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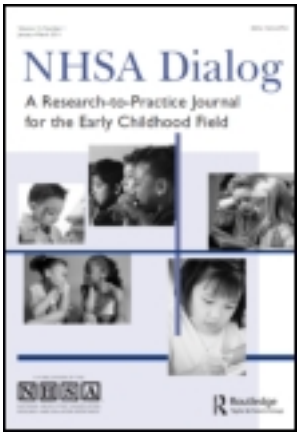

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The What, How, and Why of Effective Teacher Professional Development in Early Mathematics Education

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RESEARCH-TO-PRACTICE SUMMARIES

The *What, How*, and *Why* of Effective Teacher Professional Development in Early Mathematics Education

Jie-Qi Chen and Jennifer McCray
Erickson Institute

This article describes the successful stories of the Early Mathematics Education Project at Erikson Institute in Chicago. It intends to address three questions related to the project's work: What is the purpose and scope of the program? How does the program work to enhance the mathematical competence of early childhood teachers? What are the critical factors contributing to the program success? Specific program components and intervention strategies are detailed to help practitioners to examine and replicate the work.

Keywords: professional development, early mathematics, early teaching and learning

> I have learned more this year with Erikson's Early Math Project than I have in the past 15 years of professional development. I used to feel afraid to teach math even to preschoolers. I'm excited about teaching it now. I step more and more out of my own comfort zone in teaching math. I help my students get excited about math too.

We have heard similar comments repeatedly from teachers who have participated in our professional development (PD) sessions in early mathematics education. This teacher's comment is more than a compliment to our professional development program; it also exemplifies the changed attitudes and improved practices in mathematics that teachers experience.

Teachers who complete our PD program increase the achievement level of the children they teach. A formal evaluation of the program indicated that, for every school year children spent in the classrooms of teacher-participants, they gained an additional 3 months of mathematical learning. The growth of children who began the school year behind national norms was closer to 5 additional months of learning. (McCray, Zhang, & Chen, 2011). These results point to the

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positive impact of the program on children's learning and its particularly significant effects on the children most in need of help. What is the purpose and scope of the program? How does the program work to enhance the mathematical competence of early childhood teachers? Why is the program so successful? In this article, we address these three questions.

PURPOSE AND SCOPE OF THE PROGRAM

The Early Mathematics Education (EME) Project at Erikson Institute was launched in 2007 in response to an urgent need for teacher professional development. Prior to planning the project, we conducted a survey of nearly 340 prekindergarten teachers in Chicago Public Schools (CPS) to learn about early childhood teachers' perceptions of their mathematics teaching and needs. The results indicated that more than half of them (57%) were unsure of their own math knowledge, and more than a quarter of them (28%) did not feel confident teaching mathematics to young children (Sparr, Chen, & McCray, 2011). Early childhood teachers recognize their lack of confidence and knowledge in teaching mathematics. They identify PD as their most effective source of support (Sparr et al., 2011). Specifically, when asked to indicate the type of support they would like to receive to improve their early math teaching, 91% of teachers selected PD.

In response to the survey results, Erikson Institute partnered with the Office of Early Childhood Education in CPS and launched the EME Project, an in-service PD program in early mathematics. From its inception, the goal of the program has been to help teachers develop much needed mathematics competencies and provide quality mathematics education to inner-city children during the critical years of early schooling. Over the last 4 years, the project has provided PD training in mathematics to more than 300 Head Start, prekindergarten, and kindergarten teachers from 150 schools. The teachers we have trained serve approximately 8,000 students each year.

Teacher participation in the EME early math PD program was voluntary. Each year, the Office of Early Childhood Education in CPS posted a list of available PD topics from which teachers could choose. Our program was one among many choices. Once enrolled in the program, teachers were required to attend all sessions. Because of the voluntary nature of teacher participation and the quality of the program, we have the great pleasure to work with groups of enthusiastic learners over the last 4 years. In fact, each year after our first, we have had 2 times more teacher requests to participate in our program than we can actually accommodate. We credit this to the program's strong reputation, spread through word of mouth among teachers.

