Early childhood teachers' misconceptions about mathematics education for young children in the United States

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In this article we discuss nine common misconceptions about learning and teaching mathematics for young children that are widespread among prospective and practicing early childhood teachers in the United States. These misconceptions include: 1. Young children are not ready for mathematics education; 2. Mathematics is for some bright kids with mathematics genes; 3. Simple numbers and shapes are enough; 4. Language and literacy are more important than mathematics; 5. Teachers should provide an enriched physical environment, step back, and let the children play; 6. Mathematics should not be taught as a stand–alone subject matter; 7. Assessment in mathematics is irrelevant when it comes to young children; 8. Children learn mathematics only by interacting with concrete objects; 9. Computers are inappropriate for the teaching and learning of mathematics. These misconceptions often interfere with understanding and interpreting the new recommendations of early childhood mathematics education (NAEYC & NCTM, 2002), and become subtle (and sometimes overt) obstacles to implementing the new practices in the classrooms. We hope this article provides an opportunity for practitioners to examine and reflect on their own beliefs in order to become more effective and proactive early childhood mathematics teachers.

New vision for early childhood mathematics education in the United States

MATHEMATICS EDUCATION FOR YOUNG children is not new. Mathematics has been a key part of early childhood education around the world at various times during the past 200 years. For example, in the 1850s, Friedrich Fröbel in Germany introduced a system of guided instruction centred on various 'gifts', including blocks that have been widely used to help young children learn basic mathematics, especially geometry, ever since (Brosterman, 1997). In the early 1900s in Italy, Maria Montessori (1964), working in the slums of Rome, developed a structured series of mathematics activities to promote young children's mathematics learning. In the United States, however, as the early childhood education field has maintained its time-honoured tradition of emphasising social, emotional and physical development, historically not much attention has been paid to teaching academics, especially mathematics, to young children (Balfanz, 1999). Although there had been attempts from time to time to make early childhood programs more academically rigorous, the focus was primarily on language and literacy development (National Research Council, 2009). In the turn of the 21st century, the early childhood education field in the United States has begun to take a big step forward in promoting early childhood mathematics education. In 2002, the National Association for the Education of Young Children (NAEYC), jointly with the National Council of Teachers of Mathematics (NCTM), issued a position statement that advocates 'high quality, challenging, and accessible mathematics education for three- to six-year old children' (p. 1), and provided research-based essential recommendations to guide classroom practices. Since then, many national, state and local organisations have embraced this new vision (Clements & Sarama, 2004; NAEYC, 2003; NAEYC & NCTM, 2002; NCTM, 2000, 2006). As a result, early childhood teachers across the United States are now faced with a mandate to teach mathematics to young children.

The authors, as early childhood teacher educators and researchers, have attempted to assist prospective and practising teachers to realise the new vision of early childhood mathematics education. Our experiences tell us that many teachers, despite their good faith efforts to provide best practices to young children, are still confused and anxious about the teaching and learning of mathematics, and hesitant to change (Lee & Ginsburg, 2007a, 2007b). This hesitancy is perfectly understandable given that, until recently, instruction in mathematics was not expected in early childhood classrooms in the US (Balfanz, 1999). Rather, teachers were cautioned that purposefully teaching mathematics was unnecessary, inappropriate, or even harmful to young children (e.g. Elkind, 1981, 1998). In the absence of sound preparation for early mathematics education, many early childhood practitioners continue to hold opinions or beliefs that are not consistent with nor based on up-to-date research evidence.

