities for young children to develop mathematical ideas (Siraj-Blatchford et al, 2002; Davies, 2003; Clements & Sarama, 2007), the research studies presented in this section provide multiple ways to enhance the 'mathematical orientation' within early childhood settings. Collectively, the studies suggest that educators' increased mathematical awareness enables them to build on young children's mathematical thinking to more effectively select and respond to opportunities to learn and, where appropriate, to make the purpose of mathematical learning explicit.

Communities of Practice

Children's development of mathematical understandings, stimulated by their natural curiosity and exploration of their environment, frequently occurs in social settings (Tudge & Doucet, 2004). Whilst peer interactions can support learning, adult-child interactions are more likely to involve scaffolding and appropriation (Smith, 1999).

Pedagogical Interactions

Investigations of interactions in centres by Siraj-Blatchford & Sylva (2004) identified effective 'pedagogical interactions' as those that involved some element of sustained, shared thinking. The 'common critical point ("lifting the level of thinking") occurred when a practitioner "extended" a child-initiated episode by scaffolding, thematic conversation or instruction' (p. 723). Importantly, the researchers noted that the sustained, shared teaching episodes within a play situation extended the child's thinking while simultaneously valuing the child's contribution, thus allowing the child to retain control of the play.

Responsive pedagogical interactions contribute to an environment that stimulates exploration, offering opportunities for young children to reflect on their understanding and develop self-regulatory skills and a metacognitive knowledge base (Cullen, 1988). Based on an analysis of transcripts of children and adults playing with numeracy activities, Macmillan (2002) provides examples of how adult prompts (for example, clarifying/elaborating – 'This one here's number one. Can you find your number one?' – or recognising/appreciating – 'Wow! Look at all that matching!') can encourage young children to persevere with a problem, think about it in different ways and share possible solutions. Focusing on the development of mathematical and mathematics-related language is also a feature of Big Math for Little Kids, a US mathematics programme embedded in activities and stories. Research evaluation of the programme (Greenes et al, 2004) provided evidence of how expectations for young children to share their opinions and to

comment on other children's reasoning resulted in children's abilities to express their mathematical thinking through discussions involving conjectures, predictions and verifications.

Mathematics Learning in the Home and Community

At the centre of the children's social context, parents and families are well placed to provide opportunities for young children to benefit from the rich mathematical experiences that are typically found in the home and community environment. Carer-child relationships can 'encourage the gradual involvement of children in the skilled and valued activities of their family and the society in which they live' (Biddulph et al, 2003, p. 119).

Interested in how Australian families from lower socio-economic circumstances conceptualise and enact literacy and numeracy, Clarke & Robbins (2004) engaged parents to photograph their child participating in literacy and numeracy activities in their home and community. Photographed activities included numerations, shape and spatial activities, cooking, game playing, money, sorting and classifying, measuring, and travel and location. The parents were able to make explicit the incidental, though not accidental, numeracy opportunities: 'Every time I tuned in he was actually learning, everything was literacy and numeracy' (p. 180).

Studies involving researcher observations of home practices, however, suggest variability in both the quantity and quality of mathematical interactions between adult and child. In their US study, Tudge & Doucet (2004) investigated naturally occurring mathematical activities engaged in by three year olds. Conducting observations over the course of a single week in such a way as to cover the equivalent of a complete day, including time in the home, others' homes, the childcare centre and public places, they found that many of the children in their study were 'little or never involved in explicit mathematics activities, whether in the course of lessons or play with artifacts designed to encourage mathematical experiences' (p. 34). Despite the considerable individual variation in the number of observed mathematical experiences, it was noted that parents consistently focused more on helping their children learn to read than on their development of mathematical understanding. Tudge & Doucet (2004, p. 36) argued that 'at least with some of the parents whose children [they] studied ... there is certainly room for parents and other important people in children's lives to enhance children's opportunities for mathematical experiences'.