STRUCTURAL COMPONENTS OF THE PROGRAM

The PD program of the EME Project is based on three integrated components: learning labs, on-site coaching, and classroom implementation (see Figure 1). Working in tandem, each of the three components enhances the effects of the other two to develop the mathematics competence of participating teachers. We describe each component briefly later.

Learning Labs

Learning labs are interactive sessions in which teacher participants develop content knowledge of early mathematics under the guidance of an instructor. Provided on PD days designated by

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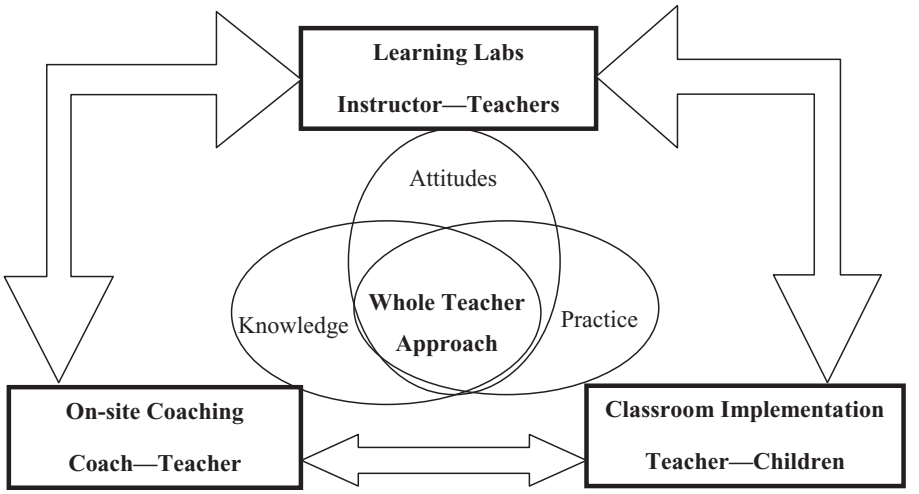

FIGURE 1 Program structural components and conceptual framework.

CPS, the early math learning labs have been offered over time in a series of either 5 full days or 8 half days. It is important to note that learning labs are scheduled 5 to 8 weeks apart during the school year to allow opportunities for teachers to engage in classroom implementation and coaching between sessions.

Central to the learning lab experience is teachers' understanding of the Big Ideas in early mathematics (see Table 1). Big Ideas are "clusters of concepts and skills that are mathematically central and coherent, consistent with children's thinking, and generative of future learning" (Clements & Sarama, 2009, p. 3). As foundational concepts, young children can begin to explore them at any early age and continue to develop understanding of them throughout the school years. Essential tools in mathematical thinking, teachers can use Big Ideas to organize the classroom environment, plan meaningful activities, engage in curriculum analysis, and articulate the underlying purpose of students' learning (National Research Council [NRC], 2009).

The central mechanism we employ to help teachers develop understanding of the Big Ideas is a specially designed adult learning experience. The experience is generally participatory and collaborative, involves some kind of kinesthetic or hands-on activity, and incorporates discussion and problem solving. For example, when teachers learn about Big Ideas in Operations, they work in groups to act out different versions of the *Gingerbread Man* for the other teachers in the learning lab. Each version illustrates different mathematical transformations when teachers acted out as the Gingerbread Man runs away. Teachers may join or leave the chase, representing the operations of joining and separating. Teachers than compare whether there are more or fewer "chasers" than when the chase began. The exercise illustrates to teachers how operations such as joining and separating can be thought of as stories—stories about how quantities change as members of a set are added or taken away.

Although the central purpose of the learning lab is to help teachers explore a set of foundational mathematical ideas, it also functions as a powerful means of addressing teachers' attitudes about math. At the most basic level, this kind of activity makes mathematics fun and childlike. Teachers are good sports who enjoy the opportunity to let someone else be in charge while they "play" with

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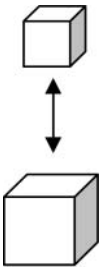
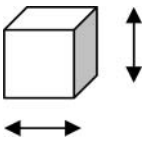
TABLE 1
Sample Big Ideas in Measurement

Topic	Big Ideas	Examples and Teaching Tips

Comparison 	• All measurement is comparison:
	  • Some comparisons are direct, but when direct comparison is not possible, indirect comparison can be used.
	  • Comparisons must be "fair," so, for example, units must be of equal size, and there must be no gaps or overlaps.
		• Children need many opportunities to directly compare objects such as weighing rocks on a pan balance.
		• Children also need experiences measuring objects that cannot be directly compared such as a table in one room and chairs in another room—this makes the need for measuring tools clear.
		• Measuring involves procedures and techniques that must be taught to children.

