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Mathematics Education for Young Children: What It is and How to Promote It

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Abstract

Effective mathematics education for young children (approximately ages 3 to 5) seems to hold great promise for improving later achievement, particularly in low-SES students who are at risk of inferior education from preschool onwards. Yet there is limited understanding of what preschool and kindergarten mathematics education entails and what is required to implement it effectively. This paper attempts to provide insight into three topics central to understanding and improving early childhood mathematics education in the United States. First, we examine young children's mathematical abilities. Cognitive research shows that young children develop an extensive everyday mathematics and are capable of learning more and deeper mathematics than usually assumed. The second topic is the content and components of early childhood mathematics education. We show that the content of mathematics for young children is wide-ranging (number and operations, shape, space, measurement, and pattern) and sometimes abstract. It involves processes of thinking as well as skills and rote memory. Components of early childhood mathematics education range from play to organized curriculum (several research based programs are now available) and intentional teaching. Third, we consider early childhood educators' readiness to teach mathematics. Unfortunately, the typical situation is that they are poorly trained to teach the subject, are afraid of it, feel it is not important to teach, and typically teach it badly or not at all. Finally, we conclude with policy suggestions. The most urgent need is to improve and support both pre-service and in-service teacher training.

 Article begins on page 3

From the Editor

It is a pleasure to introduce this issue of the *Social Policy Report*. Ginsburg and his colleagues have prepared a masterful piece on mathematical learning of and instruction forpreschool and kindergarten children. The authors describe what is known about early mathematical learning; they then apply their research to the development of a new curricula, *Big Math for Little Kids*. Their work is a great exemplar about how research informs practice as well as how a developmental scientist/scholar has been able to take his theory and build instructional materials from it. Indeed, this work reminds us that the following two statements are both true—there is nothing as practical as good theory and there is nothing as theoretical as good practice. In addition, given the state of math education for young children, such curricula have the potential to revolutionize current teaching practices. At the very least, they are likely to lead presachools to do more than the bare minimum when it comes to math education. This point is made forcefully by our two commentators—Robert Pianta and Deborah Stipek. Math education is currently a national priority because of its recognized importance to the future work force and hence to our international economic standing. Ginsburg and colleagues demonstrate the importance of basing attention to this topic on research and of the need to always place the child’s needs foremost. We hope that you enjoy this *SPR* as much as we do.

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Mathematics Education for Young Children: What It is and How to Promote It

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Mathematics education for young children—roughly ages 3 to 5, or preschool to Kindergarten in the American system—is not new. Early childhood mathematics education (ECME) has been a key part of preschool and kindergarten practice at various times during the past 200 years (Balfanz, 1999). In the 1850s, Froebel introduced a system of guided instruction centered on various "gifts," including blocks that ever since have been widely used to help young children learn basic mathematics, especially geometry (Brosterman, 1997). In the early 1900s, Montessori (1964), working in the slums of Rome, developed a structured series of mathematics activities to promote young children's mathematics learning.

Interest in ECME appears to wax and wane in response to social conditions. In the early years of the 21st century, policy makers, educators, and parents in the U.S., and indeed around the world, are again concerned with ECME. For example, in the U.S., Head Start has begun to strengthen its mathematics curriculum, and states like Texas and New Jersey are implementing new programs of ECME, especially for low-SES, minority children.

Two widespread social concerns have contributed to the current interest. The first is that American children's mathematics performance is weaker than it should be. Children from East Asia outperform their American counterparts in mathematics achievement, perhaps as early as preschool (Miller & Parades, 1996) or kindergarten (Stevenson, Lee, & Stigler, 1986). The second is that within the U.S., low-SES children, a group comprised of a disproportionate number of African-Americans and Latinos (National Center for Children in Poverty, 2006), show lower average levels of academic achievement than do their middle- and upper-SES peers (Arnold & Doctoroff, 2003).

The current situation is detrimental to our children and the nation as a whole. American mathematics education at all levels requires improvement, if not radical reform. Part of the solution may lie in effective early education, which has been shown to provide a foundation for later academic success (Bowman, Donovan, & Burns, 2001; Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001; Reynolds & Ou, 2003), especially in the short term (Gormley, 2007) and arguably in the years thereafter (Ludwig & Phillips, 2007). Early education may even be seen as a good financial investment, resulting in economic benefits over the long term (Heckman, 2000).

Initiating mathematics instruction as early as possible may be particularly beneficial. In the early years, both low- and middle-SES children have confidence in themselves as learners and expect to do well in school (Stipek & Ryan, 1997). Also, mathematics ability upon entry to kindergarten is a strong predictor of later academic success, and in fact is even a better predictor of later success than is early reading ability (Duncan et al., 2007).

But as we shall see, implementing ECME on a wide scale is a massive and difficult undertaking. To do the job effectively, we need to grapple with some key issues, among them young children's ability to learn mathematics, the nature of the early childhood mathematics curriculum, and teachers' readiness to teach. Fortunately, research in cognitive developmental and educational psychology and in mathematics education can illuminate these basic issues and serve as the basis for policy recommendations.

Are Young Children Ready to Learn Mathematics?

Over the last 25 years or so, researchers have accumulated a wealth of evidence (Baroody, Lai, & Mix, 2006; Clements & Serama, 2007; Ginsburg, Cannon, Eisenband, & Pappas, 2006) showing that nearly from birth to age 5, young children develop an *everyday mathematics*—including informal ideas of more and less, taking away, shape, size, location, pattern and position—that is surprisingly broad, complex, and sometimes sophisticated. Everyday mathematics is an essential and even inevitable feature of the child's cognitive development, and like other aspects of the child's cognition, such as theory of mind or critical thinking, develops in the ordinary environment, usually without direct instruction. Indeed, everyday mathematics is so fundamental and pervasive a feature of the child's cognition that it is hard to see how children could function without it.

Core Mathematical Abilities

Even infants display core mathematical abilities.

They can, for example, discriminate between two collections varying in number (Lipton & Spelke, 2003) and develop elementary systems for locating objects in space (Newcombe & Huttenlocher, 2000). Geary (1996) argues that all children, regardless of background and culture, are endowed with "biologically primary" abilities including not only number, but also basic geometry. These kinds of abilities are virtually universal to the species and require only a minimum of environmental support to develop.

From birth to age 5, young children develop an everyday mathematics—including informal ideas of more and less, taking away, shape, size, location, pattern and position—that is surprisingly broad, complex, and sometimes sophisticated.

