Mathematics in early childhood

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There is a rich literature exploring the nature of young children's knowledge in the area of mathematics. The literature offers valuable insights both into the nature of young children's foundational mathematical knowledge and teaching approaches that foster and extend that knowledge.

Children's foundational mathematical knowledge

The literature shows a range of views about the nature of children's foundational knowledge. There is agreement among authors that children gain mathematical knowledge and understandings from their interactions with their environment, but some authors clearly favour a formal structure to teaching and learning mathematics over an informal one (Balfanz, Ginsburg, and Greenes, 2003; Lang, 2001; Sarama and Clements, 2003.

Young children express their knowledge in a variety of contexts, and are capable of exploring a wide range of mathematical ideas and skills while engaged in free play (Balfanz, Ginsburg, & Greenes, 2003; Kirova & Bhargava, 2002; Sarama & Clements, 2003). These authors believe young children possess basic mathematical concepts, skills and strategies, but that some teachers have difficulty establishing this prior knowledge, since a lack of vocabulary may be mistaken for lack of ability. Sarama and Clements (2003) believe children are endowed with intuitive and informal capability in geometric and spatial ideas and skills, as well as numeric and quantitative ideas and skills, and have developed a software enhanced mathematics curriculum that helps young children build foundational knowledge. The programme is based on theory and research on early childhood teaching and learning by Bowman, Donovan and Burns (2001), and Clements (2001). Their programme is based on their belief that that the building of solid content knowledge is achieved by finding the mathematics in, and developing mathematics from, children's life experiences, within the framework of their interests. For example, the use of the computer's tools to slide, flip, or turn shapes to develop awareness of geometic motions (Sarama & Clement, 2003). A further example of developing mathematics within the context of play is encouraging children to translate a pattern into a series of physical movements, for example, step, hop, step, hop (Balfanz, Ginsburg, & Greenes, 2003).

Carr, Peters, and Young-Loveridge (1994) suggest the three main areas of focus for a mathematics program in early childhood should build on children's knowledge and understandings of number, space (shape and patterning), and reasoning. This view is supported by detailed research by Young-Loveridge (1988) which focused on the number concepts and skills children in New Zealand started school with, and researched how their knowledge and skills changed after one year. Some of the tasks used by Young-Loveridge (1988) in her 'Number Tasks Interview' included rote counting up to 10,20,30; forward and backward number sequence e.g. give number after 5, and before 9; addition and subtraction counting forward and back on materials, and counting forward and back by imaging. Relevant only to New Zealand, such research was fundamental in the development of the Early Numeracy Project, currently the most recent form of learning assessment and planning tools used in schools for the number strand of the mathematics curriculum.

Looking back at the international literature, those programmes designed to teach specific areas mathematical knowledge and understanding, are based on the view that more effort should be made to foster the number concept in children by beginning earlier, after children have mastered such skills as counting a collection, or at least after they have begun to say number words in the correct sequence (Baroody & Bensen, 2001). It is considered that young children are ready for and excited by a challenging and comprehensive mathematics programme, and are often engaged for significant periods of time (Balfanz, Ginsburg, & Greenes, 2003). Sarama and Clements (2002, 2003) have put together a programme that uses specifically designed building blocks to build solid content knowledge and higher-order thinking, because children can learn faster if they enjoy learning mathematics. Kline (2000) supports a more structured approach, believing that pre-school children are much more capable than we give them credit for and are ready for programmes that build on and extend their intuitive and informal mathematical knowledge. Platz (2004) explains that simple sorting and classification are process skills, and that children are quite capable of classifying objects such as pets, types of clothes, and colours. Platz (2004) draws on the research by Schultz, Colarusso, and Stawderman (1988) that discusses the pre-number areas of sorting and classification. Things that look similar may be considered the same, however, as children undergo the tasks of sorting and classifying. Seo and Bruk (2003) have developed a homework project for parents of young children, intended to help extend parent's mathematical experience in ways that allow them to support their child's mathematical learning at both home and within the centre. Lang (2001) believes children who have a well-developed 'feel' for the size of a unit and number, also have the reasoning skills to respond with sensible reasons for estimating quantity.