In this article, we discuss nine common misconceptions about learning and teaching mathematics for young children that are widespread among prospective and practising early childhood teachers in the United States. These misconceptions were identified based on our in-depth interviews with early childhood teachers about the key issues in early mathematics education (Lee & Ginsburg, 2007a, 2007b) as well as our experiences in teaching early childhood students, conducting workshops with early childhood teachers (Ginsburg, Jang, Preston, VanEsselstyn & Appel, 2004; Ginsburg et al., 2006), working with them in early childhood classrooms, and engaging in informal conversations with them. Our description of the myths is also based on available research literature (Ginsburg, Lee & Boyd, 2008). The nine misconceptions are:

1. Young children are not ready for mathematics education.
2. Mathematics is for some bright kids with mathematics genes.
3. Simple numbers and shapes are enough.
4. Language and literacy are more important than mathematics.
5. Teachers should provide an enriched physical environment, step back, and let the children play.
6. Mathematics should not be taught as stand-alone subject matter.
7. Assessment in mathematics is irrelevant when it comes to young children.
8. Children learn mathematics only by interacting with concrete objects.
9. Computers are inappropriate for the teaching and learning of mathematics.

These misconceptions often interfere with understanding and interpreting the new recommendations on sound early childhood mathematics education, and become subtle (and sometimes overt) obstacles to implementing the new practices in the classrooms (Richardson, 1996).

We hope this article provides readers with an opportunity to examine and reflect on their own beliefs (and concerns) surrounding mathematics. We believe that, through this process, readers will be able to become more effective and proactive early childhood mathematics teachers.

1. Young children are not ready for mathematics education

When we begin to talk about teaching mathematics to young children, there are always teachers who express their concerns, sometimes fiercely, that 'Young children are just not ready to learn math yet!' These teachers feel there is no need to hurry children or overwhelm them with mathematics; it would do more harm than good to children who are too young and thus not ready to understand.

Why do these teachers underestimate children's mathematical abilities in the early years? We suspect it is their interpretation of Piaget's theory, which they believe focuses on what children *cannot* do, suggesting that children so young are cognitively immature and therefore not capable of understanding abstract concepts or the logical thinking required in mathematics. So there is no point in attempting to teach or push development in this area when children are not ready to construct true understanding.

Yet, over the past 25 years or so, many researchers have focused on what young children can do, and have accumulated a wealth of evidence that young children are more competent in a wider range of mathematical abilities than Piaget's theory might lead one to believe. While young children display certain kinds of mathematical ineptitude, they also show astonishing competence. As Vygotsky (1978) stated:

> *Children's learning begins long before they enter school … They have had to deal with operations of division, addition, subtraction, and the determination of size. Consequently, children have their own preschool arithmetic, which only myopic psychologists could ignore (p. 84).*

Young children can actively construct from their everyday experiences a variety of fundamentally important informal mathematical concepts and strategies, which are surprisingly broad, complex, and sometimes sophisticated. They appear to be predisposed, perhaps innately, to attend to mathematical situations and problems. (For more extensive reviews, refer to Baroody, 2000; Clements & Sarama, 2007a.)

Teachers should not overlook these impressive informal mathematical strengths of children in the early years. Given their interests and capabilities, it does not make sense to avoid involving young children in rich and meaningful mathematical experiences. Adults who fear introducing mathematics to young children may be reacting more to their own unfortunate encounters (and their low feelings of competence) with mathematics than to any appreciation of young children's interests and capabilities. Young children are ready and eager to learn stimulating and challenging mathematics, and, as we shall see below, their mathematical learning is not limited to the concrete; it is often abstract.

2. Mathematics is for some bright kids with mathematics genes

Many teachers believe, either explicitly or implicitly, that some children may be born with mathematical aptitudes or mathematics genes, and others are not. Some teachers even believe that children from certain groups (such as gender, ethnicity and race) are blessed with superior mathematical ability. Some teachers feel there is not much that can be done to change or improve the innate ability of those unfortunate children who are inherently not good at mathematics.

When looking at mathematics achievement, disparities among children from different national, gender and income groups emerge as early as preschool and kindergarten. American children are out–performed by their counterparts from East Asia in mathematics achievement (Miller, Kelly & Zhou, 2004). Within the US, children who live in poverty, a group comprised of a disproportionate number of African–Americans and Latinos (National Center for Children in Poverty, 2006), show significantly lower average levels of achievement (Denton & West, 2002). Boys, especially in the upper end of the percentile range, demonstrate higher mathematics proficiency than girls do (McGraw, Lubienski & Strutchens, 2006; Robinson, Abbott, Berninger, Busse & Mukhopadhyay, 1997). Most of all, females and minorities of African–American and Latino backgrounds are under-represented in mathematically related areas (Jacobs, 2005).