Everyday Mathematics

Throughout the preschool years, children's everyday mathematics develops in interesting ways, often without adult assistance. As Gelman (2000) puts it, "We can think of young children as self-monitoring learning machines who are inclined to learn on the fly, even when they are not in school and regardless of whether they are with adults" (p. 26). In the ordinary environment, young children develop a comprehensive everyday mathematics entailing a variety of topics, including space, shape and pattern, as well as number and operations, and comprising several important features.

Spontaneous Interest

Young children have a spontaneous and sometimes explicit interest in mathematical ideas. Naturalistic observation has shown, for example, that in their ordinary environments, young children spontaneously count (Saxe, Guberman, & Gearhart, 1987), even up to relatively large numbers, like 100 (Irwin & Burgham, 1992), and may want to know what is the "largest number" (Gelman, 1980). Also, mathematical ideas permeate children's play: in the block area, for example, young children spend a good deal of time determining which tower is higher than another, creating and extending interesting patterns with blocks, exploring shapes, creating symmetries, and the like (Seo & Ginsburg, 2004). Everyday mathematics is not an imposition from adults; indeed adults, including teachers, are often blissfully ignorant of it.

Competence and Incompetence

Children's minds are not simple. On the one hand, from an early age they seem to understand basic ideas of addition and subtraction (Brush, 1978) and spatial relations (Clements, 1999). They can spontaneously develop (Groen & Resnick, 1977) various methods of calculation, like counting on from the larger number (given 9 and 2, the child counts, "nine…ten, eleven") (Baroody & Wilkins, 1999). At the same time, children display certain kinds of mathematical incompetence, as for example when they have difficulty understanding that the number of objects remains the same even when they are merely shifted around (Piaget, 1952) or when they fail to realize that an odd looking triangle (for example, an extremely elongated, non-right-angle, "skinny" triangle) is as legitimate a triangle as one with three sides the same length (Clements, 1999).

Concrete and Abstract

In some ways, young children's thinking is relatively concrete. They see that this set of objects is more than that; and they can add 3 toy dogs to 4 toy dogs to get the sum. Yet in other ways, young children's thinking is very abstract. They know that adding always makes more and subtracting less. They can easily create symmetries in three dimensions (Seo & Ginsburg, 2004). They have abstract ideas about counting objects, including the one-to-one principle (one and only one number word should be assigned to each object) and the abstraction principle (any discrete objects can be counted, from stones to unicorns) (Gelman & Gallistel, 1986).

Mathematics education is (in part) education in language and literacy.

Language and Metacognition

Mathematics education is (in part) education in language and literacy. From the age of 2 or so, children learn the language and grammar of counting. They memorize the first ten 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 (Ginsburg, 1989). For example, once you figure out that forty comes after thirty, just as four comes after three, it is easy to append to the forty the numbers one through nine and then go on to the next logical tens number, fifty, which comes after forty, 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 (like "more") are among the first words spoken by many babies (Bloom, 1970). Mathematical words are so pervasive that they are not usually thought of as belonging to "mathematics" and are instead considered aspects of general cognitive development or intelligence.

Perhaps most importantly, language is required to express and justify mathematical thinking. With development, children become increasingly aware of their own thinking and begin to express it in words (Kuhn, 2000). These kinds of metacognitive skills are as necessary for mathematics as for other topics and begin to develop in children as young as 4 or 5 years of age (Pappas, Ginsburg, & Jiang, 2003).

Low-SES children show less proficient mathematical performance than do their middle-SES peers, particularly when metacognition is required, but do not lack basic concepts and skills.

The hardest form of language for children to learn is the special written symbolism of mathematics, like 5, +, - or =. For example, asked to represent a quantity like 5 blocks, young children exhibit idiosyncratic (e.g., scribble) and pictographic (e.g., drawing blocks) responses and only much later can employ iconic (e.g., tallies) and symbolic (e.g., numerals like 5) responses (Hughes, 1986).

Finally, the importance of mathematical language is underscored by the fact that the amount of teachers' math-related talk is significantly related to the growth of preschoolers' conventional mathematical knowledge over the school year (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). Language is clearly deeply imbedded in mathematics learning and teaching.

SES Differences

As in many other areas, lower-SES preschool children generally perform more poorly on simple mathematical tasks than do their more privileged peers (Denton & West, 2002). At the same time, the pattern of differences is complex and interesting. First, although lower-SES children's performance on informal addition and subtraction problems often lags behind middle-SES children's, the two groups often employ similar strategies to solve problems (Ginsburg & Pappas, 2004). They both use methods like counting on from the larger number or "derived facts" (4 and 5 is 9 because I know that 4 and 4 is 8 and 5 is just one more, so the answer has to be 9). Educators can use informal strategies like these as a foundation on which to build school mathematics (Resnick, 1992). Second, although lower-SES children exhibit difficulty with *verbal* addition and subtraction problems, they perform as well as middle-SES children on *non-verbal* forms of these tasks (Jordan, Huttenlocher, & Levine, 1994). They do not lack the basic skills or concepts of addition and subtraction. Third, lower- and middle-SES children exhibit few if any differences in the everyday mathematics they spontaneously employ in free play (Ginsburg, Pappas, & Seo, 2001). In brief, although low-SES children's performance needs improvement, they exhibit a good deal of competence on which ECME can build. Of particular concern should be the enhancement of language and metacognition.

Unfortunately, low SES children are susceptible to a pervasive risk factor, namely low quality schools (V. E. Lee & Burkham, 2002) that fail to offer suitable mathematics education. Their teachers often fail to provide opportunities for mathematics learning and teach badly or not at all, as we shall see below.

Conclusions on What Children Know

In the ordinary environment, young children develop an everyday mathematics entailing a variety of topics, including space, shape and pattern, as well as number and operations. Everyday mathematics encompasses more than "numeracy"; is both concrete and abstract; involves both skills and concepts; and may be learned spontaneously as well as with adult assistance. Low-SES children show less proficient mathematical performance than do their middle-SES peers, particularly when metacognition is required, but do not lack basic concepts and skills. The question of whether young children are "ready" to learn mathematics is beside the point: without much direct adult assistance, they are already learning some real mathematical skills and ideas. Learning mathematics is a "natural" and developmentally appropriate activity for young children.

Content and Components of Early Childhood

Mathematics Education

If children are capable of learning mathematics, and if we choose to help them learn it, what kind of mathematics should we teach and how should we teach it? The decisions stem from our educational values and goals, but should be informed by psychological research. ECME promotes the learning of mathematics *subject matter* and ways of *thinking* by means of various *components* of the educational experience.