International research by Klein and Starkey, referred to in Sarama and Clements (2002), found dramatic gaps in understanding between different cultural and socio-economic groups, but discovered this knowledge gap could be remedied in about twenty ten-minute instructional sessions, using mainly interactive games. New Zealand authors, Carr, Peters and Young-Loveridge (1994) support this view by saying that the extent to which families draw attention to numbers and their usefulness for solving everyday problems at home, plays an import part in establishing children's foundational knowledge. The essential number idea that young children are attempting to understand would seem to be that a collection is made up of an exact number of concrete objects, therefore constructing basic understanding of one-to-one correspondence, which lays the groundwork for an informal understanding of numerical equivalence and number (Baroody & Benson, 2001).

Teachers' domain knowledge

Teachers create an environment that has the potential for hands-on discovery, and they are guided by their professional knowledge to extend children through play, laying the foundation of mathematics understanding. In order for children to be able to move on in their learning, teachers must first establish each child's foundational knowledge, before they can build upon it. A fundamental mathematical skill is the ability to communicate ideas in order to formalize thoughts and knowledge. Therefore, teachers need to integrate appropriate rich learning experiences into assessment, planning and evaluation practices in early childhood settings in order to provide quality learning and teaching experiences for young children. The literature on teaching approaches to children's mathematical learning ranges from support of an informal child-centred holistic approach to the teaching and learning of mathematical concepts in early childhood to advocating a teacher-directed developmental approach.

The informal approach sees children engaging in rich mathematical experiences which enable them to explore their environment, search for solutions to simple and increasingly complex problems, and develop reasoning skills in order to make sense of the world they are part of (Carr, Peters & Young-Loveridge, 1994). The mathematics for infants and toddlers includes the introduction of language and manipulation of resources, developing spatial concepts as they learn to crawl and walk. Haynes (2000) cites the example of how an infant develops their geometric thinking as they move around, learning about space and themselves within space, as they explore areas through their senses.

Baroody and Benson (2001) adopt a more child-centred approach to teaching and learning mathematics, and believe teachers can help young children develop an understanding of one-to-one correspondence through everyday situations. An opportunity to teach matching could arise from the teacher saying, "Bring a spoon for me, and a spoon for baby." They suggest that to facilitate mental representation of exact amounts of specific items teacher could ask a child to go to the kitchen and get a cup for each child at their table. Baroody and Benson give several other examples of how mathematical concepts can be integrated into everyday activities. The teacher can help children recognize that number is useful for categorizing things, and could say, "I like the puppy with two black spots." Even before children can accurately count small collections of objects, they can begin the process of defining collections, for example, "Pick out the same coloured blocks from the pile, like the one in my hand." Teachers can extend children to a more abstract understanding of collections by saying, “Put all your dirty clothes in your bag to take home.”

Teachers need to be able to recognize children’s demonstrated understandings of mathematical concepts. They also need to be able to use mathematical language to guide a child’s progress from behavioural to representational understandings of mathematical concepts (Kirova & Bhargava, 2002). These authors recommend teachers use competent peers to model concepts and guide learning for the less-competent child during a sharing activity. This co-operative learning approach encourages participants to clarify and elaborate on their ideas. They remind teachers to allow children time to construct their own mathematical knowledge without correcting the child’s answer, since disagreement with peers can help the child re-examine the correctness of his/her own thinking. Kirova and Bhargava (2002) advocate the use of social interactions such as games, as an excellent way to construct new mathematical ideas. This in turn leads to children making further connections and extending reasoning. It also helps children become more independent of the teacher.

Direct instruction plays a part in fostering number knowledge, but ‘number sense’ is not something that can be directly imposed on children. The use of counters and fingers help bridge the gap between counting concrete objects and using symbols to represent the abstract (Baroody & Benson, 2001; Carr, Peters & Young-Loveridge, 1994). Teachers need to be competent ‘problem setters’, creating opportunities for children to explore, and devise their own strategies, as they interact with their peers. The key developmental factors of sorting and classifying, recognize that a child’s age is an essential factor, since tasks that challenge a three year old child may not challenge a four year old (Platz, 2004). The element of ‘fun’ and supplying children with choices are important factors when motivating children to persist with sorting and classifying tasks.