In New Zealand, Young-Loveridge et al (1995) found that the mothers of the more mathematically 'expert' children had encouraged their children to pursue mathematical activities related to the children's own interests (for example, counting the number of engines and carriages on trains, monitoring the speedometer on the car, and dealing with money), as opposed to the interests of other family members. In contrast, although the 'novice' children were also involved in a range of mathematical activities at home, their mothers did not comment on incorporating mathematical ideas into activities that were of interest to their children. In an earlier case study of five-year-old children, Young-Loveridge found that high scorers on numeracy tasks had

a wide range of experiences involving numbers, a strong orientation towards numeracy by members of their families, and the opportunity to observe their mothers using numbers to solve everyday problems of their own. The low scorers, on the other hand, had few number experiences, an orientation by their families towards literacy but not numeracy, little opportunity to observe their mother using numbers for the solution of practical problems of their own, as well as relatively low family expectations for their mastery of skills. (Young-Loveridge, 1989, p. 43)

The link between the family's orientation to number and the mother's attitudes to mathematics was also an issue in a study in England. Aubrey et al (2003) studied the mathematical development of two 30-month-old children. Based on analysis of observation and discourse, in home and out-of-home settings, the researchers posited a relationship between the children's engagement in mathematical experiences and the roles and relationships established with significant adults. Analysis showed differences in the quantity and quality of input of mathematical dialogue over the observation period:

The mother of Child H seemed to recognise that talking and communicating were important and saw mathematics as a part of everyday life. Learning for Child H arose from play activities

chosen mainly by Child H herself. Her mother did not believe that she should sit down to 'teach' Child H in any formal way, although she did report in interview that she knew other parents did so. The mother of Child L, by contrast, saw mathematics in the home in terms of discrete activities where the goal was the acquisition of counting and arithmetical skills and in which the adult might assume a direct teaching mode. (Aubrey et al, 2003, p. 102)

These two parental styles are in accord with Walkerdine's (1988) typifications of mother-child conversations in the home: for the mother of Child H, the focus was the practical accomplishment of a task and the mathematics was incidental; for the mother of Child L, the mathematics was an explicit pedagogical focus of a purposeful activity. The researchers conjecture that the existence of these 'distinct parent pedagogical styles of supporting children's early mathematical development' (Aubrey et al, 2003, p. 102), ranging from the didactic to the more genuinely participatory, may create a mismatch between home and more formal experiences in early childhood settings. As a consequence, Aubrey et al (2003) contend that early childhood educators may need to familiarise young children who are less accustomed to play-oriented approaches and child-directed activity in the home setting with the approaches of the early childhood setting so that positive expectations and attitudes can be acquired for later mathematics learning. In particular, they claim that fostering a positive disposition to learning mathematics, with opportunities for ideas to be tested out and mistakes to be made, will be particularly important for some learners more so than others.

In another investigation of home-based practices, Anderson et al (2005) observed shared book reading to examine how parents and their young children attended to mathematical concepts. The study, involving 39 parents and their four-year-old children, all from a culturally diverse metropolitan area of Canada, found that the amount of mathematical talk differed widely across families. In addition to qualitative differences in terms of exposure to words such as 'bigger', 'small', 'six', 'lots' and 'shape' within the context of storybook reading, the researchers noted qualitative distinctions with regard to the nature of the discourse. For example, some parents encouraged comparison of the pictorial representations of objects with objects from children's everyday experiences, thereby prototypically modelling the concept of scale. In accord with Heath's (1983) foundational work on literacy practice, the researchers suggested that these parents were laying the groundwork for their children to be able to deal successfully with pictorial representations that they might encounter in mathematics classrooms. The researchers also noted that the manner in which the families shared mathematics was not entirely consistent with the ways that storybooks might typically be used within a formal learning environment. The tendency of parents to integrate mathematical talk almost seamlessly into storybook reading contrasted with the teacher practice of using a storybook as a springboard to mathematical activities. While not advocating that teachers try to emulate what parents do or that parents adopt school-like activities at home, Anderson et al (2005, p. 22) contend that it is 'prudent that educators be aware of and consider these differences'.