Subject Matter

Most preschool teachers typically instruct children in a very narrow range of mathematical content. They often limit their focus to the names of the common shapes (Graham, Nash, & Paul, 1997) and the relatively small counting numbers, up to about 20. They generally do little to encourage counting or estimation, and seldom use proper mathematics terminology (Frede, Jung, Barnett, Lamy, & Figueras, 2007, p. 21).

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Yet, as we have seen, research shows that children are capable of learning content far more complex than this. The leading professional organizations in the field recommend that early mathematics instruction cover the "big ideas" of mathematics in such areas as number and operations, geometry (shape and space), measurement, and "algebra" (particularly pattern) (National Association for the Education of Young Children and National Council of Teachers of Mathematics, 2002; National Council of Teachers of Mathematics, 2000), within learning contexts that promote problem solving, analysis, and communication (National Council of Teachers of Mathematics, 2006).

Mathematical Thinking

Understanding number involves more than saying a few counting words. It involves reasoning about number (if 2 and 3 is 5, then 3 and 2 must also be 5) (Baroody, 1985), making inferences (if we add something other than 0 to 3, the sum must be bigger than 3) (Baroody, 1992), and developing a mental number line (100 is much further away from 2 than is 20) (Case & Okamoto, 1996). Understanding shape involves more than knowing a figure's name, although knowledge of correct mathematical vocabulary is certainly necessary. (If children can learn "tyrannosaurus rex," they should have no problem with "hexagon" or "symmetrical"). Children need to learn to analyze and construct shapes and to understand their defining features (Clements, 2004).

Various metacognitive functions also play a key role in mathematics learning. Children need to learn to be aware of and verbalize their mathematical strategies. Middle-SES children are more skilled at these aspects of metacognition than are lower-SES children (Ginsburg & Pappas, 2004).

Children also need to mathematize—to conceive of problems in explicitly mathematical terms. They need to understand that the action of combining one bear with two others can be meaningfully interpreted in terms of the mathematical principles of addition and the symbolism 1 + 2. One of the functions of mathematics education is to help children to advance beyond their informal, intuitive mathematics—what Vygotsky (1986) called "everyday knowledge." In Vygotsky's view, the goal is to help children develop, over a period of years, a powerful and organized "scientific" knowledge—in this case the formal concepts, procedures, and symbolism of mathematics.

Components

Given the goals of teaching subject matter and thinking, what methods should we use? ECME can be thought of as involving the following six components.

Environment

The preschool classroom (or "childcare center"—we use the terms synonymously) should contain a rich variety of objects and materials—such as blocks, dress up area and puzzles—that can set the stage for mathematics learning. Widespread agreement on this requirement has resulted in the extensive use of the *Early Childhood Environment Rating Scale* (ECERS) (Harms, Clifford, & Cryer, 1998), which primarily provides a rating of the quality of the preschool "physical" environment. Research using this measure shows that preschool environments vary in quality and that many require considerable improvement. But a rich physical environment by itself is not enough. The crucial factor is not what the environment makes possible, but what children *do* in it. Thus, many New Jersey preschools score relatively high on the ECERS: "Over 40 percent scored 5 or better, placing them in the good to excellent quality range" (Frede et al., 2007, p. 11). Yet observation of these classrooms showed that "… the average Abbott preschool provides limited support for children's mathematical skill development" (p. 20).

Play

We know that children do indeed learn a good deal of everyday mathematics on their own (Seo & Ginsburg, 2004). Play provides valuable opportunities to explore and to undertake activities than can be surprisingly sophisticated from a mathematical point of view (Ginsburg, 2006), especially in block play (Hirsch, 1996). Although essential for children's intellectual development generally and for mathematics learning in particular, play is not enough. It does not usually help children to mathematize—to interpret their experiences in explicitly mathematical form and understand the relations between the two.

Although essential for children's intellectual development generally and for mathematics learning in particular, play is not enough.

Teachable Moment

The *teachable moment* is a form of adult guidance that enjoys widespread acceptance in the preschool world. The teachable moment involves the teacher's careful observation of children's play and other activities in order to identify the spontaneously emerging situation that can be exploited to promote learning. The popular *Creative Curriculum* program (Dodge, Colker, & Heroman, 2002) relies heavily on use of the teachable moment.

No doubt, the teachable moment, accurately perceived and suitably addressed, can provide a superb learning experience for the child (Copley, Jones, & Dighe, 2007). But there is good reason to believe that in practice the teachable moment is not an effective educational method. Most early childhood teachers spend little time in the careful observation necessary to perceive and interpret such moments (J. Lee, 2004). During free play, teachers spend very little time with children (Seo & Ginsburg, 2004) or tend only to manage their behavior (Kontos, 1999). Teachers do not appear to be sufficiently knowledgeable to see the opportunity for teaching a range of mathematical concepts in everyday situations (Moseley, 2005). In brief, teachers seldom attempt to exploit teachable moments, and even if they did, it's hard to see how they could effectively keep track of and productively respond to the haphazard occurrences of teachable moments in 20 or so young children, especially from diverse backgrounds (Hyun & Marshall, 2003).

Projects

These are extensive teacher initiated and guided explorations of complex topics related to the everyday world, like figuring out how to create a map of the classroom (Katz & Chard, 1989). This kind of project can involve measurement, space, perspective, representation, and many mathematical and other ideas (e.g., scientific) that have practical application and appeal (Worsley, Beneke, & Helm, 2003). They can help children to learn that making sense of real-life problems can be stimulating and enjoyable. Although projects can be effective, the danger is that they may turn into a "... a grab bag of any mathematics-related experiences that seem to relate to a theme…" (National Association for the Education of Young Children and National Council of Teachers of Mathematics, 2002, p. 10).

Organized curriculum is an essential part of ECME.

Curriculum

Yet projects may be useful if guided by a larger plan (Helm & Beneke, 2003), namely a *curriculum*, which is the fifth component of ECME. Organized curriculum is an essential part of ECME. A curriculum can be characterized as "…a written instructional blueprint and set of materials for guiding students' acquisition of certain culturally valued concepts, procedures, intellectual dispositions, and ways of reasoning…" (Clements, 2007, p. 36). A curriculum offers planned activities for the teaching of mathematics. It assumes that mathematics does not always need to be sugar coated or integrated with other activities to appeal to young children, but can be an interesting and exciting subject of study in its own right. What could be more fascinating in a young child's eyes than the identity of the largest number (Gelman, 1980)? Adults who fear introducing mathematics to young children may be reacting more to their own unfortunate encounters with the subject than to any appreciation of young children's interests and capabilities.

