

THE EFFECTS OF PROFESSIONAL DEVELOPMENT ON PRESCHOOL
TEACHERS' MATHEMATICS INSTRUCTION

By

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To my amazing daughters, Elif Ceren and Ceyda, my biggest cheerleaders;

and

To my sweet husband Yasin, who supported me throughout this entire venture.

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CHAPTER I

INTRODUCTION

Statement of the Problem

In order to provide high quality mathematics instruction, teachers need to continuously pursue professional development opportunities that are beyond workshops and in-service days provided by school districts and that help them understand children's mathematical development and engage children actively in mathematics in ways that fit the children's levels of understanding (see Carpenter et al., 1989, Fennema, Franke, Carpenter, & Carey, 1993, Fennema et al., 1996, Cobb et al., 1991; Cobb, Wood, Yackel, & Perlwitz, 1992; NCTM, 2000).

Although there exists an ongoing call by the educators, national associations, and researchers to strengthen teachers' professional development in mathematics to increase the quality of instruction and, as a result, to improve students learning, American students' academic achievement in mathematics is still alarmingly low. Studies have shown that while there is a mathematical achievement gap between students from low-income families and those from middle- and upper-income families in the United States (NCES, 2006, 2007; Starkey, Klein & Wakeley, 2004), American children as a group are also generally outperformed by their counterparts from other nations (Ginsburg, Cooke, Leinwand, Noell, & Pollock, 2005; Stevenson, Chen, & Lee, 1993; Stigler, Lee, & Stevenson, 1990).

International comparisons of mathematical performance of children around the world showed that American children were outperformed by their counterparts from other nations including Japan, Taiwan, and China. These results were supported by the Trends in International Mathematics and Science Study (TIMSS) for students in grades four and eight and by the Program for International Student Assessment (PISA) for students at age 15. Ginsburg and colleagues (2005) examined the results of both studies and found a high significant correlation between students' mathematics achievement in grades four and eight, and a low significant correlation between students' mathematics scores in grade eight and at the age of fifteen. As a result, they concluded that if children build up a strong foundation in mathematics in the early grades, this will positively affect their academic success in upper grades.

Also, the mathematical achievement gap among America's students from various backgrounds continues to persist. The results of the National Assessment of Educational Progress [NAEP] showed that students' socio-economic situation was a strong predictor of students' academic achievement in mathematics (NCES, 2007). In other words, students with low-incomes were outperformed by their peers from middle- and upper-income families. Mathematics achievement in upper grades is not simply a function of the instruction received in those grades, of course. Disadvantaged children due to their socioeconomic status enter school already behind their peers from middle- and upper-income families (Lee & Burkam, 2002; Jordan, Kaplan, Nabors Oláh & Locuniak, 2006; Jordan, Kaplan, Locuniak & Ramineni, 2007; NRC, 2009b). Moreover, according to the report published by the National Center for Education Statistics (NCES) in 2006, kindergarten students' socioeconomic status was positively associated with their

academic achievement in mathematics as well as in reading (NCES, 2006). Thus, the findings related to students' alarming academic achievement in mathematics suggest that low-income children should receive more intense math education early in their lives in order to decrease the gap between their academic achievement and that of middle- and upper-income students.

Even though children's mathematical understanding continues to develop considerably during the preschool years (Baroody, 1992; Clements, Swaminathan, Hannibal, & Sarama, 1999; Cooper, 1984; Newcombe & Huttenlocher, 2000; Starkey & Cooper, 1995; Wynn, 1990), only a relatively small number of studies have reported math related classroom practices at the preschool level. While those studies that have been done reveal the missing opportunities for most preschool children, they also show the weak nature of mathematics instruction that was observed (see Early et al., 2005; Graham, Nash, & Paul, 1997; Siraj-Blatchford, Sylva, Muttock, Gilden & Bell, 2002; Tudge & Doucet, 2004). Moreover, those studies are evidence of a mismatch between what teachers reported as important for learning mathematics and their practices observed in classrooms.

Considering the importance of early intervention in mathematics, it seems critical for preschool age children to receive high quality math instruction. Therefore, providing professional development programs for preschool teachers to help them enrich their math instruction is a critical necessity. However, compared to literacy development, little attention is given to preschool teachers' professional development in mathematics. Specifically, the dedicated budget for professional development programs for early childhood teachers is most often spent on emergent literacy, management strategies, and

the importance of play and strategies to improve children's social and emotional development (Copley & Padron, 1999; U.S. Department of Education, 2007) rather than mathematics. Thus, there is a pressing need to provide professional development opportunities in mathematics for teachers.

Although there are various definitions of professional development, for this particular study, the term *professional development* refers to training that gives any experiences for teachers that are intentional, ongoing, structured processes and that are provided outside of the formal education system with the goal of increasing teachers' knowledge and skills in and attitudes toward mathematics. Researchers (Loucks-Horsley, Hewson, Love, & Stiles, 1998; Sparks & Loucks-Horsley, 1989) define various types of professional development components. Examples of major components are observation and assessment, mentoring, training, online support, and curriculum development/implementation. Each component has its own advantages and disadvantages; thus, it is impractical to claim that one component has more effects on teachers' professional development than the others. In view of that, a professional development program with a combination of several components may improve the effects on teachers' professional knowledge, skills, and attitude, which warrants further research to investigate the contribution of each component individually relative to the others on teachers' instruction.

In order to achieve the desired goals, professional development opportunities with emphasis on math education should be organized based on a logic model. The logic model should begin with identifying challenges in math education at the grade level of focus and continue with organizing activities addressing the challenges identified,

evaluating teachers' immediate response to the program as well as long-term effects of it on teachers' math instruction and on students' learning, and then scaling it up after making substantial changes based on the evaluation results. Of all the components, the evaluation process is the most critical step since it shows to what extent professional development programs succeed in changing teachers' professional knowledge, skills, and attitudes and, as a result, improved child outcomes. The evaluation process also helps researchers and program developers better understand teachers' professional development and the results can strengthen those types of programs.

The existing substantial mathematics professional development programs, including the Cognitively Guided Instruction Professional Development Program (CGI) (Carpenter et al., 1996), the Educational Leaders in Mathematics Project (ELM) (Simon & Schifter, 1991), the Purdue Problem-Centered Mathematics Project (PPCM) (Cobb et al., 1991), and the Technology Enhanced, Research Based Instruction, Assessment, and Professional Development (TRIAD) (Clements & Sarama, 2007), were reviewed in order to determine to what extent these programs were successful in improving teachers' math instruction as well as students' conceptual learning. The review of the first three professional development programs (CGI, ELM, and PPCM) showed that there exist weaknesses, especially in the way they measured teacher change. Thus, more research is needed to extensively investigate the effects of professional development programs on teachers' instruction and skills, as well as beliefs. Moreover, although the three programs provided training and mentoring for their participating teachers and conducted classroom observations and assessments, the researchers did not investigate which component had better influence on teachers' instruction. Therefore, as noted previously, evidence is also

needed to determine possible contributions of different professional development models on teachers' instruction.

Different from the other programs, the TRIAD project serving four year olds has been recently developed and is beginning to be evaluated. It includes a classroom component (i.e., a math curriculum entitled Building Blocks), a home component (math activities and materials for families), and a professional development package consisting of workshops, mentoring, and online resources for its teachers. Taking into account the components of the TRIAD project, it seems to have strong effects on teachers' mathematics instruction.

Objectives

The primary purpose of this study was to critically investigate the association between preschool teachers' mathematics instruction and their participation in the TRIAD preschool mathematics intervention program in terms of three perspectives. First, the study examined whether preschool teachers' participation in the preschool mathematics intervention program had significant effects on implementing mathematical activities more often and with higher quality in their classrooms. Second, within the group of teachers who participated in the professional development program, the study examined the effects of exposure to professional development on the amount and quality of mathematics activities the teachers provided for their students and their level of implementation of the curriculum. Third, the study sought to examine the effects of teachers' overall satisfaction with the curriculum and the professional development support they received on the amount and quality of math instruction and their curriculum

implementation level. This research sought to provide important information to researchers, policymakers, educators, and designers of professional development programs interested in creating stronger mathematics instructional environments for preschool children.

CHAPTER II

REVIEW OF THE LITERATURE

Issues in Mathematics Education

Background

Since the beginning of the 20th century, reformers have been attempting to improve the teaching and learning of mathematics within schools as a whole and inside the classroom. The reform started with John Dewey who believed in experiential education that would allow children to learn mathematical theory and practice simultaneously (Wolfe, 2002). Afterward, special groups and organizations outlined specific programs and practices in order to make the reforms happen (Smith & Southerland, 2007). More recently, professional associations (e.g., National Council of Teachers of Mathematics, 1991) prescribed national standards for mathematics in ways other professional groups have published specific to their discipline areas, (National Research Council, National Science Teachers Association, and International Reading Association). For all of them, the main goals are to advance the quality of instruction by enhancing the professional development of educators, to advocate for research, policy, and practices that support the best interests of all learners, and to improve the content of the curriculum (NRC, 2009a; NSTA, 2009; IRA, 2009).

Current reform recommendations in mathematics education are guided by constructivist perspectives on the nature of children's learning, specifically social

constructivism that involves learning embedded in a social context. Tytler (2002) stressed that “a social constructivist position focuses our attention on the social processes operating in the classroom by which a teacher promotes a discourse community” (p. 19). When social constructivism is applied to mathematics education, the discourse between the teacher and students is on problem solving. Also, discourse is enriched by the interactions between students and classroom teachers as well as among students, while at the same time encouraging them to create their own strategies for solving problems. Often cited as the foundational theorist behind the constructivist approach, Vygotsky (1978) drew attention to the interactions among students and noted that social interaction with more knowledgeable others creates richer meanings for new mathematical content.

As children participate in group math activities with guidance from more knowledgeable others, they may begin to listen to each other, verbalize their reasons, and challenge themselves (Noddings, 1990). However, in order to maximize the effects of interactions, classroom teachers should scaffold student learning, that is by “controlling those elements of the task that are initially beyond the learner’s capability thus permitting him to concentrate upon and complete only those elements that are within his range of competence” (Wood, Bruner & Ross, 1976, p.9). The quality of scaffolding depends on teachers’ knowledge of their students as well as children’s mathematical development within a particular age group. The influence of the constructivist perspectives on students’ learning can be seen in the current reform actions taken by the national organizations.

Reform Actions in National Organizations

Various organizations including the Mathematical Association of America (MAA), the National Research Council (NRC), the National Council of Teachers of Mathematics (NCTM) as well as university mathematics faculty have prescribed reform programs in mathematics education. For example, specifically, Kepner, the president of National Council of Teachers of Mathematics, claimed that the Council's mission is to provide "vision, leadership and professional development to support teachers in ensuring equitable mathematics learning of the highest quality for all students" (Kepner, 2008, p.1). For this purpose, the NCTM published the Curriculum and Evaluation Standards for School Mathematics in 1989. It suggested that math educators at every grade level should support children's conceptual understanding and reasoning about mathematics rather than focusing on rote memorization (NCTM, 1989).

For content and emphasis in mathematics in the early grades, the NCTM called for curricular changes in Pre-K-4 curriculum in response to a perceived need for reforming the teaching and learning of mathematics (NCTM, 2006). For instance, while decreasing the emphasis on reading, writing and ordering numbers symbolically, the NCTM advocated increased attention to number and operations, geometry, and measurement that should be addressed during preschool years. Also, it suggested lessening the attention given to complex paper-and-pencil computations, long division, and naming geometric shapes. The NCTM (1991) had earlier proposed that changes in content areas should be accompanied by changes in the way mathematics is taught.