Balfanz, Ginsburg, and Greenes (2003, p2) believe children “engage freely in informal mathematics every day” as they play, but feel they should be extended through a research-based and developmentally appropriate early childhood mathematics programme "that would build on the diverse mathematical interests and rich, implicit understandings of mathematics that young children hold" (pp.1-2). Such a programme, they believe, should draw on young children's interests, with the knowledgeable teacher integrating mathematical thinking into daily routines and through learning experiences designed around movement, music, art, literacy, and exploration. "Play is not enough!" according to Balfanz, Ginsburg and Greenes (2003, p2). They qualify this statement by adding that, "children learn through play, but children need adult guidance to reach their full potential". Balfanz has no doubt that teachers need to raise their own level of expectations of what young children can achieve. Children enjoy challenging mathematics activities, and are capable of remarkable applications of mathematics. He feels very strongly, that there are far too few such opportunities for children to participate in rich mathematical learning environments. Edelson and Johnson (2003/2004) support an 'interdisciplinary' approach to teaching and learning mathematical concepts, and believe that teachers should be using music to promote exploration and the 'fun of learning'.

Children have a spontaneous interest in patterns and shapes, comparisons, number and their operations, classification, and spatial relationships (Kline, 2000; Lang, 2001; & Sarama & Clements, 2003). These authors feel that teachers need to be able to create activities that connect children's informal knowledge to more formal school mathematics within the early childhood years. They believe in the 'power' of young children's mathematical thinking and the power of combining teaching strategies to bring forth such thinking, guiding them through research-based well-managed practical skills. Within the number strand, teachers need the professional knowledge to apply their understandings of number, ways of representing numbers, relationship among numbers and number systems, and the learning of operations and how they relate to each other, in order to be able to provide rich mathematical learning experiences for young children. Teachers need to have the skills to use a combination of concrete objects, pictures, words, and symbols to communicate their ideas. Teachers also need to find ways to teach children how to formulate a response that is sensible and based on reason, and develop the skills that enable them to differentiate between a reasonable and an unreasonable estimate.
In summary, there appears to be two distinctly different views on the extent of

professional knowledge early childhood teachers need to extend children’s learning in mathematics, influenced by the authors image of the child.

Assessment, planning and evaluation.

From a socio-constructivist perspective, learning is more likely to occur if adults or more competent peers mediate children’s learning experiences (Baroody & Benson, 2001; Edelson & Johnson, 2003/2004; Kirova & Bhargava, 2002). When teacher’s mathematical concepts are grounded in current knowledge of child development and they know what they wish children to understand, they can plan meaningful learning experiences based around individual interests (Kline, 2000). Ongoing assessment allows teachers to monitor individual children’s progress. Observation is commonly accepted amongst early childhood teachers as the most appropriate method of assessing young children, and evaluations are made from what teachers learn from these (Balfanz, Ginsburg & Greenes, 2003; Kirova & Bhargava, 2002). Engaging children in mathematical conversations as they interact with the environment, supports Vygotsky’s socio-constructivist theory of cognitive development, by building on and extending children’s informal mathematical knowledge (Kline, 2000). As children are able to communicate their choices, this sharing by children provides teachers with opportunities to determine the attributes used by children to sort sets of objects, and talk about the reasoning behind their classifications (Baroody & Benson, 2001; Kline, 2000). Having children listen to other children’s reasoning helps them build their own understandings of number relationships, which can be used to tailor further planning (Kline, 2000; Lang, 2001; Sarama & Clements, 2003; Seo & Bruk, 2003).

Integrating the notion of belonging to a group helps children understand that objects can be grouped and regrouped in different ways as the teacher focuses on individual differences. It is recommended that teachers use objects, or even musical instruments, that are dissimilar to help children’s development of thinking skills associated with recognizing patterns and using logic (Baroody & Benson, 2001; Edelson & Johnson, 2003/2004; Kirova & Bhargava, 2002). Organizing simple sorting and classifying tasks according to levels of ability, with a view to planning more challenging tasks, leads to further learning.

A more deliberate approach to teaching and learning mathematical concepts through everyday tasks can involve simple addition and subtraction, for example, teachers could say: “Find out how many pairs of socks are in your drawer at home”; “Find shapes at home that are a circle, square, triangle, or rectangle”; “Line up some shoes from smallest to biggest”, or “Hand out one mandarin for each child, and how many more do we need for the teachers?” Giving children opportunities to reflect on their activities and verbalize their ideas helps them construct mathematical meaning from those experiences (Seo & Bruk, 2003).

Samara and Clements (2003) suggest giving children composition tasks that young children enjoy and understand, such as puzzles, since children learn to slide, turn, flip, combine, or make up basic geometric shapes. `These authors believe computers used wisely, can be developmentally appropriate, when children have to think ahead and talk amongst themselves about which actions or shapes to choose next, causing them to be reflective.