Concerns about differential home experiences in mathematics (Young-Loveridge, 2004) have prompted a range of intervention programmes that focus on home-centre links. An evaluation of 14 experimental family numeracy programmes in Britain (Basic Skills Agency, 1998) noted that those programmes found to be most effective had three key strands: joint and separate sessions for parents and children; a structured numeracy curriculum; and bridging activities that parents could use to develop their child's numeracy at home. Working within the context of an urban *Koori* preschool, Macmillan (2004) reported the successful use of take-home numeracy kits. Through a process of mutual enculturation, the kits provided a bridge between the families and centre staff. Other successful linking activities reported in research include inviting family or visitor speakers, field trips to local sites of interest and the use of wall displays to stimulate community reflection (Haynes et al, 2007).

In summary, these studies confirm that contexts that are rich in perceptual and social experiences are readily available in the home and community. Shared mathematical activities and communication can assist in fostering effective and sustainable relationships between the home, community and centres. For teachers to cater effectively for children's different and diverse pathways, it is imperative that they connect with and build upon the children's rich base of mathematical experiences in ways that acknowledge and support the family's role.

Hurdles and Bridges within Early Years Education

Amid calls for greater teacher awareness of mathematics and increased opportunities for learning mathematics, Gifford (2004, p. 100) cautions that effective early mathematics pedagogy is also about achieving a delicate balance: 'While we may want young children to start school mathematically confident, there is a danger of over-pressurising them and creating mathematics anxiety, as many adults are only too well aware.'

Despite mathematics education researchers arguing for the need to ensure that task challenge – determined by a combination of familiarity of context, meaningfulness of purpose and complexity – is appropriate (Carr et al, 1994), there continues to be evidence of restricted mathematics learning occurring in early childhood settings. In the United Kingdom, Siraj-Blatchford et al's (2002) large-scale study found that approximately 5% of four year olds' time was spent doing mathematics activities. Digging deeper, these researchers and others (for example, Aubrey, 1997; Young-Loveridge et al, 1998; Davies, 2003; Sarama & Clements, 2004; Papic & Mulligan, 2005) report that many early childhood teachers are unclear about recognising mathematical learning and express low confidence about their own mathematical knowledge.

In the past, teacher beliefs rather than teacher knowledge have been regarded as the most important determinant of quality teaching and learning interactions in early childhood settings (Hedges, 2002). Recent initiatives, however, accord the teacher a more active role in children's learning – a position that places greater demands of teacher content knowledge. According to Perry & Dockett (2002, p. 103), in order to fulfil the role of the 'knowing assistant and supporter', a teacher needs to understand the mathematics that children are dealing with and to be aware of the many opportunities that present themselves for the learning of mathematics. Addressing concerns about teacher knowledge and confidence has implications for initial teacher education and in-service professional development experiences. Many of the intervention studies discussed earlier that involved home-centre links (for example, Clarke & Robbins, 2004) and introduced mathematical activities (for example, Starkey et al, 2004) noted positive effects on teacher knowledge and confidence.

However, while there is general agreement that sound teacher knowledge of mathematics, allied with increasing children's access to mathematical experiences, can result in achievement gains, early childhood educators caution that these gains are not secured at the expense of personal and social learning. The challenge of an integrated curriculum for young learners is to enhance and highlight mathematical knowledge while supporting an *orientation* towards learning. It is here that a more explicit bridge is needed to connect the preschool and early primary school curricula, pedagogies and learning communities.

In New Zealand, the early childhood curriculum document *Te Whāriki* (Ministry of Education, 1996) offers a distinctive approach with regard to the history and philosophy of the sector. Emphasising 'a model of learning that weaves together intricate patterns of linked experience and meaning rather than emphasising the acquisition of discrete skills' (p. 41), *Te Whāriki* sets itself apart from the school curriculum through its outcomes: negotiability and responsiveness to the learner substitute for the specificity and accuracy that are typically associated with the more formal mathematics of the school sector.