In relation to the suggested pedagogical changes, the NCTM (2006) put a stronger emphasis on problem solving, reasoning, communication, and making connections

among other mathematical topics and between mathematics and other discipline areas. With these changes, the role of teachers became to provide their students with a learning environment that allows children to have access to challenging mathematics instruction (Bennett, Elliot, and Peters, 2005; Padro'n, 1992; Pierce, 1994; Wang, Haertel, & Walberg, 1993; Waxman & Huang, 1997) that is enriched with math manipulatives (Ball, 1992; Fuson & Briars, 1990; Marsh & Cooke, 1996; NCTM, 1991; Russell, 2000; Thompson, 1992; Uttal, Scudder, & Deloache, 1997). In addition, this environment should be supported through classroom discourse (Ball, 1991; Cobb, Yackel, Wood, & Wheatley, 1988; Lappan & Schram, 1989; NCTM, 1991; Sherin, 2002; Vacc, 1993), developmentally appropriate activities (Hiebert et al., 1997; NCTM, 1991; Whitenack, Knipping, Novinger, & Underwood, 2001), and ongoing assessments (Baker & Mayer, 1999; Beevers, Goldfinch, & Pitcher, 2002; Gardner, 1991; NCTM, 1991, 1995; Neuman, Copple, & Bredekamp, 2000). Although all of these factors promote a high degree of mathematical competency for young children, creating such learning environments depends on teachers' understanding of students' mathematical development. In the following section, children's construction of mathematical knowledge is discussed.

Construction of Mathematical Knowledge

In addition to the suggested content and pedagogical changes, the last 20 years of research and recommendations from the national professional associations have emphasized the presumption that students construct mathematical knowledge and must be actively engaged in order to do so (Bransford et al., 1999; Cobb, 1994; Cobb, Wood, &

Yackel, 1990; Hiebert et al., 1997; Labinowicz, 1987; National Council of Teachers of Mathematics, 1989, 1991; Simon, 1995). The argument is that teachers need to develop structured understandings of children's mathematical thinking and learning that will lead them to make instructional changes in order to help students construct mathematical knowledge (e.g., Bransford et al., 1999; Carpenter, Fennema, Franke, Levi, & Empson, 2000; Carpenter, Fennema, Peterson & Carey, 1988; Ginsburg et al., 2006). Carpenter and Lehrer (1999) stated that teachers who do not develop understanding of mathematics as well as understanding of students' thinking will dominate their instruction with curriculum scripts and "will not be able to establish the classroom norms necessary for learning with understanding to occur" (p. 31). This was supported by Fuson, Carroll, and Drucek (2000). The researchers examined academic achievement of second and third graders using a standards-based curriculum and their teachers. Results of the investigation showed that, for superior teachers, "in- depth discussion of student thinking articulated their vision of the curriculum as consisting of a progression or range of solution methods through which they helped all children move" (2000, p. 292). These are defined as learning trajectories (Simon, 1995). Those teachers felt comfortable to stop the lesson to follow up on students' thinking and conducted worthwhile and in-depth discussions with their students, rather than following the curriculum script. A similar definition is provided by Clements and Sarama (2004). They believed that learning trajectories are "descriptions of children's thinking and learning in a specific mathematical domain and a related, conjectured route through a set of instructional tasks designed to engender those mental processes or actions hypothesized to move children through a developmental progression of levels" (p. 83).

Various professional development programs for teachers have been created in an attempt to reflect the concerns expressed by NCTM and others – that teachers must understand children’s mathematical development and engage children actively in mathematics in ways that fit the children’s levels of understanding (see Carpenter et al., 1989; Cobb et al., 1991; Cobb, Wood, Yackel, & Perlwitz, 1992; Fennema, Franke, Carpenter, & Carey, 1993; Fennema et al., 1996; Fuson, Carroll, & Drueck, 2000). The researchers assert that teachers who considered students’ thinking as a key point in their instruction are able to provide higher quality math instruction for their students by placing greater emphasis on problem solving and less on computational skills, expecting more multiple-solution strategies, and listening to their students.

In order to understand students’ thinking, teachers need to develop effective classroom discourse in which students’ ideas are at the center as Stein, Silver and Smith (1998) envision the reform effort in mathematics. The authors put strong emphasis on students’ sharing meanings rather than sharing results. More specifically, they stated that “mathematics classrooms must become communities in which students engage in collaborative mathematical practice, sometimes working with each other in overt ways and always working with peers and the teacher in a sense of shared community and shared norms for the practice mathematical thinking and reasoning” (Stein et. al, 1998, p. 19). A similar recommendation was given previously by the NCTM (1991): students should be provided with environments where time is spent on exploring mathematical ideas during which they can discuss their ideas with one another.

In traditional classrooms, discourse typically occurs through spoken language, but it is language with certain characteristics -- the role of the classroom teacher is to present

new information (Sherin, 2002) and the role of the student is to listen to the teacher, to observe, and to evaluate how new knowledge relates to their prior knowledge (Bruner, 1996). On the other hand, in student-centered classrooms the main focus is on teachers and students working cooperatively in order to develop classroom learning environments that support doing and talking about mathematics (Ball, 1991; NCTM, 1991, 2000). In student-centered classrooms, one strategy that can be useful in helping students learn mathematics is engaging them with interesting classroom discussions. Effective classroom discourse should lead students to share their ideas and solutions about given problems as well as to respond to their classmates' solutions (Sherin, 2002). Also, classroom discourse influences students' reasoning, problem solving competence, self-confidence, and social skills acquisition (Lappan & Schram, 1989).

In order to have students share their ideas and be actively involved in classroom discussions, classroom teachers should create an environment where students feel secure and comfortable enough to share their beliefs, ask questions, hypothesize, and make mistakes (Ball, 1991; Cobb, Yackel, Wood, & Wheatley, 1988; Vacc, 1993). According to Vacc (1993), classroom teachers may reduce students' anxiety and increase their willingness to participate in classroom discussions by asking questions that have no incorrect answers, arranging seats in a circle so that students can easily see classmates as they speak, letting students discuss their ideas with a partner before sharing them with the whole group, and giving students an opportunity to think about the problem before sharing their thoughts with their classmates.

In summary, considering the importance of engaging students' thinking as a key starting point to help them construct mathematics, the previous discussions have focused

on the notion of encouraging teachers to develop effective classroom discourse in order to determine students' thinking. Despite the reform actions and curricular and pedagogical recommendations, including use of students' thinking to shape mathematics instruction, evidence shows that in the United States, students' academic achievement in mathematics is alarmingly low. The following section focuses on the literature regarding students' mathematical achievement.

Academic Achievement in Mathematics

Many studies have demonstrated that American children as a group are generally outperformed by their counterparts from other nations (Ginsburg, Cooke, Leinwand, Noell, & Pollock, 2005; Stevenson, Chen, & Lee, 1993; Stigler, Lee, & Stevenson, 1990). In addition, there exist differences among the academic achievement in mathematics of American students who differ by their socioeconomic status (NCES, 2006, 2007; Starkey, Klein & Wakeley, 2004).

Differences between American students and those from other countries have been found at least since the 1980s. Stigler, Lee, and Stevenson (1990) assessed first- and fifth-grade children in Japan, Taiwan, and the United States in order to examine differences in their mathematical knowledge. The results showed that American children were outperformed by their counterparts from Japan and Taiwan in computation, speed, and the application of mathematical principles. For instance, children were asked to make up a word problem to fit an equation (e.g., $5+2=?$). Among the first graders, 79 percent of Japanese students responded correctly, compared to 39 percent of Chinese and 44 percent of American students. By fifth grade, while the Japanese and Chinese percentage had

risen to 86 and 85 respectively, the American percentage was only 60. Another example of American students' deficiencies focused their abilities to interpret the correct meanings of mathematical equations. While almost all Japanese and Chinese first graders identified $3+4$ as an addition problem, less than 65 percent of the U.S. first-grade students were able to interpret it correctly. More complex questions concerning students' knowledge of equations were given at fifth-grade level (e.g., $(4 + 5) + 2 = 4 + \underline{\quad}$). Only 42 percent of the U.S. fifth graders responded to the given example correctly, compared to 88 percent of Japanese and 90 percent of Chinese students. Stevenson, Chen, and Lee (1993) conducted other comparative studies of American, Chinese, and Japanese students in 1980, 1984, and 1990. The results consistently showed that American elementary school students in 1990 lagged behind their Chinese and Japanese peers as they did in 1980 and 1984.

In 2003, these results were supported by the Trends in International Mathematics and Science Study (TIMSS) for students in grades four and eight and by the Program for International Student Assessment (PISA) for students at age 15. While TIMSS assessed students' knowledge of the mathematics content in the participating countries, PISA aimed to assess students' ability to apply mathematical ideas to solving real-world problems. Ginsburg, Cooke, Leinwand, Noell, and Pollock (2005) compared U.S. mathematics performance with that of 12 countries that participated in assessments at all three age levels. Among the countries, the United States mathematics scores rank 8th on TIMSS-4, 9th on TIMSS-8, and 9th on PISA. Considering a high significant correlation between TIMSS-4 and TIMSS-8 and a low significant correlation between TIMSS-8 and PISA, Ginsburg and colleagues (2005) concluded that if children build up a strong

foundation in mathematics in the early grades, this will affect their academic success in upper grades.

In addition to considering achievement differences between American students and students from other nations, there is also a significant differentiation among America's students from various backgrounds. The National Assessment of Educational Progress [NAEP] is the only national assessment of what students at grades 4, 8, and 12 in the United States know and can do in various subject areas including mathematics (National Center for Education Statistics, 2009). Tests are administered to a representative sample of students across the country, and the scale ranges from 0 to 500. Results show that the family income status (determined by eligibility for free or reduced price lunch) was a predictor of how well children performed in math. The NAEP results also showed that mathematics knowledge had increased in all grade levels, perhaps as a result of the NCTM reform efforts. Students who were eligible for reduced or free lunch performed better in 2007 than in all previous assessments. However, they continued to be outperformed by their peers who were not eligible for reduced or free lunch in all assessments (NCES, 2007).

Mathematics achievement in the 4th and 8th grades is not simply a function of the instruction received in those grades, of course. In fact, according to a recent national report, *Inequality at the Starting Gate*, disadvantaged children due to their socioeconomic status enter school already behind their peers from middle- and upper-income families (Lee & Burkam, 2002). A similar result was found by Jordan and colleagues (Jordan, Kaplan, Nabors Oláh & Locuniak, 2006; Jordan, Kaplan, Locuniak & Ramineni, 2007). Recently, the Board of the Center for Education at the National Research Council

established a committee on early childhood mathematics to review research to develop appropriate mathematics learning objectives for preschoolers. The committee also reported that students from low-income families start out behind in mathematics due to lack of opportunities to learn mathematics either in preschool classrooms or homes or in communities (NRC, 2009b).

Also, Starkey, Klein and Wakeley (2004) focused on the possibility that SES related differences in later mathematics knowledge begin in early childhood. To this end, the authors conducted an assessment of informal mathematical knowledge in pre-kindergarten children from low- and middle-income families. The results showed a significant effect for socio economic situation (SES), with young children in the low-income group scoring lower than those in the middle-income group. This finding was supported by a research and development report published by the National Center for Education Statistics (NCES) in 2006. According to the report, kindergarten students' socioeconomic status was positively associated with their academic achievement in mathematics as well as in reading (NCES, 2006). Indeed, considering the evidence showing the correlation between students' mathematical achievement and their level of income and the fact that gaps in understanding seem to begin even before school entry (see Guarino, Hamilton, Lockwood, Rathbun, Hausken, 2006; NCES, 2006, 2007; Starkey et al., 2004), it may be concluded that low-income children should receive more intense math education early in their lives in order to decrease the gap between their academic achievement and that of middle- and higher-income students. In short, despite the limited research examining young children's mathematical development in preschool settings, the existing studies show a need to understand more fully the emergence and

importance of mathematics and number skills young children develop in order to improve educational experiences and to ensure better outcomes for all children (Fuchs, 2004).

In conclusion, the poor math achievement of American students, and especially American students from low-income backgrounds, may have implications for math instruction in early ages. The research shows that children at risk due to low family income enter school already behind; and, for upper grades, there exists a gap between these children and their counterparts from middle- and upper- income families in terms of their academic achievement. However, there is influential evidence that a strong foundation in preschool education can reduce the academic gap and help to promote students' learning in the later years (Barnett 1995; Bowman, Donovan, & Burns, 2001; Haskins, 1989; Hauser-Cram, 2004; Love, Schochet, & Meckstroth 1996; Peisner-Feinberg et al., 2001; Ramey & Ramey, 2004; Schweinhart, Barnes, & Weikart, 1993). In short, taking into account the fact that children's mathematical development starts as early as the first weeks of life (e.g., Gallistel & Gelman, 2000; Huntley-Fenner, 2001; Sophian & Adams, 1987; Starkey & Cooper, 1980; Strauss & Curtis, 1981; Xu & Spelke, 2000), it seems critical for preschool age children to receive high quality math instruction. The next section presents what is known about how mathematics instruction should occur in preschools and how those characteristics relate to how mathematics is currently being taught.