Intentional Teaching

Deliberate instruction—teaching—is of course required by curriculum and is a key part of ECME. It is the responsibility of educators to do more than let children play or respond to teachable moments. "In high-quality mathematics education for 3- to 6-year-old children, teachers and other key professionals should… actively introduce mathematical concepts, methods, and language through a range of appropriate experiences and teaching strategies" (National Association for the Education of Young Children and National Council of Teachers of Mathematics, 2002, p. 4). Preschool teachers need to engage in deliberate and planned instruction, an activity some think is developmentally inappropriate, as we shall soon see.

Preschool teachers need to engage in deliberate and planned instruction...

New Curricula

Fortunately, within the past 10 years or so, several curricula inspired by cognitive developmental research have become available. All are devoted to improving low-SES children's achievement.

The *Big Math for Little Kids* curriculum (Balfanz, Ginsburg, & Greenes, 2003; Ginsburg, Greenes, & Balfanz, 2003) uses activities and storybooks to engage children first in learning key concepts of number, then shape, pattern, measurement, operations on number, and finally space. Activities are offered for each day of the school year. Within each of the larger topics, the activities are arranged in order of difficulty, as indicated by research on the developmental trajectories of children's mathematics learning. Thus, in the case of number concepts, children first begin to learn number words, and then encounter concepts of cardinal number, representation, and next ordinal number, in that rough order. Research on the curriculum's effectiveness is currently underway.

Building Blocks (Clements & Sarama, 2007a) draws upon an extensive body of research on developmental trajectories to create materials "… designed to help children extend and mathematize their daily activities, from building blocks… to art and stories…" (Clements & Sarama, 2007b, p. 138). The materials are unique in integrating three types of media: computers, manipulatives, and print. The curriculum focuses on two major topics, space/geometry and number/quantity. A "small scale summative research" study showed impressive gains for low-SES children, especially in the areas of subitizing ("seeing" a number quickly, without counting), sequencing, shape identification, and the composition of shapes (Clements & Sarama, 2007b). Subsequent research presents even more impressive support for the program's efficacy (Clements & Sarama, 2007c; What Works Clearing House, 2007).

The *Measurement-based* approach (Sophian, 2004) was developed for teaching mathematics in the Head Start program. Drawing on the work of Russian psychologists (Davydov, 1975) and developed in collaboration with teachers, the program assumes that the concept of unit is crucial to the early understanding of number, measurement, and geometric shapes. The curriculum includes a weekly project activity conducted by Head Start teachers, various supplementary activities, and weekly home activities for parents to conduct with their children. An evaluation "…showed significant, albeit modest, positive effects of the intervention" (Sophian, 2004, p. 59). Sophian also notes that an indirect outcome of the program was to elevate teacher and parent expectations about preschool children's potential for learning mathematics.

The *Number Worlds* curriculum (Griffin, 2007b) covers basic number concepts from preschool through the sixth grade. It pays special attention to helping children navigate among the three different worlds of "…real quantities that exist in space and time, the world of counting numbers… and the world of formal symbols" (Griffin, 2007a, p. 375). Building on the natural developmental progression, the program attempts to teach concepts foundational for learning and to promote rich connections among different areas of knowledge. *Number Worlds* relies heavily on hands-on games and activities that "capture children's emotions and imaginations as well as their minds" (p. 379), and stresses the central role of language. The program, aimed primarily at low-SES children struggling in school, has shown promising results (pp. 390-392).

The *Pre-K Mathematics Curriculum* (Klein & Starkey, 2002) includes 29 small-group preschool classroom activities employing manipulatives and 18 home activities for parents to use with their children. "The activities are designed to be sensitive to the developmental needs of individual children. Suggestions are provided for scaffolding children who experience difficulty…" (Klein, Starkey, Clements, & Sarama, 2007, p. 5). The content of the program involves number and operations, space, geometry, pattern, measurement and data, and logical reasoning. The program also made use of the *DLM Express* software (Clements & Sarama, 2003), an earlier version of the *Building Blocks* software discussed above. Evaluation research showed impressive gains, with large effect size, for low-SES children in the treatment group.

Storytelling Sagas (Casey, 2004) is a series of specially created supplementary mathematics storybooks for preschool through grade 2. Each of the six books focuses on a different content area (such as space, pattern, or measurement) and combines oral storytelling with hands-on activity. The books all have a strong visualization/spatial reasoning component. The series of books obviously stresses the very important role of language as it involves children in active learning of mathematics. Evaluations of the program are underway. One study showed that embedding mathematics activities in stories is an effective pedagogical method for promoting spatial reasoning in a sample of low-SES kindergarten children (Casey, Erkut, Ceder, & Young, in press).

In addition to these developments, the *High/Scope* curriculum (Hohmann & Weikart, 2002), one of the most popular in early childhood education, is being updated and will be called *Numbers Plus*. As the title suggests, the new curriculum will focus on number, but will also include activities in shape, space, measurement, "algebra" (mostly patterns), and data analysis. The new High/Scope mathematics curriculum will provide far more challenging (and we think appropriate) mathematics than did its earlier version, which was limited in scope and content, and will include professional development activities. The new curriculum will be carefully evaluated as well.

Although the curricula described above vary in many ways, they are all research-based and seem to hold promise for promoting the mathematics education of young children, particularly those from low-SES backgrounds.

Are early childhood teachers ready?

Early childhood education is increasingly becoming a common experience for young children in the U.S. Between 1970 and 2005, enrollment in some type of school (including private childcare centers, publicly supported preschools and kindergartens, and Head Start) increased substantially: for children ages 3 to 4 enrollment grew from 20 to 54 percent, and for children ages 5 to 6 it grew from 89.5 to 95.4 percent (U.S. Department of Education & National Center for Education Statistics, 2007). Many children are in school, ready and eager to learn mathematics. But are teachers and other childcare providers (for our purposes we refer to them as teachers as well) ready to teach them?

Teacher Qualifications

How do we know whether a person is qualified to teach early mathematics? The consensus of professional leaders and policy makers is that the minimum standard for early childhood teachers should be a four-year undergraduate degree with specialization in early childhood education (Bowman et al., 2001). Yet the certification requirements for early childhood teachers vary considerably across the U.S. For example, during the 2005-2006 school year, only 18 of the 38 states funding preschool programs required the lead teachers in every classroom to have a four-year college degree (although it may not involve training in ECME). The other 20 states had no such requirement (Barnett, Hustedt, Hawkinson, & Robins, 2006).