More recent advocated school pedagogy practices, associated with the recognition of children's intuitive solution methods within numeracy programmes, provide a point of commonality between sectors. However, some researchers (for example, Peters, 2004b; Perry & Dockett, 2005) question whether those numeracy practices in early schooling centred on formal assessment of children's mathematical capabilities are too far removed from those promoted in early childhood settings. Based on a study of children in transition to school, Peters (2004a) offers a cautionary note about predetermining young children's capabilities in mathematics. Concerned that assessment against developmental progressions in number may overlook children's competency in other areas, she recommends that educators focus on a child's existing skill accomplishments, knowledge and life experiences, and then proceed in a differentiated way to extend and expand a child's mastery to different and more complex levels. There is support for Peters' claim that we consider young children's achievements more holistically. In contrast to earlier research reports that young children's numeracy skills were extremely stable (Young-Loveridge, 1991; Wylie & Thompson, 1998), Horne's (2005) five-year longitudinal study of 572

children from 70 schools involved in the Early Numeracy Research Project in Australia found that children's mathematical understanding developed at different rates and that many children moved position relative to their peers. Challenging the belief that children who arrive at school in the lower group are condemned to remain in it, Horne suggests that:

we need to be very careful not to label children on the basis of demonstrated achievement. Children do learn at different rates ... Students who arrived at school with little knowledge in number domains made considerable gains, often moving ahead of students who had great knowledge. (Horne, 2005, p. 449)

Such findings are matched by evaluations of numeracy programmes within Australasia that report teachers' increased awareness of children's capabilities (Perry et al, 2006). Informed by the success of numeracy pedagogical practices of diagnostic interviewing, Perry et al (2006) developed and trialled a numeracy matrix that combines (i) developmental learning outcomes (DLOs) which reflect the integration of learning and development, and allow for different developmental pathways of individual learners, with (ii) the powerful mathematical ideas exhibited in young children's learning. The DLOs and the powerful mathematical ideas are fused together through 'pedagogical questions' related to children's learning outcomes. This approach, with similarities to that offered by Peters (2004b; see Figure 1), provides a possible pedagogical bridge between the prior-to-school setting and the first year of school in terms of what is valued and attended to in young children's mathematical learning.

Conclusions

Effective Pedagogy in Pāngarau /Mathematics: best evidence synthesis iteration (BES) (Anthony & Walshaw, 2007) claims that pedagogies which acknowledge the complexity of learners and settings are grounded in a set of common underlying principles that appear to hold good across people and settings. In acknowledging that all students, irrespective of age, have the capacity to become powerful mathematics learners, mathematics education researchers argue that young children's developing understandings are most appropriately situated within 'social and cultural contexts that make sense to the children involved' (Perry & Dockett, 2004, p. 103). Studies offer evidence that the most effective settings for young learners provide a balance between opportunities for children to benefit from teacher-initiated group work and freely chosen, yet potentially instructive, play activities. Research across early years settings also attributes increasing importance to the development of appropriate relationships and supportive learning communities – communities that foster productive mathematical dispositions and participation for diverse learners. In accord with the accepted need for sound specialist mathematical knowledge in the school sector (Ball et al, 2005), recent research in the preschool sector strongly endorses the importance of sound teacher knowledge.

Our review of studies to be included in the BES highlights the limited number of projects on effective mathematics pedagogy that span the continuum of early years educational settings. An increased focus on pedagogical practices associated with numeracy instruction, however, appears to have opened the conversations between mathematics education researchers working within preschool and early school educational settings. Specifically, the use of diagnostic interviews associated with developmental frameworks has created cross-sector interest in young children's development in numeracy. Whilst unease about assessment practices between sectors is apparent, there are signs that researchers are keen to promote awareness of innovative practices that may bridge differences. In addition to drawing our attention to synergies between the mathematics embedded within respective preschool and school curriculum documents (Haynes, 2000; Perry & Dockett, 2005), policy makers and mathematics educators need to be increasingly informed by research that bridges the early years divide if calls for greater harmonisation of approaches to the teaching of mathematics across early years education (Hedges, 2003; Macmillan, 2004; Perry et al, 2006) are to be realised.

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