Math Instruction in Preschool Settings

In regard to children's mathematical development, the NCTM principles and standards (2000) strongly recommend that preschoolers develop foundational

understanding for skills in number and operations, algebra, geometry, measurement, data analysis and probability, problem solving, reasoning and proof, communication, connections, and representation. In addition to the content areas, it is suggested that teachers use effective teaching strategies to help their students deepen their mathematical understanding. To this end, mathematics teachers have been urged to provide a classroom environment that allows children to have access to challenging mathematics instruction (Bennett, Elliot, and Peters, 2005; Padro'n, 1992; Pierce, 1994; Wang, Haertel, & Walberg, 1993; Waxman & Huang, 1997) and one that is enriched with math manipulatives (Ball, 1992; Fuson & Briars, 1990; Marsh & Cooke, 1996; NCTM, 1991; Russell, 2000; Thompson, 1992; Uttal, Scudder, & Deloache, 1997). Left exploring on their own, children may not establish the necessary connections between manipulatives and mathematical expressions (Bruner, 1966; Fuson & Briars, 1990; Hiebert & Carpenter, 1992). Therefore, children's understanding should be supported by classroom discourse (Ball, 1991; Cobb, Yackel, Wood, & Wheatley, 1988; Lappan & Schram, 1989; NCTM, 1991; Sherin, 2002; Vacc, 1993), developmentally appropriate activities (Hiebert et al., 1997; NCTM, 1991; Whitenack, Knipping, Novinger, & Underwood, 2001), and ongoing assessments (Baker & Mayer, 1999; Beevers, Goldfinch, & Pitcher, 2002; Gardner, 1991; NCTM, 1991, 1995; Neuman, Copple, & Bredekamp, 2000). Taken together, all of these suggestions have the common goal of establishing characteristics of high quality math instruction.

Despite the content and pedagogical suggestions provided by researchers and national associations, studies focusing on mathematics instruction in preschools report that children's exposure to mathematics is very limited. Graham, Nash, and Paul (1997)

observed children in order to explore the mathematical activities and dialogue in which children and preschool teachers engaged. During their twelve hours of observation, there were primarily only four mathematical concepts with which children were engaged: telling their ages, rote counting, recognizing numerals, and naming shapes. More importantly, children's exposure to mathematics was carried out through a series of closed questions that usually had short answers (e.g., "what number is this?" or "what is after 7?"). In addition to classroom observations, the researchers conducted interviews with the teachers in order to understand their beliefs about mathematical understanding and teaching of young children. Teachers reported that counting, addition and subtraction, recognizing numbers, and/or comparing amounts are the content areas that children should master before they start formal schooling. In addition, teachers noted that they play informal number games with children in order to support their mathematical development. Although teachers stressed the importance of mathematics during the interviews, classroom observations suggested that they did not seem to translate their beliefs into practice (Graham et al., 1997). A similar mismatch was found by Wilkinson and Stephen (1994). The authors noted that there was an important disparity between what teachers claimed in planning and what they did in classrooms.

Another study examined effective pedagogy in the early years through detailed case studies in fourteen preschool classrooms (Siraj-Blatchford, Sylva, Muttock, Gilden & Bell, 2002). Based on the classroom observations, the authors found that math-related activities were the least preferred activities among four-year old children –either those provided by the classroom teacher or those selected by children. More specifically, they reported that approximately five percent of preschoolers' time was spent doing math

related activities. During that time, the most common mathematical activities in which children were observed to be engaged were calculations, number concepts, teacher-led unison activities, and reading/writing math symbols. A similar study was conducted by Tudge and Doucet (2004). They observed 39 children for 18 hours over the course of a single week. The results showed that 60 percent of children were never observed being exposed to mathematics. In addition, the math activities that children were exposed to were related to rote counting, number recognition, comparing small number of groups, and naming shapes. Moreover, Farran and colleagues (Farran, Lipsey, Watson, & Hurley, 2007) examined math instruction that preschool children were exposed to in literacy-oriented classrooms. The researchers conducted classroom observations for three times in ten preschool classrooms. Their eighteen-hour observation results showed that classroom teachers spent less than one percent of their time on mathematics-related activities. In addition, the researchers noted that limited math materials were available for children to explore. Researchers also administered a pre- and post- standardized test to assess preschoolers' math gains over the school year. The results showed that students either did not gain any new skills in mathematics or lost math skills over the year (Farran et al., 2007).

The National Center for Early Development and Learning (NCEDL) conducted two studies to understand the variations among state-funded preschool programs in eleven states. In total, over 2900 preschool children were included in both studies. Their findings related to the proportion of time children were engaged in learning activities (e.g., literacy, math, science, social studies etc.) highlighted the problematic areas in preschool classrooms (Early et al., 2005). While preschoolers spent 48% of their time on

academic activities, the rest of the time was used for non-instructional activities such as transition, waiting in line, and snack and meals. Specifically, during the instruction time, preschoolers spent more time in literacy activities than any other activities – 21% of the time on literacy, 16% of the time on social studies, 10% of the time on science, and 8% of the time on mathematics. Also, the findings showed that early childhood teachers prefer to teach mathematics indirectly through, for instance, puzzles, blocks, songs, and fingerplays, rather than through activities with a primary focus on mathematics.

In summary, although students' preschool experience is correlated with that readiness for school and later academic achievement in mathematics, as well as in other areas, studies focusing on current preschool mathematics instruction highlight missing opportunities for young children. Indeed, little time is spent on mathematics in preschool classrooms, and teachers' objectives do not go beyond surface-level – that is rote counting, number recognition, naming shapes, and so on. Since the goal of professional development programs is to help teachers' provide high quality instruction for their students, it is critical to investigate professional development programs with emphasis on mathematics education for preschool teachers.

Professional Development in Early Childhood Education

Providing professional development opportunities for teachers is one way to improve the quality of mathematics instruction teachers provide. Recognizing the importance of providing professional development opportunities for teachers, the national associations, including NCTM and NAEYC, announced mission statements and standards specifically for early childhood educators and mathematics teachers. These

mission statements and standards all require professional development. Generally in 1993, the NAEYC noted that high-quality early care depends on teachers' professional development, and that all early childhood educators, therefore, should continuously seek professional development as a life-long commitment to their profession. With regard specifically to mathematics, the NCTM Principles and Standards statement pointed out that "effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (2000, p.1-2). It suggested that teachers continuously improve their own mathematical knowledge and pedagogy while engaging in professional development and self-reflection. A similar recommendation came more recently from the NAEYC and NCTM joint statement (2002). It suggested that teachers make instructional adjustments based on a deep understanding of young children's cognitive, linguistic, physical, and social-emotional development.

Despite the reforms in mathematics education and the mission standards from various organizations, the dedicated budget for professional development programs for early childhood teachers is most often spent on emergent literacy, management strategies, and the importance of play and strategies to improve children's social and emotional development (Copley & Padron, 1999) rather than mathematics. Recently the United States Department of Education provided competitive funds for professional development programs for early childhood educators, with a budget of approximately \$15 million (U.S. Department of Education, 2007a). The main purpose of the programs it funded was to improve the knowledge and skills of early childhood educators in order to support school readiness and improved learning outcomes of young children. However, the only

focus of these programs was to “provide primarily research-based training that will improve early childhood pedagogy and will further *young children’s language and literacy skills* to prevent them from *encountering reading difficulties* when they enter school” [italics added] (U.S. Department of Education, 2007a). This statement shows the U.S. Department of Education’s strong emphasis on literacy and, unfortunately, none at all on mathematics. Indeed, little attention is given to teachers’ professional development in mathematics. Thus, in addition to literacy development, there is at least a similar pressing need to provide professional development opportunities in mathematics for teachers.

Summary

Since the beginning of the 20th century, the objective of reform in mathematics education has been to improve teaching and learning. For this purpose, researchers and national organizations put strong emphases on the relations between effective teaching and students’ achievement at all grade levels. Their main goals are to advance the quality of instruction by enhancing the professional development of educators, to advocate for research, policy, and practices that support the best interests of all learners, and to improve the content of the curriculum.

Specifically, teachers of mathematics have been encouraged to ensure equitable mathematics learning of the highest quality for all students in every grade. To this end, curricular and pedagogical changes have been suggested to promote a high degree of mathematical competency for children. Despite those actions in math education, children’s academic achievement in mathematics is still alarming. Also, even though

children's mathematical understanding continues to develop considerably during the preschool years (Baroody, 1992; Clements, Swaminathan, Hannibal, & Sarama, 1999; Cooper, 1984; Newcombe & Huttenlocher, 2000; Starkey & Cooper, 1995; Wynn, 1992), only a relatively small number of studies have reported math related classroom practices at the preschool level. Those studies that have been done highlight the missing opportunities for most preschool children. Additionally, those studies show the weak nature of mathematics instruction that was observed as well as a mismatch between what teachers reported as important for learning mathematics and their practices observed in classrooms.

Considering the fact that children start developing mathematical understanding in the first weeks of their life and preschool education can help to promote students' learning in the later years, it seems critical for preschool age children to receive high quality math instruction. Therefore, providing professional development programs for preschool teachers to help them enrich their math instruction is a critical necessity. However, little attention is given to preschool teachers' professional development in mathematics.

In order to better understand the nature of professional development programs with emphasis on mathematics instruction, the following section is devoted to the definition of professional development, the logic model of professional development programs, and major components of such programs. In addition, four professional development programs are examined as examples of comprehensive programs focused on mathematics.

Professional Development Programs in Mathematics

Defining Professional Development

Emphasis given to professional development has increased dramatically in recent years for every discipline area. Researchers have attempted to find out how professional development affects teachers' beliefs, their classroom instruction, and students' academic achievement (e.g., Carpenter et al., 1989, 1996; Cobb et al., 1991, 1992; Simon & Schifter, 1991). However, in their reports, researchers often did not define the term professional development. Many educators regard professional development as training – that is a special event or job-embedded learning experience that lasts three or four days during the school year (Guskey, 2000; Monahan, 1996; Sparks, 1994; Sparks & Hirsh, 1997). However, in the present study, the term *professional development* is used to refer to training that gives any experiences for teachers that are intentional, ongoing, and structured, that are provided outside of the formal education system and have the goal of increasing the knowledge, skills, and attitudes of teachers.

Logic Model for Professional Development Programs

A logic model describes linkages between inputs, the activities to be employed, the immediate outcomes of such efforts, and the desired long-term impacts (Julian et al., 1995). To construct professional development in mathematics for preschool teachers, researchers should start the logic model by identifying challenges in math instruction for young children, considering the activities that address those challenges and the inputs needed to support those activities. Examples of such challenges are the low amount and

the low-quality of math instruction occurring in preschool. Accordingly, activities addressing these challenges may focus on helping teachers understand how children develop mathematical understanding. The next step in the process would be to organize a professional development program focused on improving the activities that the model asserts are likely to improve math instruction and ultimately student outcomes. The last step is to evaluate the program in order to determine teachers' immediate response to the program as well as the long-term effects on teachers' math instruction and on students' learning. This evaluation serves two purposes. The first is to see whether the program succeeded in achieving the desired outcomes. The second purpose is that it helps researchers and program developers confirm and/or refine their initial logic model on the relationship between classroom teaching and student achievement. The value of having a well defined logic model is that parts of it can be tested separately.

Components of Professional Development Programs

Major components of professional development models have been described by Sparks and Loucks-Horsley (1989), and Loucks-Horsley, Hewson, Love, and Stiles (1998). They define five possible components: observation and assessment, mentoring, training, online support, and curriculum development/implementation.

Observation and assessment. Although some models of professional development involve an observation and assessment component, this component is not generally used alone in professional development programs; rather it is supported through other components. Often this type of component requires classroom teachers to be observed by an expert and to be provided with feedback on their performance in the classroom. People

who are observed and assessed may “benefit from another’s point of view, gain new insights, and receive helpful feedback” (Guskey, 2000, p.24). A similar conclusion comes from Bruce and Rose (2008). They note that receiving constructive feedback from a respected peer may lead teachers to enhance their goals, to take risks about making changes in their instruction, and to implement challenging teaching strategies.