Yet the existence of these differences, especially the differences young children bring to school, cannot be attributed to a certain group having a genetically-endowed advantage in mathematics. Rather, it is the result of a complex set of factors such as family, linguistic and cultural experiences.

For example, while American parents tend to believe that innate ability influences their children's mathematical achievement, Asian parents tend to emphasise effort (Uttal, 1997), and tend to encourage their young children to spend more time on mathematics related activities (Song & Ginsburg, 1987). As well, mothers in the US are more likely to purchase mathematics and science items for their sons than for their daughters (Jacobs & Bleeker, 2004). Regular number-naming systems in Asian languages such as Korean (the Korean word for 'eleven' is ship ill, or 'ten one'), compared to irregular English names, make it easier for Korean children to learn certain number concepts (Miura, 2001). Also, although poor children exhibit difficulty with verbal addition and subtraction problems, they perform as well as their more privileged peers on non-verbal forms of these tasks. It seems that weak language proficiency interferes with the comprehension of problems and the demands of a task (Jordan, Huttenlocher & Levine, 1994).

The mathematical interests and knowledge young children bring to school may indeed differ, but the causes are more likely to be their varying experiences, rather than their biological endowment. While teachers should be aware of and sensitive to these differences, they should never lose sight of the fact that all children, regardless of their backgrounds and prior experiences, have the potential to learn mathematics. In fact, the gaps in early mathematics knowledge can be narrowed or even closed by good mathematics curricula and teaching (Clements & Sarama, 2007b; Griffin, 2007a; Klein & Starkey, 2002; Sophian, 2004). Teachers should strive to hold high expectations and support for all children, without any ungrounded biases. When a teacher expects a child to succeed (or fail), the child tends to live up to that expectation.

3. Simple numbers and shapes are enough

Many teachers typically have a very narrow concept of the mathematical content that young children should learn. Teachers often limit their focus to one-to-one correspondence, simple counting and numbers, and perhaps naming and sorting simple shapes, even when children are capable of learning far more complex content. It is unfortunate that mathematics is often equated to arithmetic or numeracy (perhaps because it rhymes with and seems at the same level as literacy).

Early childhood mathematics education is both deep and broad. It should cover the big ideas of mathematics in many areas—including number and operations, geometry (shape and space), measurement, algebra (particularly pattern), and data analysis—within learning contexts that promote problem-solving, analysis and communication (NCTM, 2000, 2006). In turn, each of these big ideas comprises several interesting sub-topics. Consider the domain of geometry, for example. The topic of shape includes not only simple plane figures (e.g. circle, triangle) but also hexagons and octagons (if young children can say and understand 'brontosaurus', they can do the same for 'octagon'), solids (e.g. cubes, cylinders), and symmetries in two and three dimensions. Spatial relations include ideas such as position (e.g. in front of, behind), navigation (e.g. first go three steps to the left), and mapping (e.g. creating a schematic representing the location of objects in the classroom). Children can enjoy and learn the full spectrum of all of these topics in geometry.

In order for mathematics education to include more than a superficial focus on simple numbers and shapes, teachers need to expand their concept of mathematical content for young children, and develop a deep appreciation and understanding of the fundamental mathematical ideas that young children should learn.

4. Language and literacy are more important than mathematics

Many teachers claim that language and literacy are by far the most important topics to be taught in early childhood, and that a focus on these subjects leaves little time for mathematics. While teachers speak passionately and confidently about language and literacy, the silence can be deafening regarding the teaching of mathematics.

Mathematics is at least as important as language and literacy, if not more. Mathematics ability upon entry to kindergarten is a strong predictor of later academic success, and is in fact an even better predictor of later success than early reading ability. While reading predicts only later reading ability, mathematics performance predicts not only later mathematics but also later reading ability (Duncan et al., 2007). Mathematics is indeed a core component of education from very early ages to the higher grades.