Attributes 	• Many different attributes can be measured, even when measuring a single object. • Isolating the attribute to be measured is an important precursor to measuring. • Giving a number to an attribute of an object helps to specify and compare *how much*.	• A bucket has many measurable attributes, for example, height, weight, capacity, or circumference. • It is important for children to develop language to identify and describe particular attributes; not just *bigger* but also *longer, heavier*, or *wider*. • Quantifying measurement allows you to say *how much* longer or *how much* heavier.

one another. Activities like these, in which teachers see themselves as the learners, help teachers who are anxious about mathematics to become more comfortable and confident. Over the course of the PD program, comfort and confidence grow as teachers become more competent.

The collaborative nature of the learning experience is equally important. Learning labs present a unique opportunity for teachers to develop stronger professional identities as they meet new peers, share their experiences, and learn about other teachers' struggles and success with early math. By providing structured opportunities for teachers to work together in a spirit of fun and exploration, adult learning exercises help create a sense of unity among teachers. Group learning becomes another positive association with mathematics.

On-Site Coaching

Taking place between learning lab sessions, on-site coaching is designed to support individual teachers' classroom practice, transforming that practice into a learning experience. Coaches are veteran teachers, trained by EME project instructors, to implement our distinctive early math coaching process. Adapted from cognitive coaching (Costa & Garmston, 2002), early math coaching is delivered in a series of cycles. Each cycle focuses on the planning, observation, and analysis of a mathematics activity that teachers conduct in their own classrooms. In our program,

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each coach was responsible for eight to 10 teachers each year. They met with each teacher three times a year for about 1 hr each time.

When this PD component was originally implemented, we discovered a problem. Teachers who designed their own math teaching activities for the coaching cycle were not uniformly successful in representing the Big Ideas in early mathematics. We determined that the development of teacher knowledge of mathematics was not adequately supported by this process. To address this problem, we developed Research Lessons—lesson plans for developmentally appropriate activities that address Big Ideas of mathematics and that teachers could implement as the focus of their coaching observations. Through Research Lessons, the Big Ideas that were studied at the last learning lab were reactivated and applied in the classroom. With this additional structure in place, coaches were able to implement the lessons themselves and study them as a group before attempting to coach teachers. Research Lessons that all teachers implemented and could discuss at learning labs served as an additional opportunity for teachers to revisit Big Ideas they had previously explored, further integrating and elaborating their content knowledge. Through the addition of Research Lessons, early math coaching cycles could focus on the knowledge teachers were studying in the learning labs. Coaching simultaneously supported teachers' understanding of content knowledge and teaching that knowledge to young children. The translation of content knowledge into classroom practice, long a missing link that has weakened PD programs, became a seamless process. With the support of a coach, teachers applied what they learned and reflected on that application to deepen and further their understanding.

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Classroom Implementation

When Research Lessons were added to the PD program to increase the effectiveness of coaching, they also had a major impact on teachers' classroom implementation. Previously, teachers had been responsible for planning their own activities for teaching Big Ideas to children in their classrooms. Now they had a prescribed activity for math lessons in the classroom. Although this created supportive structure and made classroom implementation richer and more productive for developing classroom practice, it also diminished teacher autonomy. Given teachers' initial uneasiness about teaching mathematics, we determined that the Research Lessons needed an "in" for teachers—an element to help them feel comfortable with implementing the lesson plan and extend the positive associations generated in the learning labs.

To this end, we designed each Research Lesson to begin with favorite books of both teachers and children. Early childhood teachers tend to have very positive associations with children's literature. Story reading is a soothing, engaging, and child-friendly activity. Further, early childhood teachers are fairly comfortable in this context. They tend to know more about the key elements of early literacy than they do about mathematics, and they are generally confident that children will enjoy and learn from the activity. In addition to their appeal to teachers, many children's books invite young children's exploration of mathematical ideas.