The underlying assumption that teachers develop better pedagogical practice, adopt curriculum, and improve professional relationships through a reciprocal process of observing one another teach and providing feedback and support has been supported by several studies (Bruce & Rose, 2008; Darling-Hammond, 1996; Glickman et al., 1998; Gordon, Nolan & Forlenza, 1995; Lemlech & Kaplan, 1990; Lieberman & Miller, 1991; Little, 1982; Ponticell, Olson & Charlier, 1995; Smith 1989; Swafford, 2001). The process works effectively for inexperienced teachers and can be used successfully with student teachers (Lemlech & Kaplan, 1990). However, it is a time consuming and expensive approach that requires commitments of time from both the observer and the one being observed so that few studies rely on this component. Another disadvantage of this component is that in-service teachers may be reluctant to have a peer in their classroom to observe them (Allen & Calhoun, 1998; Freeman, 1982). Teachers may consider the process of observation and assessment as re-examining their teaching, rather than as an opportunity to build on the skills they already have.

Mentoring/Coaching. The second component included in many models of professional development is mentoring or coaching that involves providing one-on-one learning opportunities for teachers with the focus on improving their teaching practices. The disadvantage of mentoring is that it requires commitments of time and money;

however, it can be helpful for novice teachers. Specifically, when mentors are experienced teachers, those interactions help novice teachers learn to deal with difficulties that may occur in the classroom (Amico, 1995; Bey, 1990; Holahan, Jurkat, & Friedman, 2000; Odell, 1990; Swan & Dixon, 2006). Moreover, people who receive the support of mentors are reported as “goal-directed, increasingly serious about the importance of detail, selfconfident [and] reflective” (Daresh & Playko, 1992, p. 150). Wang and Odell (2002) analyzed the literature associated with mentored learning. They noted that as inexperienced teachers are provided opportunities to enhance their knowledge about concepts that are required for teaching, students’ learning of the subject matter, and the ways to examine subject-matter teaching with mentors’ help, their pedagogical and content knowledge can be developed. Also, Peers and colleagues reported that curriculum implementation, as a form of instructional change, is problematic because it deals with teacher capability; hence, teachers require significant support from appropriate mentors (Peers, Diezmann & Watters, 2003).

The most important issue in mentoring is that it should “involve more than simply behavior. Professional practices are manifest in behavior, of course, but they entail thoughts, interpretations, choices, values, and commitments as well” (Sanders & McCutcheon, 1986, p. 51). In other words, mentors should consider themselves as agents of change in line with reform actions.

These findings suggest that unless teachers are prepared to make use of their mentors by possessing dispositions that value collaboration and help-seeking, the relationship between teachers and their mentors might be superficial at best (Tellez; 1992).

Training. Training is another major component of professional development models. Teachers participate in large group presentations, discussions, workshops, or seminars organized by a group of people who share their ideas and expertise with the participating teachers. Although training is the most efficient and cost-effective professional development model among those described (Albrecht & Engel, 2007; Guskey, 2000), one-time training is unlikely to result in positive, long-term changes in teachers' professional knowledge, skills, and/or attitudes (Guskey, 2000; Loucks-Horsley, Hewson, Love, & Stiles, 1998). Indeed, Bradshaw claims that "nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when the teachers returned to their classrooms" (Bradshaw, 2002, p. 131). The reason may be teachers' negative attitudes towards such professional development opportunities due to their perceptions that they lack control over their own professional growth (Fullan, 1995; Miller, 1998; Novick, 1999; Sandholtz, 2002; Wilson & Berne, 1999).

Another reason may be that instruction is influenced by teachers' beliefs, skills, and knowledge. Since instruction is very individualized action, it may be difficult for teachers to give a rationale for content they cover and techniques and approaches they use in their instruction. Cohen and Ball (1999) argue that "professional norms are strong on individualism and weak on content, common expectations, and standards" and seem to drive the classroom (1999, p. 11). This strong individualism suggests the existence of separate styles within a school and each of its classrooms. McMillian (2003) concurs, referring to teaching practices as highly idiosyncratic processes. Cohen and Ball (1999) go on to suggest that, despite the money spent on in-service training, they are

“intellectually superficial, disconnected from deep issues of curriculum and learning, fragmented, and non-cumulative” (p. 12).

Online support. Learning technologies for the professional development of learners have emerged recently. While it gives teachers time for reflection, it also allows for flexibility in scheduling and timing (Sprague, 2006). In addition, it gives teachers the ownership of their own development. Examples of such learning technologies are the World Wide Web, electronic portfolios, multimedia resources, e-mails, video-conferences, web-based discussion software, and so on (Edwards & Hammond, 1998; Harris, 1999; Sharpe & Bailey, 1998).

Downer and colleagues (Downer, Kraft-Sayre & Pianta, 2009) aimed to provide classroom-focused and scalable professional development experience for preschool teachers to facilitate their high-quality teacher-child interactions. To do this, they designed a website that included consultation process and resources for their teachers. After two years of implementation, the results showed an association between the quality of teacher-child interaction and the amount of their access to the website. In addition, in their follow-up assessment, they identified factors that affected teachers' interaction with the website. Those factors are related to the website (i.e., including dynamic and engaging resources), the consultants' characteristics, and teachers' characteristics (i.e., years of teaching experience) (Downer, Locasale-Crouch, Hamre, & Pianta, 2009). They called for further work to examine those factors' effects on the effectiveness of the online professional development on teacher change.

In terms of effectiveness of learning technologies, Biggs (1999) provides four important factors: motivational context, a well structured knowledge base, learner

activities, and interaction with others. In respect to motivational context, Goodyear and Steeples (1998) note that such technologies should “enable key elements of real-world working knowledge, that are tacit and embedded in working practices, to be rendered into shareable forms of professional learning” (p.16). In order to create a well structured knowledge base, MacKenzie and colleagues (2001) identified six individual components that need to be explicitly delivered to the learners: expected learning outcomes, resources, key concept map, frequently asked questions, self-assessment, and conference.

Online professional development programs should also include activities for learners. Biggs (1999) noted that deep learning relies on active learning; so that such online programs should provide activities for its learners to improve their level of interest. Finally, on the behalf of the interaction with others, MacKenzie and colleagues (2001) discuss that the online programs should allow learners to discuss/share issues and insights with each other.

Although online professional development programs provide flexibility in scheduling and timing for its learners, there exist challenges that designers may face (Barab, Barnett, & Squire., 2002; Sprague, 2006). For instance, one of the challenges is to find out what motivates teachers to seek online professional development opportunities. Another challenge is to balance the resources on demand. Learners who seek online professional development have to search for resources on their own, which may decrease teachers’ willingness. Also, the quality of the resources is another issue that designers should take into account.

Curriculum implementation/development. The last major professional development model is involvement in the development or improvement of a curriculum.

Such programs require teachers to acquire new knowledge or skills about the curriculum and its implementation through reading, research, discussions, and observations (Guskey, 2000). Specifically, Loucks-Horsley and colleagues noted that, through such programs, participating teachers have the opportunity to “increase their understanding of both content and pedagogy by thinking carefully about the broad goals of the curriculum and specific concepts, skills, and attitudes that students need to acquire” (1998, p. 81). However, this component is rarely used by the professional development providers (Clements, 2007a). Especially in mathematics education, few studies examined the effects of textbooks (Senk & Thompson, 2003).

In order to implement/ develop a curriculum, there are important points that program providers should take into account. Lumpe, Czerniak, and Haney (1999) evaluated a comprehensive school curriculum that was developed for student of K-6 through sustained professional development and involvement in curriculum. Based on their evaluation, the researchers stated that for a successful development of a science curriculum, the following are required: purposeful interactions among all important stakeholders in the project, peer mentoring by experts in the area, purposeful experiences with the science curriculum materials, interdisciplinary connections to other disciplines, adoption of quality science curriculum materials, professional development experiences that promote the nature of science, professional development on science content related to the curriculum materials and experiences that lead to positive teacher beliefs. Similar conclusion was drawn by Guskey and Peterson (1996) and Supovitz and Turner (2000). It should be noted, however, that few sustained activities actually have teachers construct the curriculum they will use.

In conclusion, five components of professional development models were described. Due to the advantages and disadvantages of each component, it is impossible to claim that any single combination is more effective than any other. Accordingly, a professional development program with the combination of several major components may improve the effects of it on teachers' professional knowledge, skills, and attitude. Thus, possible impacts of professional development programs consisting of several components on classroom instruction as well as student outcomes warrant further examination. In addition, additional research is needed to investigate what each professional development component included in the programs contributes individually relative to the others. There are several professional development programs with emphasis on math instruction that combine several of those components. The following section introduces some of such programs and examines them in order to better understand their logic model and whether the programs had positive influence on teachers' professional development.

Examples of Professional Development Programs

This section is dedicated to the investigation of four professional development programs that aimed to help early childhood teachers facilitate better mathematical learning in their children. Note that although the present paper focuses on the impact of professional development with preschool teachers, the majority of the research on effective professional development has been conducted with teachers at elementary grade levels. Thus, the theory behind the professional development discussed in this study was mainly drawn from work done at primary grade levels as well as at preschool level.

The three elementary school professional development programs are the Cognitively Guided Instruction Professional Development Program (Carpenter et al., 1996), the Educational Leaders in Mathematics Project (Simon & Schifter, 1991, 1993), and the Purdue Problem-Centered Mathematics Project (Cobb et al., 1991). Also, the last professional development program reviewed is the Technology Enhanced, Research Based Instruction, Assessment, and Professional Development project organized for preschool teachers by Clements and colleagues (Clements & Sarama, 2004, 2007a, 2007b).

The four programs have been selected for three important reasons. The first is that the programs attempted to improve teachers' pedagogical and content knowledge in mathematics instruction while emphasizing the importance of students' understanding and their learning. In addition, the foundation of each project was a constructivist perspective. The second reason is that the four programs were all combinations of the components of professional development identified earlier. These programs organized training for their participating teachers, they continued to support their teachers during the school year by conducting classroom observations providing mentoring, and/or provided online resources. Finally, all four programs connected professional development with students' learning. Despite their similarities, the programs differed from each other in terms of their implementation. A description of each professional development program and an evaluation of its effectiveness are given below.

Cognitively Guided Instruction Professional Development Program (CGI).

Cognitively Guided Instruction (CGI) is a professional development program that began in 1985 with a preliminary objective to investigate teachers' knowledge of students'

mathematical thinking, to find ways to enable teachers to benefit from this knowledge, and to determine if teachers' use of this knowledge influenced students' mathematical understanding (Carpenter et al., 2000). As their starting point, Carpenter and colleagues (1989) focused on teachers' limitations (e.g., not taking advantage of students' knowledge in order to shape their instruction) and claimed that if teachers understand what their students know, then they can alter instruction to address their students' needs.

Considering the constructivist premise that a problem can be solved through different solutions or instructional endpoints rather than teacher-anticipated solutions (Noddings, 1990), Carpenter and colleagues anticipated that as teachers recognized and appreciated the development of students' mathematical thinking, they would be able to reflect on their own instruction and make changes in order to facilitate children's learning. In other words, the CGI considered students' thinking as a context for teachers to enhance their understanding of mathematics.

The CGI team organized workshops for their participating teachers. While the team held whole-group and small-group lectures and discussions, the team also provided free time for the teachers. During this time, teachers were able to read previously selected articles, explore videotapes of children solving mathematical problems, talk with other participants and/or the staff, and evaluate textbooks and materials. In addition, professional development teams continued to provide support for their teachers. During the school year, the project trainers visited each classroom on a regular basis. Specifically, during the classroom visits, the project teams attempted to map teachers' existing knowledge, classroom practices, and beliefs toward teaching and learning mathematics through classroom observations. During the observations, the team focused

on the setting (e.g., whole-group, small-group etc.), mathematics content, teacher behavior (e.g., pose problems, listen to process, feedback to answer etc.), and strategies (e.g., direct modeling, recall, derived facts etc.) (Carpenter et al., 1989).