Mathematics education is, in part, education in language and literacy. Children learn to speak, read and write the language of mathematics in order to communicate mathematical ideas. From the age of about two years, children learn the language and grammar of counting. They memorise the first 10 or so counting words (which are essentially nonsense syllables with no underlying structure or meaning) and then learn a set of rules to generate the higher numbers. For example, once you figure out that 40 comes after 30, just as four comes after three, it is easy to append to the 40 the numbers one through nine, and then go on to the next logical ten number, 50, which comes after 40, just as five comes after four.

Young children also learn other kinds of mathematical language, like the names of shapes ('square') and words for quantity ('bigger', 'less'). Indeed, some of these words (such as 'more') are among the first words spoken by many babies (Bloom, 1970). As children grow, they expand their vocabulary and mathematical concepts embedded in it. That is, they learn that terms and expressions such as 'altogether', 'put together', and 'in all' are often used to indicate addition; that 'how many are left?', 'take away', and 'the difference between' are often used to indicate subtraction; and that 'equal shares' and 'share equally' are often used to indicate division (Moseley, 2005). Mathematical words are so pervasive in everyday life and so deep in the core of human cognition that they are not usually thought of as belonging to mathematics.

The most important kind of language children can learn in a stimulating mathematics program is the language of thinking, justification and proof. Children learn to talk about their own thinking ('I added by counting them all up on my fingers'). They learn to justify their answers ('I knew it was a triangle because I saw that it had three sides'). They may even learn to propose proofs ('This can't be a circle. It only has straight lines'). This kind of communication is a key part of mathematics, certainly more important than remembering that five and four is nine.

In addition, children struggle with a very narrow form of mathematical language, namely formal symbolism. Children begin to use the mathematical symbols, such as addition (+), subtraction (–), and equals (=). The special written symbolism of mathematics is the hardest form of language for children to learn. For example, when asked to represent a quantity such as five blocks, young children exhibit idiosyncratic (e.g. scribbling) and pictographic (e.g. drawing blocks) responses, and only much later can they employ iconic (e.g. tallies) and symbolic (e.g. numerals such as '5' responses (Hughes, 1986).

The importance of mathematical language is underscored by the fact that the amount of teachers' mathematics-related talk is significantly related to the growth of preschoolers' mathematical knowledge over the school year (Klibanoff, Levine, Huttenlocher, Vasilyeva & Hedges, 2006). Also, promoting children's mathematics through books and literature is an effective teaching practice (Hong, 1999). Language and literacy are clearly deeply embedded in mathematics learning and teaching.

5. Teachers should provide an enriched physical environment, step back, and let the children play

Another common misconception is that the teacher's role is to set up a physical environment with a rich variety of mathematical objects and materials, and that mathematical learning occurs incidentally, through exploration during free play, with little teacher participation.

Teachers need to play an active role in teaching early mathematics to young children. A rich physical environment, while an important indicator of quality, is not enough by itself. The crucial factor is not what the environment makes possible, but what children actually do in it. The environment may provide 'the food for mathematical thought', but the existence of mathematical food for thought in a classroom does not guarantee that children will ingest it, let alone digest it.

Children do indeed learn some mathematics on their own from free play. However, it does not afford the extensive and explicit examination of mathematical ideas that can be provided only with adult guidance. As we have discussed, early mathematics is broad in scope and there is no guarantee that much of it will emerge in free play. In addition, free play does not usually help children to mathematise—to interpret their experiences in explicitly mathematical forms and understand the relations between the two. For example, children need to understand that combining one bear with two others can be meaningfully interpreted in terms of the mathematical principles of addition and the symbolism 1 + 2.

Free play can provide a useful foundation for learning, but a foundation is only an opportunity for building a structure. Adult guidance is necessary to build a structure on the foundation of children's informal mathematics (Hildebrandt & Zan, 2002). Teachers should actively assist children to advance beyond their informal, intuitive mathematics to the formal concepts, procedures and symbolism of mathematics.