As an example, a Research Lesson on measurement, called "Just Right for Me," begins with a discussion of the story of *Goldilocks and the Three Bears*. In this lesson, teachers ask children, "Why was baby bear's bed 'just right' for him? How about papa bear's bed? Would papa bear's bed be just right for baby bear?" Teachers tell children they will explore the classroom to find things that are "just right" for them and illustrate that "just right" in this case means the same size as the

length of their hands from wrist to fingertip. Children get excited about hunting in the classroom. As they find objects, they bring them back to the group, where the teacher leads a discussion about what they have found, asking children to compare each object with their hands to determine whether it is "just right." By using children's books and stories as an entry point, Research Lessons utilize teachers' familiarity and comfort with children's literature to continue developing positive attitudes about mathematics. This emphasis on attitude, in turn, creates optimal conditions for constructive learning of content knowledge for math teaching during classroom implementation. In this way, attitudes are employed in the service of both practice and knowledge.

FACTORS CONTRIBUTING TO THE SUCCESS OF THE PROGRAM

Many factors help to account for the success of the EME PD training program. We briefly describe three factors in the following section. They are sustained support from funders, true partnership with the Office of Early Childhood Education in CPS, and a clearly defined conceptual framework.

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Sustained Support from Funders

The EME Project was funded exclusively by private foundations in the Chicago area in its first 4 years of operation. The 4 years of continuous support have been invaluable for developing an early math teacher training program that has been proven effective with a sustained impact on the education of teachers and young children. Too often, training program developers are afforded only a short time period to complete their work. As a result, programs are not thoroughly tested. Their lack of effectiveness frustrates teachers as well as program developers. In our case, and we expect in the case of many other early educators as well, a protracted period of funding has made the difference in achieving program success. We simply could not do in 2 years what we have achieved in 4 years.

As critical as they were, the generous grants were only one kind of support that our funders provided. From the beginning, our funders recognized the emergence of early math achievement as a major concern in early education and the larger society. A shared vision encouraged us to take the risks that innovation in educational practice often requires. We and our funders frequently worked together to develop ideas and long-range plans. Many of the program officers visited our PD sessions. Some also invited their board members to observe our teachers as they applied what they learned to teach children in the classroom. Their presence made the foundation's support visible and personal.

Partnership with CPS

The strong partnership with the Early Childhood Office in CPS has been vital to successful development of the PD program. Some researchers complain about the bureaucracy and inefficiency of public school systems. We are extremely fortunate to have worked with a group of devoted early childhood educators in the CPS system. We have worked closely with the office staff from the inception of the program concept. We discussed the project's goals, shared the

program design, and received many useful suggestions from the office staff. The collaboration with CPS contributed to the successful and efficient completion of critical tasks such as teacher recruitment, coach selection, the scheduling of PD sessions, classroom visitation, and program evaluation, to name a few. In addition, the staff of the Early Childhood Office promoted the EME Project by encouraging teacher participants to present their early math work in local conferences for early childhood educators.

A number of administrative personnel in the CPS Early Childhood Office, including Barbara Bowman serving as Chief Officer, visited our PD sessions. This sent a strong message to our teacher participants that their PD in math was valued and important. Expressing her strong support of the program, the CPS Director of Kindergarten Programs sent each kindergarten teacher participant $100 for early mathematics materials and a box of blocks. Also, the Office of Early Childhood donated many children's books to the program for use in our PD sessions. For these reasons and many more, the successful development of the training program was made possible through our true partnership with the staff in the CPS Early Childhood Education Office.

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Clearly Defined Conceptual Framework

Also central to and accounting for the program's success is the conceptual framework of the project: the development of the Whole Teacher (Chen & Chang, 2006; McCray, 2009). Whereas most PD programs emphasize content knowledge only, the Whole Teacher framework also targets the development teachers' positive attitudes and effective classroom practices. The Whole Teacher framework guided the design of our intervention as well as our program evaluation (see Figure 2). Learning labs, on-site coaching, and classroom implementation are the structural components intentionally designed to promote development of the whole teacher.