In a series of studies, the effects of the program on primary grade teachers' knowledge and beliefs and on children's learning were investigated (Carpenter et al., 1989; Fennema, Franke, Carpenter, & Carey, 1993; Fennema et al., 1996). The CGI teams asked teachers to complete several measures of attitudes and beliefs before and after the program. Also, the team administered a standardized test and a mathematics test developed by the researchers. The examination of the attitude and belief questionnaire showed that the project teachers considered students' thinking as a key point for their teaching. In addition, classroom observations showed that, compared to the control teachers, the CGI teachers placed greater emphasis on problem solving and less on computational skills, expected more multiple-solution strategies, and listened more to their students. In terms of students' academic achievement, the results demonstrated that CGI students had significant gains in problem solving. Carpenter and colleagues assert that their findings support the importance of including research-based knowledge about students' thinking and problem solving in professional development for teachers.

Although the reports seemed promising in terms of changes in teachers' instruction as well as students' learning, there were weaknesses in the design of the study in which the instruments were used. Particularly, the instrument used during the observations did not measure the quality of math instruction. Rather, it measured how many times the teacher posed questions, explained process, and so on. Indeed, it would be valuable to measure teacher's ability to elicit children's solution methods, to support

children's conceptual understanding, to extend children's mathematical thinking, and to assess children's understanding. In addition, in their analyses, the researchers did not take into account different levels of the system (e.g., district, school, individual) that may influence teacher's instruction. Indeed, their reports may not reflect the changes that happened due to the program after controlling for system related factors.

Educational Leaders in Mathematics Project (ELM). The Educational Leaders in Mathematics (ELM) project was conducted by Simon and Schifter (1991). The main goal of the project was to create an in-service program for elementary school as well as secondary school mathematics teachers by introducing research-based knowledge about how children learn mathematics. The project started with a pilot year in 1985; both elementary and secondary school teachers were involved in the project for three years. The ELM project held the view that students actively construct their own understanding with the opportunities and the stimulations that are provided by the teacher. Therefore, the ELM trainers attempted to show teachers that students should be actively engaged with mathematical problem situations to generate ideas and hypotheses, justify and verify them individually, in pairs, and in whole class discussions. In addition, accepting the idea that the teacher was not the sole judge of mathematical validity (Rhodes & Bellamy, 1999), the project pointed out the responsibilities of classroom teachers in terms of balancing the students' interest and questions with his/her curriculum goals, asking probing questions, requesting paraphrases of ideas, managing and focusing the discussions as needed, and avoiding comment on the correctness or the value of particular ideas. The ELM team provided a context for the participating teachers where the teachers

could see how constructivist and socio-cultural perspectives influence their students' thinking.

For its participating teachers, the ELM team organized workshops that involved whole-group lectures and discussions in order to facilitate teachers' understanding of pedagogical processes and students' understanding of mathematics. During the workshops, teachers watched videotapes of children solving math problems, which aimed to help them study students' understandings and misconceptions. Also, teachers were asked to keep a daily journal to reflect on what they experienced in the workshops. In addition, after the workshops, the team provided support for the teachers during the school year. The main goals of the support were to provide feedback, to demonstrate teaching, to provide opportunities for reflection and suggestions with the teachers' own goals in mind (Simon & Schifter, 1991).

In order to investigate the effects of the program on teachers' thinking and practice and on children's mathematical achievement, Simon and Schifter (1991) analyzed teachers' self-reflections. The evaluation of teachers' self-reflections demonstrated significant changes in teachers' knowledge of mathematics, their feelings about doing mathematics, and their ideas about what constitutes good teaching. Also, the ELM trainers stated that teacher-reported and student-reported surveys showed a significant change in students' beliefs and attitudes toward mathematics (Simon & Schifter, 1993). Although Simon and Schifter reported the ELM project as an effective professional development program that accomplished significant change in many of its participants, the methods to evaluate the program are not sufficient to validate its approach. The researchers relied on only a single type of source, interviews conducted

with the participating teachers and teachers' journals. In order to ensure the validity of self-reported data, the changes in teachers' beliefs that were reported in the interviews should be validated with another set of data collected during structured classroom observations. This allows researchers to determine whether teachers' classroom behaviors reflect their self-reported changes in instruction. Since no evidence beyond that self-report was provided by the ELM team, it is unknown whether the ELM project was successful in changing teachers' actual behaviors in line with the professional development program they received.

Purdue Problem-Centered Mathematics Project (PPCM). The Purdue Problem-Centered Mathematics project was organized by Cobb, Wood, Yackel and their colleagues (1991) in order to examine how teachers help young children's mathematical development within an elementary school classroom. Cobb and colleagues stated that the philosophical orientation behind their project was compatible with constructivism in terms of agreeing that learning is a continuous process in which learners actively construct their own knowledge (Cobb, 1994). In addition, their work was influenced by the socio-cultural perspective. More specifically, while learners actively construct knowledge, learners become a member of a community in which opportunities for learning occur through social interactions among community members (Noddings, 1990). More explicitly than the other projects, Cobb and colleagues considered the actual classrooms of the participating teachers themselves as learning environments where teachers would have opportunities to determine students' thinking and make instructional decisions as needed. To this end, the team worked with an elementary school teacher during the pilot year to create instructional activities for children. Also, the researchers

benefited from children solving mathematics problems in the classroom during their observations as they created the activities. The activities had multiple solutions, which accommodate students' individual differences. Cobb and colleagues benefited from their interactions with the teacher and later inducted more teachers into the project.

The PPCM team organized workshops for its teachers. During the workshops, the teachers watched video clips of children solving math problems as well as whole-group and small-group interactions occurred in classrooms. Additionally, after the workshops, teachers were given the instructional activities to employ in their classrooms. Rather than given a script for those activities, the teachers had the opportunity to create activity sequences based on their students' needs. Moreover, the project staff visited classrooms to provide support for the teachers. Different from the other programs, the teachers conducted group meetings weekly at their schools to discuss difficulties and insights.

The researchers conducted studies in order to assess the effectiveness of the project. The PPCM team asked teachers to complete several measures of attitudes and beliefs developed by the trainers, and/or conducted classroom observations. The researchers found that their project had a positive impact on teachers' beliefs toward teaching and learning mathematics. Also, the researchers used standardized achievement tests and an arithmetic test developed by the PPCM team in order to examine whether children's computational skills changed as a result of teacher participation in a professional development program. The results showed that the project students outperformed their peers in non-project classrooms on conceptual understanding and problem solving in arithmetic at the end of third grade (Cobb et al., 1992).

However, in order to examine the impact of the professional development program on teachers' beliefs and instruction, the PPCM team made use of a single evaluation tool: a belief questionnaire completed by the teachers before and after the professional development program. Responses to the questionnaire indicated that the program had a positive impact on teachers' reported beliefs toward teaching and learning mathematics. In addition, Cobb and colleagues reported that the project helped teachers realize the value of students' thinking and the ways to challenge students' understanding. However, the positive change found in the belief questionnaire was not verified with other subsequent outcomes including structured classroom observations; thus, it is difficult to assert with certainty the success of the PPCM project in changing teachers' behaviors in line with the professional development program. In addition, as the researchers examined the change in students' learning, they did not take into account the fact that students were nested within classrooms and students in the same classrooms may have similar behaviors. Thus, the results of the assessments may not reflect the main effect of the professional development after controlling for those similarities.

Technology Enhanced, Research Based Instruction, Assessment, and Professional Development Program (TRIAD). The Technology Enhanced, Research Based Instruction, Assessment, and Professional Development (TRIAD) program is a professional development program organized by Clements and colleagues (2004; 2007a) and implemented in preschool programs serving low-income children. The pre-K math intervention includes a classroom component, a home component (math activities and materials for families), and a professional development package that includes mentoring, workshops, and web-site distance education. The classroom component, which is Real

Math Building Blocks (BB) curriculum, was designed by Clements and Sarama (2007c). The curriculum is based on their studies of children's natural developmental progression in learning mathematics, which is defined as learning trajectories by Simon (1995). As their starting point, the researchers reviewed the literature concerning the implications for the effective curriculum development and then created activities based on their theoretical foundation (Clements & Sarama, 2007a, 2007b; Sarama & Clements, 2004). Then, they provided professional development support for preschool teachers to familiarize them with students' mathematical development as well as the activities. Their next step was to evaluate the appeal, usability, and effectiveness of the curriculum by collecting empirical data through clinical interviews and observations. The path that Clements and colleagues followed to design the project was similar to the logic model suggested by Julian and colleagues (1995). The project designers stated that their process of developing a curriculum slowly and basing its development on research may contribute to "(a) more effective curriculum materials, (b) better understanding of students' mathematical thinking, and (c) research-based change in mathematics curricula" (Clements & Sarama, 2007a, p. 137).

The intervention program started in 2005 and is still in process (U.S. Department of Education, 2007b). In order to help teachers learn the curriculum as well as strengthen their knowledge of children's mathematical development, the TRIAD team benefits from the major professional development components: curriculum implementation, workshops, mentoring, and online support. The workshops consist of whole-group sessions in order to discuss how students learn mathematics as suggested by Bransford and colleagues (1999), Carpenter and colleagues (1988, 2000), and Ginsburg and colleagues (2006).

Also, teachers have the opportunity to get familiar with the components of the curriculum in general. In addition, they have small-group discussions to further discuss how to provide excellent math activity for children as recommended by NRC (2009a), NSTA (2009), and IRA (2009). More specifically, teachers and the trainers talk about how to manage classroom, what to expect from students, and how to facilitate and support students' understanding through inferential questions. Additionally, each teacher receives intense support from mentors who visit every classroom on a regular basis, observing and facilitating the implementation. Also, facilitators discuss possible implementation problems with the teachers. Moreover, the TRIAD system provides online resource, Building Blocks Learning Trajectories (BBLT), for the treatment teachers to strengthen their professional development. In terms of factors related to the effectiveness of learning technologies (Biggs, 1999), the application has motivational context (e.g., video-clips of teachers employing BB activities), a well structured knowledge base (e.g., articles related to students' mathematical growth and the curriculum and learning trajectories that are connected to the video clips), learner activities (e.g., opportunity for teachers to test their knowledge of curriculum and learning trajectories), and interaction with others (e.g., opportunity to post thoughts, insights, and difficulties about the curriculum and students' learning).

As noted previously, the intervention and its evaluation are still in progress. Although the effectiveness of the project is not fully evaluated yet, the researchers examined the efficacy of the mathematics program on a small scale. The researchers conducted pre- and post-assessments for children in both control and experimental groups. The summative research results show significant effects of the curriculum on

students' learning (Clements & Sarama, 2007a). Specifically, the project students increased their ability to use complicated numerical strategies and advanced their spatial imagery. Moreover, if a teacher implemented the curriculum with at least a moderate degree of fidelity, the curriculum materials helped preschool students develop mathematical understanding and skills. In addition, the team asked teachers to fill out beliefs questionnaire and conducted classroom observations to determine whether there was any change in teachers' instruction in line with the TRIAD program. The observations focus on the mathematical focus, teaching approaches and interactions, teacher's use of teaching strategies, his/her expectations for students, ability to elicit students' solution methods, ability to support students' conceptual understanding, ability to extend students' mathematical thinking, and ability to make instructional adjustments. Since the evaluation is still in progress, the results of the observations are not published yet; thus, it is not possible to talk about its effectiveness yet.

Comparison of the Programs. Researchers point out several factors that influence the effectiveness of professional development. One factor is the focus of the program (Cohen & Hill, 2000; Kennedy, 1998; Loucks-Horsley et al., 1998; Penuel et al., 2007). All four teams supported their projects with an emphasis on teachers becoming better at assessing students' mathematical understandings. They conjectured that as teachers strengthened their knowledge of young children's early mathematical development, they would create more effective math learning environments, which would be linked to an increase in quality of math instruction and eventually higher mathematical achievement for the students. To this end, each project team organized professional development

programs that consisted of several components (i.e., workshops, mentoring, curriculum implementation, online support, and/or observation and assessment).

While two programs (PPCM and TRIAD) created instructional activities for their teachers to employ in their classrooms, the other two programs (CGI and ELM) only provided professional development support for their teachers. After creating the activities through observing children doing math, the PPCM team asked teachers to implement those activities in their classrooms (Cobb et al., 1990). On the other hand, the TRIAD team followed a specific path to create the instructional activities: drafting initial goals, building an explicit model of students' learning, creating an initial design for activities, investigating the components, assessing curriculum, conducting a pilot study in a classroom, and publishing (Sarama & Clements, 2002). By following this path, Sarama and Clements (2002) identified their curriculum as a research based curriculum.