6. Mathematics should not be taught as stand-alone subject matter

Many teachers said they did not and should not teach mathematics as a single subject. They strongly believed that mathematics should be discussed only when children show interest or when it is integrated or disguised within other activities (so that children do not know they are learning mathematics).

All of this is not surprising, since the field's endorsement of an integrated curriculum approach sometimes also seemed to mean a rejection of a subject-matter curriculum. This is reflected in statements such as 'because a subject-matter approach to the curriculum is expert-based, much of the content is difficult for children to understand' (Jalongo & Isenberg, 2000, p. 205); and an example of inappropriate practice is 'times are set aside to teach each subject without integration' (Bredekamp & Copple, 1997, p. 130). Yet, as Wheatley (2003) writes, 'inappropriate curriculum is not necessarily a result of an emphasis on subject matter' (p. 98). In fact, particularly in mathematics, it is recommended that 'teachers must set aside time specifically for the study of mathematics and be purposeful in planning experiences that help children develop specific mathematical understandings' (Richardson & Salkeld, 1995, p. 42). Mathematics can be an interesting and exciting subject of study in its own right. Children are fascinated with numbers and shapes for their own sakes. Mathematics does not always need to be integrated within other activities, or sugarcoated to appeal to young children.

The integrated approach to teaching mathematics has its own merits. It allows children to engage in, explore, and elaborate on mathematics as it arises in the course of their in-depth investigation of a central theme or topic. Thus, it situates the mathematics learning in a highly motivating investigation of real-life problems, and also takes advantage of the natural relationships between subjects such as literacy (Whitin & Piwko, 2008) and music (Geist & Geist, 2008). However, 'the curriculum should not become, in the name of integration, a grab bag of any mathematics-related experiences that seem to relate to a theme or project' (NAEYC & NCTM, 2002, p. 8). In addition, an integrated curriculum too often results in an overemphasis on content areas that teachers feel most comfortable with, and a neglect of mathematics, often one of teachers' least favourite subjects (Copley & Padron, 1998).

In addition to integrating mathematics into classroom routines and learning experiences across subject matters, 'an effective early math program also provides carefully planned experiences that focus children's attention on a particular mathematical idea or set of related ideas', (NAEYC & NCTM, 2002, pp. 11-12). The organised mathematics curriculum is an essential part of high-quality early childhood mathematics education. It can serve as a blueprint and guide focus on mathematics for thematic units in an integrated curriculum. Fortunately, there are research-based mathematics curricula available. Some examples in the United States are:

- *Big math for little kids* (Balfanz, Ginsburg, & Greenes, 2003; Ginsburg, Balfanz, & Greenes, 2003)
- *Building blocks* (Clements, 2007; Clements & Sarama, 2007b)
- *Measurement-based* (Sophian, 2004)
- *Number worlds* (Griffin, 2007a, 2007b)
- *Pre-K mathematics curriculum* (Klein & Starkey, 2002)
- *Storytelling sagas* (Casey, 2004; Casey, Erkut, Ceder & Young, 2008)
- *Numbers plus in the High/Scope curriculum* (Hohmann & Weikart, 2002)

7. Assessment in mathematics is irrelevant when it comes to young children

In the discussion of mathematics, very few teachers spontaneously mentioned assessment. Some reported that they used observation to find out whether children are interested in mathematics or not, but not so much to gather information about what children know and are able to do in mathematics. When we brought up the topic, the responses often included, 'I don't test or quiz my kids, especially in math!' These teachers appeared to have a narrow image of mathematics assessment as a paper-and-pencil test. This may not come as a surprise considering that, just as mathematics has been neglected for many years in early childhood education, so have the methods needed to assess and evaluate it.