If possession of the BA is the criterion, the largest number of "qualified" teachers can be found in programs located in public schools. Around the year 2003, all kindergarten teachers and eighty-seven percent of pre-kindergarten teachers in public schools had at least a bachelor's degree (Barnett, 2003). Teachers in other center-based settings (for example, Head Start programs) are less qualified (as defined by degree).

Of course, educational credentials are only a proxy for relevant knowledge and skills acquired in the colleges and universities. The real issue is whether an undergraduate degree—especially an undergraduate degree in early childhood education—provides teachers with knowledge and skills useful for teaching early childhood mathematics. The answer is discouraging. The undergraduate degree—even with a major in early childhood education—is not a good predictor of classroom quality and children's academic outcomes (Early et al., 2007).

One reason may be that postgraduate programs do not appear to adequately prepare early childhood education majors to teach domain-specific knowledge to young children (Isenberg, 2000), especially mathematics (Copley, 2004; Sarama, DiBiase, Clements, & Spitler, 2004). For example, although almost 80% of preschool to grade 3 preparation programs in New Jersey 4-year colleges offer coursework targeted to literacy, only 16% offer coursework targeted to mathematics; 74% offer mathematics education only as a part of a comprehensive early childhood education course; and 10% do not offer mathematics education at all. The situation is not better for 2-year community colleges; 18% of them do not offer early childhood mathematics; almost 50 percent offer it only as part of another course; and less than 40% offer it as a stand alone course (Lobman, Ryan, & McLaughlin, 2005a). Colleges and universities provide prospective teachers with few opportunities to learn about ECME.

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Teachers' Beliefs

Our personal experience suggests that many prospective and current preschool teachers do not like mathematics, are afraid of it, and do not want to teach it. The available research does not put the issue so bluntly, but provides evidence consistent with our observations. In general, early childhood teachers place higher priority on the social, emotional, and physical domains in their classrooms than on intellectual or academic activities (Kowalski, Pretti-Frontczak, & Johnson, 2001; J. S. Lee, 2006). Preschool and kindergarten teachers alike emphasize that, in order to be ready for success in school, young children need to be healthy and socially and emotionally competent, but that it is not as important for them acquire basic literacy and mathematics knowledge and skills (Lin, Lawrence, & Gorrell, 2003; Piotrkowski, Botsko, & Matthews, 2001). One exception is that the greater the school's poverty level and the greater the number of minority students enrolled, the more kindergarten teachers identify lack of academic skills as a major problem to be addressed in the transition to elementary school (Rimm-Kaufman, Pianta, & Cox, 2000).

But in general, early childhood teachers do not place a high value on teaching mathematics. A focus group study showed that very few preschool teachers, professional development providers or administrators, teacher educators from 2- and 4-year institutions of higher education, or state policymakers spontaneously discussed *any kind* of subject matter knowledge as relevant for preschool. Furthermore, during eight focus group meetings, none of the stakeholders discussed mathematics at all (Lobman, Ryan, & McLaughlin, 2005b). When explicitly asked to compare the relative value of different academic topics, early childhood teachers rate mathematics as significantly less important than literacy (Blevins-Knabe, Austin, Musun-Miller, Eddy, & Jones, 2000; Musun-Miller & Blevins-Knabe, 1998).

Yet early childhood teachers may be aware of the changes in the field that demand more rigorous ECME. When asked directly to focus on the role of mathematics in early childhood education, they generally agree that their young students could and should engage in mathematical learning, especially basic "numeracy readiness skills" such as one-to-one correspondence, understanding of more and less, simple counting, and sorting. Geometry and measurement concepts were less popular (J. S. Lee & Ginsburg, 2007b; Sarama et al., 2004).

At the same time, goals and beliefs about methods of early mathematics education vary depending on the population of children teachers serve (J. S. Lee & Ginsburg, 2007a, 2007b). Preschool teachers working with middle-SES children at private preschool programs for the relatively affluent appear to take a relatively unstructured approach to mathematics education. They feel that it is important to foster children's positive dispositions and feelings, but that it is not as crucial to teach mathematics knowledge or skills. They believe that children should learn mathematics through self-initiated play, exploration, discovery learning, and problem solving.

By contrast, preschool teachers working with children from low-SES families at publicly funded preschool programs such as Head Start or Universal Pre-kindergarten place strong emphasis on the need for ECME to prepare their children for kindergarten and beyond. They believe that teachers should work with overall goals and plans for mathematics education, set time aside specifically for mathematics, and expect their students to participate in mathematics activities regardless of their interests. In order to achieve their goals, these teachers tend to rely heavily on ready-made curricula and materials and to use computers to promote children's mathematical learning.

In brief, early childhood teachers believe that social emotional learning is more important than literacy, which in turn they see as more important than mathematics. When asked directly about teaching mathematics, teachers agree that children should learn some basic aspects of number. Teachers of low-SES children tend to favor more directive instructional methods of than do teachers of middle-SES children.

Teaching Practice

Early childhood teachers' low emphasis on mathematics also manifests itself in their practice. Empirical observation of a large number of classrooms shows that: "We can characterize these early education environments as socially positive but instructionally passive" (Pianta & La Paro, 2003, p. 28). Moreover, teachers spend much less classroom time on mathematics than on literacy. Layzer and colleagues (1993) observed that in preschool only 15% of the class time during periods of core programmatic activity in the morning was spent teaching mathematics *and* science, compared to 29% spent on teaching reading and language. Similarly, according to Early and colleagues (2005), only 8% of classroom time is spent on math activities involving counting, time, shapes, sorting, while 21% is devoted to literacy activities.

> The poor quality of instruction is...troubling.

> Our most urgent need is to improve teacher training and support.

The situation is similar in kindergarten. Teachers report spending 39 minutes in each session, 4.7 days a week, for a total of 3.1 hours each week on mathematics, whereas the comparable figures for reading are 62 minutes, 4.9 days, and a total of 5.2 hours (Hausken & Rathbun, 2004). Because children's mathematics gains over the course of their schooling are related significantly to the amount of time they spend on the subject (Guarino, Hamilton, Lockwood, Rathbun, & Hausken, 2006), the quantity of early childhood mathematics instruction is a cause for concern.