In terms of their context, all four project teams organized workshops for their teachers. During the workshops, they provided whole-group and small group sessions to talk about how children learn mathematics. There exist some distinctive differences among the projects in terms of their workshop agendas. For instance, the CGI team provided free time for their teachers so that they could review materials, read related articles, and study video tapes of children solving math problems. On the other hand, while the ELM teachers worked on a journal about their daily experiences during a certain time of the workshops, the TRIAD team spent time on familiarizing teachers with the online support system.

In addition to workshops, the teams provided mentoring for their teachers during the school year by assigning one or more staff member/mentor to each participating

teacher or school. Specifically, during the classroom visits, the mentors attempted to map teachers' existing knowledge, classroom practices, and beliefs toward teaching and learning mathematics. Then, through observations and discussions, they aimed to help teachers think about their knowledge, skills, and beliefs, evaluate these based on the new information they constructed, and revise them, if necessary.

Different from the others, the TRIAD had a website, BBLT, for its teachers. The BBLT, with flexibility in scheduling and timing (Sprague, 2006), provided an opportunity for teachers to reach helpful articles, learning trajectories, video clips of other teachers employing curriculum activities and so on.

Although four projects benefited from various professional development components, they did not provide information about whether more or less exposure to such components had impact on teachers' mathematics instruction. Therefore, further research is required to examine the effects of amount of exposure to different types of professional development components on mathematics instruction.

Another factor that may influence the effectiveness of the projects is the duration of a project. There are two aspects related to the duration of the program. The first aspect is about the contact hours, which refers to the total number of hours that the teachers spend in activities of the professional development program. The second aspect is time span, which means that the total time that the professional development program covers. For instance, for a professional development program that requires participants to meet once a week for 4 hours for a month, the total contact hours are 16 hours (4 x 4) and the time span is one month. In terms of time span, giving time to teachers to plan for implementation is found as a critical aspect of effective professional development

programs (Barak & Waks, 1997; Brown, 2004; Darling-Hammond & Sykes, 1999; Garet et al., 2001; Garrett & Bowles, 1997; Ingvarson, Meiers, & Beavis, 2005; Penuel et al., 2007; Supovitz & Turner, 2000). Depending on what teachers bring with them, the teachers must have time to process new materials in order to make the materials meaningful to them and in turn to enrich their instruction. Although the reviewed programs lasted longer than a school year, the researchers of the programs did not specify how much time their teachers were exposed to professional development (i.e., contact hours). Indeed, the researchers did not investigate the possible association between the change in teachers' instruction and the amount of professional development that teachers were exposed to.

Teachers' attitudes toward professional development programs are a critical factor that may have impact on the effectiveness of the program (Kilgallon, Maloney, & Lock, 2008; Nir & Bogler, 2008; Novick, 1999; Wilson & Berne, 1999). In order to determine teachers' attitudes towards the programs, each team followed different ways. The PPCM team closely observed participating teachers; as a result, Cobb and colleagues (1990) noted that as teachers realized the weaknesses in their instruction and the insufficiency of the textbooks they were using in their classrooms, they agreed to consider alternative approaches to teaching mathematics to children. Similarly, the ELM team announced teachers' positive attitudes toward the program by analyzing the journals that teachers wrote. On the other hand, rather than teachers' positive responses toward the project, the CGI team preferred to report the concerns that their participating teachers had (e.g., how to use students' thinking in teaching, how to select activities, and how to clarify students' understanding). Although the researchers reported teachers' attitudes towards the

programs, they did not statistically investigate the association between teachers' positive attitudes towards the program (e.g., satisfaction) and the change in their instruction. Therefore, more research is needed to investigate to what extent teachers' attitudes toward the professional development program and/or materials had impact on their mathematics instruction.

Another possible factor that may influence the effectiveness of the program is teacher characteristics (Cooper, 2004; Cooper & Jackson, 2005; Darling-Hammond, 2000; Haycock, 1998; Kaplan & Owings, 2001; Kyriakides, Campbell, & Christofidou, 2002; Sanders & Horn, 1998; Wright, Horn & Sanders, 1997). Mainly, teacher characteristics refer to teacher's teaching experience, educational background, and certifications (Darling-Hammond, Chung, & Frelow, 2002; Laczko-Kerr & Berliner, 2002). The researchers provided information about teachers' average years of teaching experience, educational background, and/or their credentials; however, they did not include those in their analysis of the effects of professional development. Since there is a possibility that teacher characteristics may affect the direction and/or strength of the relation between the professional development and teachers' instruction, skills, and beliefs, future research should examine the impact of professional development on teacher's instruction, skills, and beliefs in the presence of the effects of teacher characteristics (i.e., teaching experience, educational background, and certifications).

This review of the professional development programs, however, showed that weaknesses existed, especially, in the way they measured teacher change. Particularly, except for the TRIAD team, the others relied on single instrument to measure the change and/or conducted observations in project classrooms only after the training. Also, they

measured, for instance, how many times a teacher posed questions, rather than quality of the instruction. Therefore, for the three programs, the CGI, ELM, and PPCM, it is difficult to talk about the change in teachers' behavior in line with the professional development support they received. Thus, this warrants more research to develop an investigation that avoided those weaknesses and to examine the possible associations between professional development programs and teachers' classroom practices.

Summary

Substantial evidence exists to support the idea that there is a pressing need to strengthen teachers' professional development in mathematics in order to improve students' academic achievement in mathematics and, also, to investigate the effects of these opportunities on teachers' instruction and their students' learning. However, research shows that, compared to literacy development, relatively little attention is given to teachers' professional development in mathematics, especially in early childhood education.

The success of a professional development program with emphasis on math instruction depends on its logic model. After naming the vital issues in math education, activities to address those issues need to be identified. After organizing the program based on those issues, it is critical to evaluate it to determine whether the program improved participating teachers' mathematics instruction in line with the program and, as a result, improved students' learning. The evaluation of four professional development programs with emphasis on math instruction shows that there exist weaknesses in the ways they measured teacher change. More specifically, in order to determine changes in

teachers' behaviors due to professional development, in the future, it is critical to use various instruments to measure the change in teachers' instruction and to take into account possible teacher related factors (i.e., attitudes toward professional development and background information). Moreover, although the reviewed programs provided training, classroom observations and assessments, and mentoring for their participating teachers, the researchers did not investigate which component had better influence on teachers' instruction. Therefore, evidence is also needed to determine the contribution of each professional development component individually relative to the others on teachers' instruction, skills, and beliefs.

Conclusions and Hypotheses

Recent studies have shown that American children in upper elementary and high school lag far behind their counterparts from different nations. Also, children from low-income families enter school already behind their peers from middle- and upper-income families. Given this context, the math achievement of American students, and especially American students from low-income backgrounds, requires attention when the children are young.

Although children's mathematical development starts as early as the first weeks of life, low-income children do not benefit from preschool education as much as their peers from middle- and higher-income families. Evidence suggests that instruction in mathematics in the preschool classroom is minimal and focused on a limited number of topics. Therefore, there is a strong need to work with preschool teachers to help them understand the specific needs of children, especially ones at risk, learning mathematics so

they may deliver math instruction effectively. An important component of this instruction is for teachers to develop effective classroom discourse strategies in order to help them determine students' thinking and adjust instruction accordingly. In order to bring about this change in the instructional practices of in-service teachers, focused professional development is required.

To encourage increased attention on math development in younger children, the national associations NCTM, and NAEYC have already announced mission statements and standards specifically for early childhood educators and mathematics teachers. Realizing the gravity of poor mathematical skills of American children, researchers and national organizations have put strong emphases on the relations between effective teaching and students' achievement at all grade levels.

The professional development of teachers has received a lot of attention in recent years. Researchers have discussed different components of professional development including assessment and observation by the peers, mentoring, training, and online support. Currently there is neither consensus about how much time and resources should be allocated for professional development of teachers nor their exact definitions. In the present study, the term professional development is used to refer to training that gives any experiences for teachers that are intentional, ongoing, and structured, that is provided outside of the formal education system and has the goal of increasing the knowledge, skills, and attitudes of teachers.

The logic model of any professional development program consists of three steps, illustrated in this paper by professional development focused on improving mathematics instruction. The first step is to identify issues in mathematics education that need to be

addressed. The second step is to organize the program so that the activities included aim to solve those identified issues. The last, and most important, step is to extensively evaluate the effectiveness of the program to determine whether it achieved the desired short- and long-term goals.

There are several professional development programs with emphasis on math instruction that combined some of those components. In order to determine their success, four of them were reviewed in detail. The evaluation of those professional development programs shows that there exist critical limitations especially in the way they measured teacher change. Such limitations warrant several implications for future research. The first one is to examine whether exposure to different professional development components have impact on teachers' instruction, and skills. The second implication is to investigate the association between teachers' attitudes toward professional development program and classroom instruction. The last one is to explore whether teachers' background characteristics have impact on the effectiveness of such programs.

This study sought to investigate the association between a professional development programs directed at preschool classrooms and teachers' mathematics instruction as a consequence. Considering the logic model of professional development, it is hypothesized that

1. Pre-kindergarten teachers who have received professional development in an early childhood math curriculum will implement mathematics activities more often and with higher quality than teachers who have not had the training.
2. Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development will implement

- mathematics activities more often and with higher quality than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure, they will be more receptive to the professional development support they received.
3. Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development support will implement more components of the curriculum than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure, they will implement more components of the BB curriculum.
 4. Teachers' implementation of the components of a curriculum as well as quality and quantity of mathematics activities will be associated with their satisfaction with the curriculum. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure and are also satisfied with the curriculum, they will implement more components of the BB curriculum and will conduct math activities more often and with higher quality.
 5. Increase in the quantity and quality of math instruction and in curriculum implementation will be associated with teachers' satisfaction with the professional development support they receive. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background,

more teaching experience, and teaching licensure and are also satisfied with the professional development, they will provide math instruction more often and with higher quality and implement more components of the curriculum.

CHAPTER III

RESEARCH DESIGN AND PROCEDURES

Research Site and Participants

Research Site

The data for this study were obtained as a part of the Scaling Up the Implementation of a Pre-Kindergarten Mathematics Intervention in Public Preschool Programs Project. The project implemented a pre-kindergarten math intervention program entitled the Technology Enhanced, Research Based Instruction, Assessment, and Professional Development (TRIAD) Treatment, as a scale up project involving two types of public preschool programs serving low-income children in Buffalo, Boston, and Tennessee. The pre-kindergarten math intervention includes a classroom component (whole-group and small-group math activities, math software, a math learning center), a home component (math activities and materials for families), and a professional development package consisting of workshops, one-on-one facilitation and a website to implement the intervention with fidelity on a large scale and at a distance from the curriculum developer.

Vanderbilt University served as a “scale up” site for the curriculum developed by researchers at the State University at New York at Buffalo (SUNY-Buffalo). Within Tennessee, two types of programs were represented. While the first program was a pre-kindergarten program administered by an urban school system, the other program was the

local Head Start administered by a metropolitan non-profit agency. These two types of programs provide the vast majority of preschool educational opportunities to low-income families in the US, but differ in their administrative structures and income requirements for the populations they serve.

The intervention project was intended to be conducted during a five-year period. During the first two years, the main goal was to train internal facilitators from the preschool programs and to begin training the teachers in the intervention condition. The treatment teachers attended workshops, received on-site training by internal facilitators, and were encouraged to use the website. The main study of the implementation occurred in 2007-2008 school year. During the remaining two years, training activities were directed toward training the control teachers and non-study teachers and following and assessing participating students at the end of kindergarten and first grade. The present study used the data obtained in the Tennessee site and aimed to evaluate the effectiveness of the intervention in terms of enhancing the quantity and quality of math instruction in preschool classrooms during the implementation year.

Technology Enhanced, Research Based Instruction, Assessment, and Professional Development (TRIAD) Treatment

The pre-kindergarten math intervention includes three important components: (1) a classroom component, (2) a home component, and (3) a professional development package that includes a one-on-one facilitation model, workshops, and a website to implement the intervention with fidelity on a large scale and at a distance from the

curriculum developers. For the purpose of the study, the design and implementation of the intervention are summarized below.