It is essential for teachers to 'support children's learning by thoughtfully and continually assessing all children's mathematical knowledge, skills, and strategies' (NAEYC & NCTM, 2002, p. 4). While many educators are concerned (and complain) about teaching for testing, assessment should drive instruction and curriculum. As mentioned previously, young children come to school with intuitive ways of thinking and reasoning regarding mathematics, although their ways may not always be the same as those of adults. As children enter school, their mathematical understanding and abilities continue to develop quickly and broadly, in and out of school, with much individual variation (Clements & Sarama, 2007a). Thus, 'well-conceived, well-implemented, continuous assessment is an indispensable tool in facilitating all children's engagement and success in mathematics' (NAEYC & NCTM, 2002, p. 10).

In early childhood classrooms, observation is used most commonly for understanding the children, as it is non-threatening and can be done unobtrusively. In the case of mathematics, teachers often use checklists to record their observations about whether a child has demonstrated certain mathematics knowledge. Items in number and operation, for example, include 'counts out loud in the correct order to 5, 10, 15 or 20', and 'counts or creates groups of objects and says how many altogether'. A checklist like this is very broad and uncomfortably vague. Knowledge of 'how many altogether', for example, is not at all easy to assess, as cognitive research makes abundantly clear (Ginsburg, 1997). Obviously, observation is not enough.

For instance, a child says that 'three apples and two apples altogether, are six apples'. This incorrect response is clearly important and needs to be corrected. But it is even more important to understand the thought process underlying the response in order to provide a sensitive guide to instruction. The child may have got it through faulty memory ('I just knew it'), faulty calculation (the child miscounts the objects in front of him) or faulty reasoning ('I know that three and two is more than four, and six is two more than four'). Depending on the reason, the teaching solution may differ. To reach below the surface to learn about children's conceptual understanding and the strategies behind their answers, whether right or wrong, teachers need to engage children in a dialogue, which we term 'flexible interviewing', asking the child to elaborate on his or her ways of interpreting and approaching a problem (Ginsburg, 1997).

No one method of assessment is perfect, always accurate, or completely informative. Because of the natural fluctuation and rapid development of children, a single assessment—whether done by observation or flexible interview—may not provide accurate information. It is possible, and sometimes desirable, to blend the methods. The teacher can observe in the natural setting and at the same time give the children simple tasks and interview them. It is necessary to assess young children frequently and to base educational decisions on multiple sources of information.

8. Children learn mathematics only by interacting with concrete objects

Many teachers assume that young children learn mathematics by touching and moving concrete objects. In much of the talk about improving mathematics education, concrete objects, physical materials, or manipulatives have been seen as essential for mathematics learning. For example, Murray (2001) writes:

> *Concrete. Math is tangible. Children learn better when they're using their senses; therefore, they should complete math tasks using three–dimensional [sic] objects to represent the numbers under examination (p. 28).*

It is a widespread belief that 'concrete is inherently good; abstract is inherently not appropriate—at least at the beginning, at least for young learners' (Ball, 1992, p. 16).

But mathematics is not tangible; it is a set of ideas. Mathematics in the early years does not need to be limited to the concrete or tangible. While Piaget is widely cited regarding the concreteness of children's thinking, what he meant by concrete was different from what people usually mean by it. To Murray (2001), like many others, it means something tangible that children can have their hands on. Piaget, on the other hand (pun intended), showed that children were very abstract, and in fact from the age of two onward sometimes over-generalise, employing concepts that are overly inclusive, as when they refer to all men as 'daddy' (Ginsburg & Opper, 1988; Piaget & Inhelder, 1969). Their thinking might be egocentric but is not concrete in the sense that some writers believe.

These days there is a variety of mathematics manipulatives on the market that are designed specifically to help children learn mathematics: pattern blocks, counters, number sticks, base-10 blocks and Cuisenaire rods, to name a few.

No matter how well-designed, these manipulatives, in and of themselves, do not guarantee meaningful learning (Baroody, 1989). The use of materials is effective only when they are used to encourage children to think and make connections between the objects and the abstract mathematical idea. It is not so much important that they simply have their hands on, but rather that they have their minds on.