The poor quality of instruction is also troubling. Graham et al. (1997) observed that mathematics was not a salient topic of discussion, not even opportunistically or spontaneously, in two preschool programs with a reputation for high overall quality. When mathematics was discussed, the conversation lasted less than a minute, primarily centering on very basic concepts such as age, numeral recognition, and names of shapes. Interestingly, these teachers reported that they believe mathematics is important, and that they indeed engaged in mathematical discussions with their children. Observing 20 preschool classrooms, Brown (2005) rarely saw teachers scaffolding children's exploration of mathematical ideas or suggesting challenges. Brown also found that those teachers who rated mathematics as important did not necessarily teach it frequently. In short, mathematics seems to be seriously overlooked in preschool classrooms even when teachers say that it is important and that they teach it.

The picture does not look much better at kindergarten level. Chung (1994) found that, although 30 public school kindergarten teachers were observed to spend a quarter of their classroom time on mathematics, it was usually integrated with other learning activities and seldom taught as a separate subject. Even more troubling, most of the mathematics time was spent on rote learning of basic skills. Many early childhood teachers seem to be adept at preparing the physical environment that includes mathematics, but not at teaching it (J. Lee, 2004).

Where do we go from here?

We have seen that:

- There is a clear need for ECME, particularly to enhance the school success of low-SES students who are at risk of school failure;
- Children have the potential and desire to learn mathematics, even at an abstract and symbolic level;
- ECME is more complex, deep and difficult than usually assumed;
- The means for teaching early mathematics—most importantly research-based curricula—are available (al-

Early Childhood Mathematics Education: What is Math and What is Education?

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As Ginsburg, Lee, and Boyd document so clearly, young children are capable of a wide range and depth of thinking and learning in mathematics; such capacities appear to be sensitive to environmental input; and the systems in place for ensuring the quantity and quality of such inputs are at best third-rate. Their nine recommendations are sensible, appealing to developmental scientists, early educators, and education researchers. But for these recommendations to have desired effects, several challenges remain to be addressed.

First, there is a core question – what skills and knowledge fall within the domain of mathematics? The studies of math performance catalogued by Ginsburg and colleagues are a laundry list of content and cognition: number, space, memory, time, quantity, etc.. Children *are* capable of more than what classrooms require of them, but we need a more detailed documentation of the *developmental* connections among what young children can learn and the skills tested in school. Visit any elementary school and *if* you see math instruction (see Pianta, Belsky, Houts, Morrison, & NICHD ECCRN, 2007), you will be struck by the hodge-podge of activities, focus, and target-skill areas. At the risk of oversimplification, more than 2 decades of research on language development and early literacy helped describe the developmental course of literacy and role(s) played by skill areas such as phonological processing; now every early literacy curriculum emphasizes instruction in phonological *and* meaning-based skills, rather than one versus the other.

Developmental science has yet to map mathematics trajectories to the same extent. If there is to be some systematic link among children, teachers, and curriculum, we need to know how mathematics is organized developmentally – how does understanding quantity or order translate into the kind of performance we call “mathematics” in 4^{th} grade? What skills are essential as a focus of instruction? Clearly-articulated developmental pathways are essential if instruction is to move beyond the “skill of the week,” and a particular challenge is whether the disparate skills observed in various labs are the product of some underlying, organizing process. The design of curriculum and training of teachers are very different if four domains of math skills develop independently or whether a common cognitive capacity accounts for growth in each.

Studies of development in mathematics must also consider issues of context, scaling, and assessment if findings will translate from lab to classroom. Although knowledge is increasing about what young children can do in lab situations, research has yet to describe whether such skills are necessary or present norms for their performance, information that could drive the construction of useful assessment systems. And because the learning of mathematics is embedded in interactions with the “stuff” of the world and with “teachers,” it is dependent on the knowledge of the teacher and their skill engaging young children through feedback, sensitivity, and attentiveness to cues for learning. Well-described trajectories or developmental curricula will not by themselves increase mathematics performance; literacy curricula proven effective in rigorous trials often fall short when scaled in typical implementation contexts.

Ginsburg and colleagues are right to focus on the knowledge and skills of teachers, and how to effectively improve them, as a central focus of research if the progress of developmental science will be realized in gains in children’s competence. The very low levels of active, cognitively-engaging teaching that occurs in most classrooms, even when staffed by certified, licensed, or degreed teachers (see Pianta et al., 2005) is sobering. We need more careful study of effective instructional processes, of ways to assess these processes reliably in large samples, of factors that regulate their presence and how to improve them. This requires a science linking the “what can be” in the lab with “what is” and too often “what will be” in the classroom, a science of teachers and teaching requiring the joint attention of both developmental and education scientists.

Ginsburg, Lee, and Boyd advance a timely argument for serious attention to mathematics both by policy-makers that attend to early education and by scholars who focus on development. Their argument identifies two challenges facing the field: the need for a developmental mapping and theory of mathematics skill and how to systematically study teaching as it can be produced, leveraged, and improved.

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The Price of Inattention to Mathematics in Early Childhood Education is too Great

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Looking across international comparative studies, American students' performance in mathematics is in the bottom third (Ginsburg, Cooke, Leinwand, Noell, & Pollock, 2005). This is not news. We have known that American students perform poorly in math and science on international comparisons for many years. More recently, longitudinal studies have shown that math concepts, such as knowledge of numbers and ordinality, at school entry are the strongest predictors of later achievement, even stronger than early literacy skills (Duncan et al., 2007). It is curious that so little attention is paid to the mathematical learning of young children, which serves as the foundation for future math understanding and school achievement.

Ginsburg, Lee, and Boyd remind us that young children can and do learn mathematical concepts, and they could learn much more if we supported their learning. But, as they explain, preschool teachers are given almost no preparation to teach mathematics. The consequence, apparent to me in visits to hundreds of preschool and kindergarten classrooms, is that mathematics is simply not taught. When we planned to assess instructional strategies in math we often had to go back to a program day after day to see anything that looked like an effort to facilitate children's math learning. When we did see it, variations on two approaches predominated. The first involves sheets of paper with numbers on one side and groups of objects on the other. Children draw a line from, for example three stars on the left to the number 3 on the right, or from four balloons to the number 4. The other common activity involves painting macaroni and pasting them in boxes on colored paper in groups that reflected the number written in each box. Children seemed to enjoy both tasks, to be sure. And they may develop some eye-hand coordination or artistic talent in the macaroni painting and pasting activity. But it is hard to imagine a more inefficient way to promote an understanding of number.