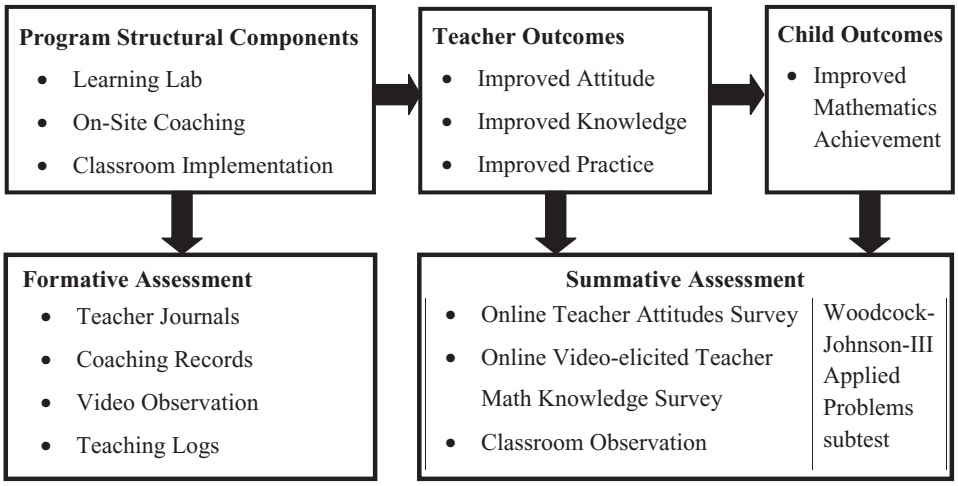

FIGURE 2 Logic model of Early Math Project's professional development.

The Whole Teacher approach simultaneously targets multiple dimensions of teacher development: attitudes, knowledge, and practices. All three variables play equally important roles in teacher PD. The focus on multiple dimensions offers teachers multiple pathways to learning. For some teachers, attitudes will be the most important first step, for example, overcoming fear of failing in teaching mathematics. For others, classroom practice will be the key, as when children's excitement and interest in learning mathematics affects teachers' attitudes. Knowledge, too, can play a pivotal role, as an "aha" moment in a PD session makes a teacher feel competent enough to try something new. Accessing multiple learning pathways allows PD to build on teachers' motivations and respond to their needs rather than requiring that all teachers follow the same course of learning.

For early childhood teachers, there is one additional benefit to the explicit adoption of the Whole Teacher framework for PD. It is readily understood and meaningful to early childhood teachers because it resembles a widely accepted principle in early education, namely, the importance of addressing the development of the "whole child" (Copple & Bredekamp, 2009). Familiarity with the *whole child* concept helps teachers reorient how they see themselves and welcome and integrate shifts in their attitudes, knowledge, and practices that will make them effective early math teachers.

In summation, the importance of improving early mathematics education has drawn increasing attention in recent years (National Association for the Education of Young Children & National Council of Teachers of Mathematics [NAEYC & NCTM], 2002; NRC, 2009). High-quality mathematics education for young children builds a strong foundation for future mathematics learning. Through challenging and engaging early math education, young children acquire such important mathematical concepts as number sense, geometry, measurement, and logical reasoning abilities. Recent studies indicate that early mathematics understanding contributes significantly to school achievement in later years (Duncan et al., 2006; NRC, 2009).

Young children do not become skilled at mathematics without instruction (Clements, Sarama, & DiBiase, 2004). The single most important determinant of what children learn is what teachers know (Darling-Hammond & Bransford, 2005). For youngsters to perform well in mathematics, their teachers must be mathematically proficient. Unfortunately, many early childhood teachers do not feel adequately prepared to provide children with "high-quality, challenging, and accessible" mathematics education (NAEYC & NCTM, 2002). This is especially true in urban schools where children from low-income families fall far behind their middle-class peers in school performance.

This article describes an innovative effort to narrow the achievement gap. Our effective PD program has updated teachers' mathematics knowledge, exposed them to new teaching strategies, sustained their teaching effectiveness, and prompted continuous growth (McCray et al., 2011). It is our conviction that teachers who develop sufficient knowledge and skills in early mathematics will be able to help students to develop the foundational math knowledge so critical to their school learning and success.

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