Mathematics ideas are not in the manipulatives; they are in the child's mind. In this sense, the particular medium may be less important than the fact that it could be used or manipulated to reflect and to construct new meanings and ideas (Baroody, 1989). The medium could be concrete objects, pictures of objects or mental images, as long as they can be used or manipulated to think and reflect, and to construct meanings and ideas (Baroody, 1989). Thus, as long as children can think about what 'four' means in their minds, 'fourness is no more in four blocks than it is in a picture of four blocks' (Clements, 1999a, p. 48) or computer displays of pictured objects. Computers could indeed be an effective learning tool, providing meaningful or concrete experiences to young children.

9. Computers are inappropriate in teaching and learning of mathematics

Many teachers think computers are inappropriate learning tools for young children, especially for mathematics, as they involve no thinking and elicit mindless, random responses from children. Some even misunderstood the concrete nature of computer experiences as hands-on keyboard and mouse. In general, many teachers feel that computers isolate children and prevent social interactions and communications, and so fear that children will become antisocial.

Contrary to these beliefs, computers can be useful in teaching children mathematics, if used appropriately. In fact, computers have some unique advantages (Clements & Sarama, 2008). For example, computers increase children's flexibility with manipulatives as they can move, cut, or even resize onscreen objects; often it is more difficult, or even impossible, to do these things with real objects. Onscreen objects do not pose the awkwardness of handling that real ones might. Further, children can save and retrieve their work on computers, and so can work on projects over a long period. Computers can also provide immediate feedback. Capitalising on these advantages, teachers can bring mathematics ideas to children's explicit awareness.

Not all software designated for young children's mathematics education is age–appropriate or high-quality. The same can be said of almost any educational material: manipulative, textbook, or television show. Teachers need to select wisely. They should not let colourful graphics, cute animation and music mislead them. Teachers need to critically review content and underlying objectives to evaluate what kinds of learning opportunities and experiences the software will provide for their young students. Drill and practice software may lead to gains in certain rote skills but not be as effective in improving children's conceptual understanding of mathematical ideas. It can easily end up being an electronic version of worksheets or flashcards. Discovery–based software may be valuable when children are encouraged to think and to apply mathematical ideas to solve problems.

In addition, effective use of computers can elicit, encourage and extend children's communication and collaboration in learning. As Clements (1999b) reports, computers serve as catalysts for social interaction. Children working at the computer solve problems together, talk about what they are doing, and help and teach friends. We do not mean to say computers should replace concrete objects or other real-life experiences or learning activities. Rather, computers can extend the range of tools children use in their learning experiences. It makes as little sense to say that computers are bad for children as it does to say that books or manipulatives are good. It all depends on what kind of computer software and books and manipulatives are used, and how they are used.

Conclusion

The concerns of many prospective and practising early childhood teachers in the US, and their reluctance to teach mathematics to young children are based on common misconceptions or misunderstandings as discussed above. As the field has embraced the new vision of early childhood mathematics education, teachers need to change their ideas about what kinds of mathematics should be taught, and how they should be taught in their classrooms. Further, as a result of fresh knowledge, teachers need to change their classroom practices so they will support young children's mathematical learning. There is a gap, a rather wide one, between new recommendations and the current state of classroom practices (Ginsburg et al., 2008).

The most pressing need in early mathematics education is to improve early childhood teacher preparation and ongoing professional development (Ginsburg et al., 2008). Currently, very few teacher preparation programs in the United States offer courses devoted specifically to mathematics education in early childhood. Most of them require their students to take, at most, only one course in mathematics, compared to several courses in language and literacy. For practising teachers, in-service professional development needs to move beyond one-time workshops or occasional readings of articles on the topic. As in other areas, teachers need to keep up diligently with advances in research and best practices, by reading professional journals or books, taking courses, participating in conferences, and the like. In order for teachers to implement effective early mathematics education, they need to be supported by better teacher preparation and ongoing professional development opportunities. The teacher is the key to effective, high-quality mathematics education in early childhood classrooms.

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