Curriculum Model. In treatment classrooms of this study, the Real Math Building Blocks curriculum (BB curriculum) was implemented (Clements & Sarama, 2007c). The BB curriculum is a technology-enhanced curriculum that explicitly recognizes the teacher's critical role in preschool math instruction. More specifically, it was designed "to provide thorough background, teaching strategies, and resources to support teacher delivery of a coherent and effective mathematics curriculum" (Clements & Sarama, 2007c, p.T26). The Building Blocks curriculum consists of 30-week lesson plans for teachers.

As teachers use the curriculum, they are expected to follow a consistent plan on a daily basis. The plan consists of six components: whole-group activities, small-group activities, hands-on math center activities, computer center activities, family letters, and math-throughout-the-year activities. Teachers are required to report which activities they completed and to keep track of students' participation in each activity. Detailed information about each component is given below.

1. Whole-group activities. Whole-group activities are to be used for warm-up purposes every day for 10 to 20 minutes. Examples of whole-group activities are finger plays, songs, and introducing the new activities. During whole-group activities, teachers are not required to take notes about children. Teachers are allowed to replace or change the order of the suggested whole-group activities with the ones that teachers believe would benefit children more.

2. Small-group activities. The purpose of small-group activities is to provide a learning opportunity for a group of students in a setting that allows the teacher to closely monitor and record the children's responses, a setting that provides for the possibility of interactions between teacher and students and among students themselves. It is a highly controlled setting, with a specified goal of helping children advance their understanding of mathematics based on the learning trajectories. Teachers are encouraged to complete one or two small-group activities for each child per week for 15 to 25 minutes. The teacher is supposed to ensure active participation of each child in a conversation about math during the small-group activities. Teachers are also required to reflect on what children say as well as to use scaffolding if necessary by using inferential questions such as “how do you know?”, “why?”, and “show me how.” As teachers conduct the small-group activities with children, they are encouraged to record children’s responses, strategies, and their trajectory levels.

3. Hands on math center activities. Teachers are encouraged to organize hands-on math centers that give children concrete experiences with math concepts often as a follow up to the small group activity. Depending upon the complexity of the activity and the ability of the child, hands-on activities should be implemented in a way that requires minimal supervision. Thus, in order to have children benefit from this type of activities, the materials in the center should be introduced to children before they visit the center.

4. Computer center activities. One of the core components of the BB curriculum is the set of computer activities that are web based and connected to all the concepts teachers are covering in small groups. Teachers are encouraged to have every child use the BB software two times a week. Each BB computer math activity addresses specific

developmental levels of the math learning trajectories. As children engage with the computer software, they need to be monitored carefully to ensure active participation of all children. Activities are assigned to children based on their prior performance. The assignments can be made by the teachers or, in the absence of a teacher assignment, the web will assign the child the next appropriate task.

5. Family letters. The BB curriculum requires teachers to send a family letter to home on a weekly basis in order to increase the communication between family and school. Through the letters, parents are informed about what their children are doing in mathematics, which is aimed to help parents support their children's mathematical understanding and development at home.

6. Math-Throughout-the-Year activities. In addition to provide math instruction during certain times (e.g., whole-group or small-group time), the BB curriculum recommends teachers to connect daily events to mathematical concepts. Specifically, teachers are encouraged to set up some routines at the beginning of the school year and continue them throughout the year. Examples of such routines are attendance, daily calendar and weather, lining up, physical activities including counting motions and spatial relations, and so on.

Mentoring. In order to provide on-site training to the treatment teachers, four internal facilitators (IF) were hired. They were former teachers or administrators selected by the systems to serve as facilitators of the curriculum. The facilitators were assigned 6 - 10 classrooms. They kept monthly records of facilitation time and type of support they provided for their teachers. The roles and responsibilities of the facilitators were

- sharing teaching strategies or information about early childhood teaching and learning mathematics in early childhood;
- sharing information with the teacher about program procedures, guidelines and expectations;
- sharing information about the curriculum components;
- sharing information about effective use of computers;
- linking the teacher to appropriate resources;
- offering support by listening and by sharing their own experiences;
- giving guidance and ideas about management, scheduling, planning, organizing the day, and other topics;
- assisting the teacher in arranging, organizing and/or analyzing the physical setting;
- counseling the teacher when difficulties arise;
- allowing the teacher to observe themselves or other colleagues; and
- promoting self-observation and analysis.

During the first and second years of the project, the internal facilitators learned to implement the Building Blocks curriculum as well as to provide on-site mentoring to teachers through workshops and meetings organized by the Vanderbilt staff. The meetings were held twice a month during Year 1. Throughout the implementation year, the project staff and the facilitators met on a monthly basis to discuss the common problems occurred in the classrooms. The meetings were devoted to providing intensive training in the classroom components of the intervention. Among the components, small-group activities were given greater emphasis. In addition, the internal facilitators

continued to be trained through the website. In order to fulfill their responsibilities, the internal facilitators were trained to use a fidelity instrument to make fidelity ratings of the implementation of the math curriculum by the treatment teachers. The fidelity observations were conducted twice each semester, and then, the facilitators used these observations to provide on-site training to the teachers.

The internal facilitators' goal was to spend a total of 10 hours a week helping the teachers they were assigned. Specifically, during their meetings with the teachers, the facilitators were encouraged by the curriculum developers and the Vanderbilt project team to put strong emphasis on conducting small-group activities that were adapted based on students' developmental level in mathematics and that were enriched with inferential questions.

Workshops. As a part of the TRIAD treatment, the project teachers attended workshops. Since Clements and Sarama (2007) designed the curriculum based on children's natural developmental progression in learning, the trainers' main objective in the workshops was to strengthen teachers' knowledge of children's mathematical development. Specifically, they discussed "the thinking and learning processes of children at various levels, and the learning activities in which they might engage" (2007, p.B1) with the teachers. In addition, teachers were introduced to the Real Math Building Blocks curriculum, and taught the components of the curriculum (i.e., whole-group activities, small-group activities, computer activities, hands-on activities, math-throughout-the-year activities, and family letters). Among those components, the greatest emphasis was given to small-group activities. The reason is that small-group activities are

considered by the developers as an effective and convenient means of monitoring children's learning.

During workshops, the developers, the Vanderbilt project staff, and the teachers had whole-group sessions in order to discuss how students learn as well as the components of the curriculum in general. Also, they had small-group break-out sessions to further discuss how to provide math activities for children. More specifically, teachers and the trainers talked about how to manage classroom, what to expect from students, and how to facilitate and support students' understanding through inferential questions. For ease of reference, Table 1 highlights the workshops, dates, and durations in a chronological order (See Appendix A for a sample workshop agenda).

Table 1

Workshops, Dates, and Durations in Hours

	Total Duration	Duration of whole-group lecture and discussions	Duration of small-group discussions	Durations of computer access	Durations of breaks and lunch
Workshop 1 August 2006	25	5.75	7.50	7.83	3.92
Workshop 2 November 2006	2	-	-	2	-
Workshop 3 January 2007	14	5	6	-	3
Workshop 4 April 2007	7	2.25	3.33	0.50	0.92
Workshop 5 August 2007	7	3.75	-	2	1.25
Workshop 6 August 2007	11	4	6	-	1

The details for each workshop are given below.

Workshop 1: The introductory workshop was held in August 2006. The main goal was to introduce the Real Math Building Blocks Curriculum and the TRIAD program to the participating teachers. The workshop was taught by Douglas Clements, Julie Sarama, and Dale C. Farran with the assistance of the Vanderbilt project staff. In addition to the teachers in the treatment group, the facilitators also participated in the workshops. The workshop involved about seven hours of participation each day for four days. A typical

day included a whole-group lecture and discussions led by Clements and Sarama, which focused on mathematical development in young children and the ways to support this development through Building Blocks curriculum. During the remaining hours, teachers were introduced to the Building Blocks whole-group activities, small-group activities, and instructional software on lesson plans and learning trajectories. Teachers were encouraged to keep track of children's participation in the activities for small-group and computer center activities. Teachers had the opportunity to review the textbook and manipulatives, and to practice a few activities. On the third day, teachers were introduced to the Building Blocks Management Software System, which was designed to help teachers to manage children's use of computer activities. Each day, the workshop ended with a whole-group reflection session.

Workshop 2: In November 2006, per Head Start teachers' request, a two-hour workshop was organized for those teachers. During the workshop, the main focus was to familiarize teachers with the online resource BBLT. With the guidance of Vanderbilt staff, the teachers logged on to the website, practiced how to assign computer activities to their students, and watched video-clips of teachers employing the BB activities.

Workshop 3: In January 2007, teachers attended another workshop that lasted for two days. The workshop involved 7 hours of participation each day. A typical day started with a whole-group lecture and discussions led by the developers. Then, the discussions were held in small-groups led by the Vanderbilt project staff. Also, the internal facilitators became part of a group and moved through the small-groups with three or four teachers. The discussions focused on computer management issues, the definition of inferential questions and the ways to enhance children's expressive understanding

through inferential questions, common challenges and solutions to working with small-groups of young children, integration of BB into daily curriculum and schedule, computer trajectories and lessons, scaffolding strategies, and ways of enhancing the BB activities. Each day, the workshop ended with a 45-minute whole-group reflection session.

Workshop 4: This one-day workshop was called ‘Trajectory Game Day.’ The main goal was to familiarize teachers with the learning trajectories through games. Following an hour lecture and discussion led by Douglas Clements on the learning trajectories and the differences between small-group and hands-on activities, teachers rotated through four sessions of games. Each game, BB Squares, BB Millionaire, BB Beat the Clock, and BB Concentration, had been adapted from TV game shows to highlight specific math learning trajectories. Finally, the four groups of teachers played the “Trajectory Jeopardy.”

Workshop 5: A one-day workshop was conducted for teachers who replaced teachers in treatment classrooms or had been placed in newly opened classrooms at participating sites. It involved 7 hours of participation. A two-hour lecture and discussion was led by Clements with the focus on understanding mathematics and the development of mathematical thinking in young children in number and geometry. Then, teachers rotated through sessions focused on instructional activities and materials. In addition, teachers were provided the opportunity to familiarize themselves with the BB software. It ended with a whole-group reflection session.

Workshop 6: All teachers were expected to attend the workshop on August 2-3, 2007. The first day of the workshop was conducted at Vanderbilt University. The main focus of this day was to discuss BB activities (i.e., whole-group activities, small-group

activities, computer activities, math-throughout-the-year activities, and family letters) and to talk about the research plans during the implementation year, including recruitment of students and families, individual assessments of children, teacher surveys and child reports, and classroom observations. The teachers also met with their facilitator and other project staff to discuss solutions to common curriculum problems, especially the problems related to small-group activities. In the afternoon, the teachers had the opportunity to meet with an expert in human development and special education to discuss behavior management strategies. The first day of the workshop ended with a 15-minute whole-group reflection session. The second day was held in each teacher's classroom to set up the math center, computer center, and manipulative center and to discuss implementation plans with a facilitator and a Vanderbilt project staff.

Online Professional Development. The TRIAD system provided a website, Building Blocks Learning Trajectories (BBLT), for the treatment teachers to strengthen their professional development. The website consisted of learning trajectories, curriculum activities and their associations with each learning trajectory, articles related to students' mathematical growth and the curriculum, and video clips of preschool teachers doing BB activities. Such learning opportunities were designed to make the ideas and processes of the curriculum accessible, memorable, engaging, and therefore usable. Also, the BBLT site gave the teachers the opportunity to test their knowledge and to post their thoughts about each activity/trajectory. In order to use the BBLT, each teacher was given a username and a password in the August 2006 workshop and introduced to the BBLT site. In addition, during the implementation year a Vanderbilt project staff provided tutoring for teachers about the BBLT site per individual requests.

Participants

The study sample consisted of 20 sites, where “site” refers to a Head Start center or public school with one or more classrooms clustered at that location. As noted previously, there were two types of pre-school programs participated in the study. While the first group included 4 Head Start centers (4 - 9 classrooms per site), the second group included 16 public schools (1 - 4 classrooms per site). After introducing the project to site managers/principals, some agreed to participate voluntarily whereas the others were required to participate by their system. The sites within each type of program were grouped into pairs that were similar with regard to the size of the site (total number of classrooms), number of single-age and mixed-age classrooms, and, to the extent possible, ethnicity of the pre-kindergarten children. Within each pair, one was then randomly assigned to receive the math intervention (N=10) and one to participate in the control condition (N=10). While there were 31 classrooms in the treatment condition, 26 classrooms were in the control condition. Demographic information of the teachers is presented in Table 2.