Early mathematic in the New Zealand context

The learning and teaching of mathematics within the New Zealand early childhood context, is integrated through play, and adopts an informal approach. New Zealand’s early childhood curriculum, Te Whaariki, implies that there should be no particular structures, rules, right or wrong answers, and that each child’s learning should be developed through their own interests. This is in contrast to following the learning outcomes required by a formal education structure, such as the New Zealand Curriculum Framework.

The principle of empowerment contained within Te Whaariki “relates to the New Zealand Curriculum Framework principles of encouraging children to become independent and life long learners” (Ministry of Education, 1996, p40). Hill (1995, p3) believes the six strands in Mathematics in the New Zealand Curriculum, “form an excellent basis for making the links between the experiences and beliefs of early childhood teachers and the meaningful mathematizing of children's learning experiences, in a constructive and developmentally appropriate way". Within the communication and exploration strands of Te Whaariki, Goal Three, sit the mathematical processes of critical thinking, problem solving, and reasoning, which guide teacher's professional knowledge "to create and design classroom programmes" (Carpenter, 2001, p.119).

Over the last decade New Zealand has followed the overseas trends of assessment, placing emphasis on monitoring and accountability. May and Carr (2000) refer to the criticism directed at the 'laissez faire' progressive approaches to curriculum, which relies more on child and/or teacher interest and the ideals of individual growth and development. "The title, Te Whaariki, is a central metaphor," explains May and Carr (2000, p.156). The principles, strands and goals provide a 'spider web' type framework that "weaves through the process of talk, reflection, planning, evaluation, and assessment," and emphasizes a model of knowledge and understanding that grows through increasing complexity and richness.

Soler and Miller (2003) make interesting comparisons between the English Foundation Stage Curriculum, Te Whaariki, and Reggio Emilia. Central to these three differing contemporary early childhood curricula and approaches is the 'image of the child' and socio-political influences. The English Foundation Stage Curriculum adopts the instrumental view that puts an emphasis on the aim of government to prepare children for the world of work, and produce citizens who will benefit society. In complete contrast is the Reggio Emilia approach that is unencumbered by a national curriculum framework, and "represents a localized learner-centred approach," and consequently avoids pressure "from instrumental and vocationally orientated views of curriculum" (Soler & Miller, 2003). Progressive ideas of early childhood focus on the central role of play and movement and the adult as a and moderator, ideals influenced by the likes of John Dewey, Stanley Hall, and Maria Montessori. Te Whaariki recognizes that very young children can develop their understanding of mathematical concepts through play and every day routines. For example in Te Whaariki, under the strand of 'Exploration' Goal 3 states, “children experience an environment where they learn strategies for active exploration, thinking and reasoning” (Ministry of Education, 1996, p88). The role of the early childhood teacher, therefore, is to provide engaging mathematical learning experiences for children, which encourage them to explore their environment, find solutions to problems, and develop reasoning skills. The principles of Te Whaariki also link to the New Zealand Curriculum Framework (1993) that provides a sound basis for the development of core skills and knowledge. The six strands of Mathematics in the New Zealand Curriculum are broken down into achievement aims for each strand, and are structured in a similar way to the goals of Te Whaariki. Hill (1995, p3) states that “Mathematics in the New Zealand Curriculum is an empowering framework for early childhood education” since most young children can work at level one with guidance from subject-content knowledgeable teachers. In practical terms, early childhood centres “vary from the laissez-faire ‘maths is everywhere’ approach, to the ‘maths lesson’ in junior primary mode, often highly structured and teacher-directed” (Hill, 1995.)

Conclusion

A number of early childhood mathematics educators strongly believe children can be taught meaningful mathematical concepts prior to school entry. Other early childhood educators believe this formal approach is unwise. As children’s foundational knowledge grows and matures through experience, supported by knowledgeable teachers, children may show a readiness for learning more specific mathematical concepts. Planned sequences of learning experiences that introduce and reinforce children’s knowledge and understandings of number, space, and reasoning, should follow. These experiences should include a wide variety of hands-on activities, small-group cooperative teaching of specific skills, with opportunities for children to talk about and share their mathematical ideas in a responsive, reciprocal environment, where learning is seen as valuable and fun.

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