We cannot blame the teachers. Until recently we have not expected instruction in mathematics in early childhood education programs. And in addition to not being trained, many are not comfortable with their own mathematical skill. Furthermore, the difficulty of teaching young children mathematics is typically underestimated. I once observed a group of highly qualified preschool teachers receive intense training in assessing young children's mathematical understandings. They became adept at diagnosing children's misunderstandings. But after many months of weekly meetings they all confessed that they were not at all sure what to do after they had identified a problem. We realized that they needed much more than training in assessment.

Ginsburg et al. describe the many different strands of mathematical thinking and skills young children need to learn, as well as the many ways we can facilitate their mathematical learning -- with materials, opportunities to play, taking advantage of teachable moments, guiding children's explorations, and using math curriculum as a guide for instruction. The teacher is key to all of these strategies for promoting math understanding. Even children's play needs to be guided to focus their attention on math concepts (e.g., providing props for a post office or store, and modeling buying and selling). Until we make mathematics learning a priority, and until we invest in preparing early childhood educators to be effective math teachers, we can expect avoidance and ineffective practices to continue, and we will continue to be embarrassed by the poor performance of children in the country that has been the world leader in innovation.

I am deeply grateful to Ginsburg, Lee, and Boyd for calling our attention to a serious national problem.

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though some are still being evaluated);

- Yet teachers are generally not well prepared to teach early mathematics, may not want to teach it, and often teach it badly or not at all.

In brief, the need, potential, and some means exist, but we are not currently providing sound ECME, especially to the children most in need. Given this analysis, we offer the following recommendations concerning teacher training, curricula, professional development in a curriculum, development of educational materials, research on children and teaching, and development of and research into assessment and evaluation.

Teacher Training and Support

Our most urgent need is to improve teacher training and support. As we have seen, early childhood professionals are often treated badly (low pay and prestige perhaps lead the list) and have not been given the training or resources they need to do their job properly. Yet they need to know so much! They need to understand the mathematics, the children, the curriculum, methods of assessment, and pedagogy. It is not an exaggeration to say that the most pressing need in ECME is to improve teacher education at all levels. The federal government, states and local educational authorities need to provide extensive support for both pre-service (college and university level) and in-service teacher training.

Recommendation 1: Stress relevant and rigorous content in pre-service training

As recommended by the *Eager to Learn* report (Bowman et al., 2001), an earned early childhood education degree from a four-year college should be a condition of employment for early childhood teachers. Yet that is not enough. The study leading to the degree must involve some relevant and rigorous content. As we saw, many early childhood college programs fail to provide adequate instruction in ECME. It is perhaps ironic that programs typically offer students the least help in what they find most difficult (mathematics) and the most help in what they feel is easiest (literacy). Clearly, there should be more courses devoted to ECME.

But what should they teach? We have few examples that can serve as models. In our view, a successful ECME course needs to introduce students to the new research literature on children's mathematical thinking; help them understand methods of formative assessment, like observation and clinical interview; teach them the basic mathematical ideas underlying ECME; expose them to various curricula (later, through in-service work, they will learn to implement a specific curriculum) and to appropriate pedagogy; and help them to think critically about ECME (Ginsburg, Jang, Preston, Appel, & VanEsselstyn, 2004; Ginsburg, Kaplan et al., 2006). Further, the course should supplement the traditional textbook and readings with extensive analysis of videos involving children's thinking (J. S. Lee, Ginsburg, & Preston, 2007). Teachers need to avoid both vague theory and mindless practice. On the one hand, a course needs to help prospective teachers get beyond the dogmatic parroting of what have become vacuous concepts like "constructivism" or "developmentally appropriate practice." On the other hand, it should help them to think about why an apparently attractive "manipulative" activity may or not work.

As we have seen, ECME courses are rare. Good ones may also be difficult for individual faculty members to create *de novo*. The government and education authorities should support the development and use of model college and university ECME courses and should help faculty to learn to teach them, perhaps through summer institutes and other means. The courses also need to be evaluated in a deeper manner than provided by the typical student popularity ratings.

Recommendation 2: Provide extensive in-service training and support

Teaching an early mathematics curriculum is not easy. It is more than child's play in several senses. It requires not only appreciating the essence of the curriculum, but also understanding mathematics, individual children, methods of assessment and pedagogy. Early childhood teachers need training in implementing the curriculum they are required to teach and in examining their own teaching. Specific training of this sort cannot be provided at the pre-service level, which of necessity must be generic.

Successful in-service training should be extensive, frequent and long-term. It should help teachers to reflect on their methods, to share difficulties and successes. Some workshops we have seen are mere collections of activities. They can be useful if teachers understand how and why to use them. But these "low level" workshops seldom explore these matters in any depth; they lack a conceptual framework for understanding the activities to be undertaken. Other, "high level" workshops traffic in abstract principles like constructivism or developmentally appropriate practice. These principles can be useful if teachers understand how they relate to the teaching of specific activities. Yet the high level workshops seem disconnected to a significant degree from the nitty-gritty of classroom practice. We propose that "theoretically grounded specificity" is the key (Ertle et al., in press). Teachers need to learn to think deeply about the specific activities they use and why they use them.

Recommending extensive in-service professional development is easier than providing it. As in the case of college ECME courses, few successful models of early mathematics professional development activities are available. To some extent, efforts in literacy provide some suggestions. For example, Kinzie, Pianta and colleagues have developed a web-based system with which teachers use a specially developed evaluation rubric (CLASS) to analyze videos of teaching, including their own efforts (Kinzie et al., 2006). In any event, the federal and state governments and local education authorities should not only fund extensive in-service professional development, but also encourage the development of new programs of professional development and research on their effectiveness.

> The federal government, states and local educational authorities should mandate (and pay for) the use of research-based early childhood curricula.

> We need to conduct teaching experiments that provide unusually stimulating conditions designed to push children's performance and learning to their outer limits.

Curricula

Recommendation 3: Promote curricula

The federal government, states and local educational authorities should mandate (and pay for) the use of research-based early childhood curricula. Since the NAEYC/NCTM Guidelines were released, a great deal of progress has been made. Preschools, kindergartens, and childcare Centers have begun the process of implementing curricula. Head Start is rethinking its mathematics curriculum; High Scope is strengthening its approach. But despite the best efforts of NAEYC/NCTM, there is still a good deal of resistance in the early childhood community, for a portion of which any planned, intentional curriculum—no matter how intellectually exciting—is anathema, equivalent to the worst of dreary schooling.

Recommendation 4: Develop new curricula

At the same time, the federal government, states and local educational authorities should support the development of new curricula. Early childhood mathematics curricula are only in their infancy (or perhaps early childhood). We have not yet reached the limits of our ingenuity in the creation of materials, activities, software, story books, guidelines for exploiting free play, projects, television shows, and toys. In creating these components of ECME, developers should certainly take into account research-based information on the typical "trajectories" (Clements, Sarama, & DiBiase, 2004) through which children's mathematical thinking naturally progresses. At the same time, we believe, curriculum developers should not treat them as setting final and absolute limits on what children can learn. Most research from which observed trajectories derive involves examination of children's current abilities, and does not necessarily explore what children can do under stimulating conditions. In any event, the government should support vigorous and creative development efforts, involving not only researchers but also those, including teachers, who can provide the necessary creativity, imagination, whimsy and fun that researchers are not trained to supply (and for which some may have little talent).

Research

Several kinds of research are needed. Over the past 30 years or so, cognitive developmental researchers have provided a body of knowledge that has transformed our views of young children's mathematical minds. This kind of research is flourishing and remains valuable. But more importantly we need educational research on several relatively unexplored topics—research on what children can do in rich environments, on teacher knowledge and how to enrich it, and on teaching itself.

Recommendation 5: Support research on learning potential

As both Papert (1980) and Vygotsky (1978) pointed out, children may be more capable than we expect, and we can only learn about their true abilities if we challenge them and test them under deliberately atypical conditions. Research of this type is limited, although there are a few distinguished exceptions. For example, 4- and 5-year-olds can easily be taught the basics of addition and subtraction (Zur & Gelman, 2004) and to investigate geometrical ideas like symmetry (Zvonkin, 1992). Yet most developmental research focuses on what is, not on what could be. But the issue is not what is; the issue is what we can engineer (although what is may constrain what is possible). We need to conduct teaching experiments that provide unusually stimulating conditions designed to push children's performance and learning to their outer limits. Before the web's invention, we could not have known that 4-year-olds could surf it.

Recommendation 6: Support research on teacher knowledge and how to enrich it

Teachers are the key to the success of ECME. Children are capable of learning mathematics. The issue is how to help teachers teach it. Teaching is guided by views of learners and learning (Lampert, 2001) and by knowledge of subject matter (Ma, 1999). As William James pointed out many years ago, the teacher's "intermediary inventive mind" (James, 1958, p. 24) must apply general principles to the individual case so as to promote learning. The issue then becomes understanding the teacher's mind, which unfortunately is often not as inventive as is required. We need research to illuminate how teachers think about learning, how they interpret the individual child's behavior, how they think critically about their teaching efforts and children's learning, and what they understand of both the curriculum and the mathematics underlying it. We also require teaching experiments for teachers, that is, investigations of how we can help the teacher mind to become more inventive and more facile in critical thinking. Such experiments can inform programs of professional development, which in turn should undergo evaluation.

Recommendation 7: Support research on teaching

We know little about teaching mathematics to young children, perhaps partly because it is so seldom done. Recent research (Ball, 1993; Lampert, 2001; Shulman, 1987) has added considerably to our knowledge of teaching at the elementary level and beyond. But researchers have paid scant attention to the special challenges of teaching 4- and 5-year-olds. For example, can they be taught in large groups, as they often are in Korea (French & Song, 1998)? How should the teacher of young children employ manipulatives or introduce symbolism or read mathematical stories? What kind of pedagogical content knowledge (Shulman, 2000) do they need? Research providing an understanding of *good* teaching—that is, teaching that is probably atypical—can serve to inform our views of quality ECME.

Research providing an understanding of good teaching—that is, teaching that is probably atypical—can serve to inform our views of quality ECME.

Assessment and Evaluation

Recommendation 8: Support research on and development of assessment methods

We also require research and development efforts in the areas of assessment and evaluation. To provide effective instruction, teachers need to understand what children know and don't know, and how they are learning. Methods of "formative assessment" can help teachers obtain this vital understanding. The field of early education has traditionally favored observation as the primary method for understanding young children. Yet observation, like any other assessment method, is only as good as the theory on which it is based. If they are to learn anything about children's mathematical knowledge, teachers need to know what to look for as they observe, for example, children's block play. We need research on how well teachers observe and interpret children's behavior, and we need to develop methods to help teachers improve these skills.

Yet observation is not enough. As Piaget (1976) pointed out many years ago, "... how many inexpressible thoughts must remain unknown so long as we restrict ourselves to observing the child without talking to him?" (pp. 6-7). To learn about what is hidden in children's minds, teachers need to engage in effective clinical interviewing (Ginsburg, 1997). Not many teachers—at any level of education—seem to use this method in a systematic way. The issue for developers is how to help teachers become comfortable with and proficient in use of clinical interviewing in the context of classroom activities (for example, as the child plays with blocks); the task for researchers is to investigate whether teachers can indeed learn to use the method to develop practical interpretations that can guide teaching.

Recommendation 9: Support research on and development of evaluation methods

Evaluation is another area requiring development and research efforts. Curricula need to be evaluated. We need to know "what works." But this process is fraught with conceptual difficulties. A useful evaluation instrument must have strong "construct validity." That is, it should measure what research shows to be important about young children's learning of mathematics. Yet few research-based evaluation instruments are currently available. We require research-based and theory-informed evaluation instruments that can be used to determine whether programs do indeed enhance children's meaningful learning. Fortunately, the federal government is now supporting research and development efforts designed to produce rigorous and theoretically meaningful evaluation instruments in the areas of mathematics, literacy, language, and emotional development. Nevertheless, considerably more work on evaluation needs to be undertaken by collaborative teams of researchers in cognitive development and measurement.

Conclusions

This paper has shown how research knowledge has provided a basis for sound ECME. We have also shown how implementing it presents many difficult challenges, particularly improving the education and professional development of our teachers. But as we go forward, we must remember that ECME cannot in itself perform magic (Brooks-Gunn, 2003). ECME operates as part of a larger social and educational context. For ECME to succeed, teachers need to be adequately paid and supported. Children need good education in all areas, in literacy and art as well as mathematics, and at all levels, from preschool through the university. Children need adequate health care and the emotional support provided by a warm and caring teacher (Arnold & Doctoroff, 2003). They need to escape from the debilitating effects of poverty: 18% of American children live in extreme poverty and another 21% live in low-income families (National Center for Children in Poverty, 2006). Attention to ECME must be part—only a small part—of a comprehensive educational and social agenda.

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