Table 2

Demographic Information of the Teachers

Condition/System	N	Teaching experience	Education level		State teacher credential
			Bachelor Degree	Master's Degree	
Treatment Group	31	11.2 years	61.7 %	38.3 %	56.7 %
Public schools	16	14 years	50 %	50%	100 %
Head Start	15	8.3 years	73.3 %	26.7%	13.3 %
Control Group	26	11.3 years	79.4 %	20.6 %	50 %
Public schools	17	9.8 years	58.8%	41.2%	100%
Head Start	9	12.8 years	100%	0	0

Within each classroom, the parents of all the 4-year old children eligible on the basis of age to attend kindergarten the subsequent year and enrolled in the class during the first two weeks of school were asked for consent for their child to participate in the study. Among 1020 children in the classrooms, 764 agreed to participate in the study. The sample comprised 347 boys (45.4%) and 417 girls (54.6%). The majority of the children were African American (77.1%). The remainder of students participating in the study consisted of Caucasian (9.4%), Hispanic (8.9%), and others (4.6%).

Instruments

Classroom Observation of Early Mathematics - Environment and Teaching (COEMET). The *Classroom Observation of Early Mathematics - Environment and Teaching (COEMET)* instrument was developed by Sarama and Clements (Sarama & Clements, 2007). The content of the instrument was created based on research on the characteristics and teaching strategies of effective teachers of early childhood mathematics from pre-kindergarten to 2nd grade. The instrument is not tied to a specific model curriculum and was used in both treatment and control classes.

The instrument is divided into three sections: Classroom Culture (CC), mini Specific Math Activity (mSMA), and Specific Math Activities (SMA). In the Classroom Culture scale of nine items, the observer rates the environment and personal attributes of teacher towards teaching mathematics. The second section, mSMA, allows the observer to record math activities in which neither teachers nor assistants are involved in formal instruction, or which are "simple" or "routine" activities. Examples of such mSMA activities are songs, finger plays, poems, calendar activities, and children's independent play with math materials with no adult present.

The last part of the instrument, SMA, measures the quantity and quality of specific math activities. The term *specific math activities (SMA)* refers to mathematics activities that are led by the classroom teacher or the teacher's aide and last longer than thirty seconds. In this part, average number of specific math activities, average time spent on math activities per child, number of children who participated in the activity, number of children who watched the activity, math topics that were covered, setting, teaching strategies employed, and the approximate percentage of teacher's involvement in the

activity were reported. Also, for each SMA, the observer rated the quality of the math instruction covering such aspects as the mathematical focus, the teaching approaches and interactions, the teacher's use of teaching strategies, his/her expectations for students, ability to elicit students' solution methods, ability to support students' conceptual understanding, ability to extend students' mathematical thinking, and ability to make instructional adjustments. To rate the specific math instruction, the observer used a five-point Likert scale that consists of eighteen items. The scale ranges from strongly disagree to strongly agree (see Appendix B).

For analyses purposes, two variables were obtained and used as dependent variables. The first variable is the average number of specific math activities. To calculate it, the total numbers of specific math activities that occurred during three observation periods conducted during the school year were summed up, and then averaged. The second variable represents the overall quality score of the specific math activities. Eighteen items involved assessing this quality score. Since there was no variation in the ratings obtained on one of the items, it was omitted.¹ The overall average quality score of specific math activities was calculated for each observation period, and then, the average score was obtained across three observation times. To sum up, for this particular study, two variables, one quantity and one quality score, were used as dependent variables.

In order to test internal consistency of the rating items in the instrument, Cronbach's alpha was calculated for each observation time. Cronbach's alpha assesses how well a set of items measures the same underlying construct. Cronbach's alpha takes

¹ Item 15, regarding the percentage of time the teacher was actively involved in the activity, was omitted from the analysis due to a lack of variability. By definition, a specific math activity was led by the teacher or the teacher's aide, thus, their involvement was always coded in the highest category (76-100%).

into account the number of test items and the average inter-correlation among the items (UCLA Academic Technology Services, 2004). Since the scale used in the present study was a 5-point scale, there were relatively heterogeneous variances. In this situation, the use of standardized item alpha is recommended (Reynaldo & Santos, 1999). Therefore, in this particular study standardized item alpha is reported for three-time points. The value of the alpha coefficient can range from 0 to 1 (Reynaldo & Santos, 1999). In the present study, a reliability coefficient of .70 or higher was considered as “acceptable” (UCLA Academic Technology Services, 2004). The overall standardized alpha values for the subscale measuring the quality of math instruction across three-time points were calculated as .91, .91, and .91. To sum up, the subscale was highly reliable for each observation period.

Teacher Questionnaires. At the beginning of the implementation year, all treatment and control teachers reported their licensing status, their highest educational level, and their years of teaching experience. Teachers’ licensing status was coded as 0 or 1 to represent the absence or presence of the license. Also, based on the data regarding teachers’ highest level of education, the group was divided into two groups. Teachers who had bachelor’s degree only were given a score of 0 and teachers who had master’s degree were given a score of 1. Moreover, the teachers reported how long they had been working as a teacher. In order to identify teachers who have more or fewer years of teaching experience, a median split procedure was applied to create two groups. Teachers reporting higher years of teaching experience than the median (11.2 years) were given a score of 1 and teachers reporting lower years of teaching experience than the median were given a score of 0. In order to condense the number of variables due to small sample

size, a single measure related to teacher characteristics was created by adding those three category scores across the three variables for each teacher. Thus, the scores of this variable range from zero to three. A score of three represents teachers who had more teaching experience, held master's degrees, and had teaching licenses. On the other hand, a score of zero refers to teachers who had less teaching experience, held bachelor's degrees only and did not have teaching licenses. In short, this variable was in an ordinal sequence from less to more and used as a covariate in related analyses.

At the end of the implementation year, treatment teachers completed an additional questionnaire. The teachers were asked to evaluate the effectiveness of the BB intervention. Specifically, the treatment teachers were asked to evaluate the effectiveness of five BB components (i.e., whole-group activities, small-group activities, hands-on math center activities, computer center activities, and family letters) on students' mathematical understanding and the effectiveness of professional development models (i.e., workshops at Vanderbilt, one-on-one facilitation, online Building Blocks Learning Trajectories, and Building Blocks Teacher's Manual and Resource Book) on their instruction. The two sections consist of 15 and 12 Likert scale items, respectively. Those items measure the extent to which the teacher agreed or disagreed with the item's statement. All items were coded on a four-point Likert scale from Not at All (or Never) to A Lot. For analysis, two variables were created: one refers to the average score of the effectiveness of BB components on student's mathematical understanding – or the teacher's satisfaction with the curriculum itself – and the other stands for the average score of the effectiveness of professional development models on teacher's instruction – or the teacher's satisfaction with the professional development. For each variable, mean

scores were computed. In order to test the internal consistency of the items in the instrument, Cronbach's alpha was calculated for the effectiveness of BB components scale and the effectiveness of professional development models scale as .82 and .90, respectively. To sum up, each subscale appeared to be highly reliable.

Teacher-Reported Weekly Record Sheets. Completion of the Weekly Record Sheets (WRS) on a weekly basis was a required part of the curriculum. The Weekly Record Sheets helped teachers record children's participation and progress on math activities (see Appendix C for a sample Weekly Record Sheet). The purpose of collecting the WRS was to determine the teachers' implementation level of each BB component – whole-group activities, small-group activities, hands-on activities, computer center activities, family letters, and math-throughout-the-year activities.

The WRS included the list of the activities that teachers were to give to their students. For whole-group (WG), hands-on (HO), math-throughout-the-year (MTY) activities, and family letters (FL), teachers reported whether each of the listed activities was completed or not. Within the curriculum, there were 180 WG activities, 111 HO activities, and 85 MTY activities for teachers to conduct. Also, there were 30 family letters (FL) that were to be sent home on a weekly basis. In order to find out the implementation level of the BB components the following calculations were performed. The proportions of the completed WG, HO, MTY, and FL activities over the course of the school year were calculated and saved as four different variables.

Furthermore, in the Weekly Record Sheets, each small-group (SG) and computer center (CC) activities were listed. Teachers were required to report the number of instances of children's access to the computer software and their participation in small-

group activities across the week. Since the project teachers did not specify whether each child's participation in small-group activities or computer activities occurred once or more than once, proportions for these variables could not be calculated and were thereby excluded from further analyses.

Professional Development Hours. First, attendance at the workshops was calculated. There were six workshops organized for the teachers consisting of whole-group lecture, small-group discussions and activities, computer training, and coffee and lunch breaks as described previously. Teachers varied in how many of the workshops they attended. Some teachers were not available for one or more workshops, and during the implementation year, new teachers joined the project to replace teachers who left treatment schools. The total time that teachers spent in whole-group lecture, small-group discussions and activities, and computer training during the six workshops was calculated and saved as a variable.

Second, coaching or facilitation hours were summed. As noted previously, the facilitators were required to report facilitation time and type of support they provided for their teachers on a monthly basis (see Appendix D). The time that the facilitators spent with their teachers in order to strengthen their professional development in line with the curriculum during the implementation year was obtained for each teacher and summed into another variable.

Third, online access was calculated. As discussed previously, teachers were provided an opportunity to have access to a website called BBLT in order to strengthen their professional development. Each teacher used a username and a password to log into

the website. The total number of times teachers accessed the BBLT website during the full implementation year was obtained.

While the first two variables show teachers' participation in workshops and exposure to facilitation in hours, the last variable expresses the number of actual times the teachers accessed the website (BBLT). In order to get a common measurement scale representing teachers' exposure to each professional development support, each variable was divided into four groups representing low, low-medium, medium-high, and high exposure to each type of professional development support. Thus, the scores of these variables range from one to four. A score of one represents teachers who had least exposure to the related professional development component. On the other hand, a score of four refers to teachers who had the most exposure to the related component. In short, these variables were in an ordinal sequence from less to more and used as predictors in associated analyses.

Procedures

Training. Seven observers were involved in data collection. Among the seven observers, four had been trained in COEMET during the practice year. All data collectors were knowledgeable about preschool environments and young children's behavior. Before beginning the data collection, observers were trained in data collection procedures over the course of two weeks using five preschool classrooms that were not included in the study. Two classrooms were equipped with an observation booth that had one-way mirrors and sound equipment. At the beginning of the training, all raters were trained by observing those two classrooms in its observation booth in order to exchange their ideas

and solve questions. Then, two observers were assigned to each classroom to practice and obtain practice reliability. Group members were exchanged every time to ensure that every rater was reliable with every other. At the beginning of each observation cycle, the reliability visits conducted in study classrooms. For this purpose, the groups of two observers visited three study classrooms for the first cycle, two classrooms for the second cycle and one classroom for the third cycle in order to obtain reliability.

Reliability. Reliability was calculated for the Classroom Observation of Early Mathematics - Environment and Teaching (COEMET) for each observation time. Reliability scores were based on the observations of seven observers and they were obtained during three observation periods. Reliability for the COEMET scale was calculated by percent agreement [$\text{agreement} / (\text{agreement} + \text{disagreement})$]. Observers paired off for checking the reliability and went out to the participating classrooms for collecting data as teams. The reliabilities for the COEMET scale were 84.2%, 87.1%, and 87.6%, for an average of 86.3%. Each pair of observers discussed the items on which they disagreed and made consensus ratings or codings as final data.

Observation Procedure. Observations were repeated three times across the year to complete the *Classroom Observation of Early Mathematics - Environment and Teaching (COEMET)*. The first visit was scheduled in late-mid October, 9 weeks after school began. Mid-year visits were conducted from mid January till mid February. The final visits were scheduled from Mid February till the end of March. Each observer was assigned to observe five to twelve classrooms. Also, each observer was assigned to visit different classrooms within treatment and control classes and across the two systems for each observation time. The classroom teachers were informed about the observation days

and asked to make the observation day typical in terms of the amount of math instruction children's receive.

Each observer arrived at the classroom by 7:45 and introduced him or herself to the teacher and the assistant. Observations were conducted between 8:00 a.m. and 12:00 p.m. During the visit, if the lead teacher was doing math-related activities with children, the observer focused his/her attention mainly on what the lead teacher was doing. If the teacher left the room or otherwise engaged in other activities that were not related to math, the observer focused on what the teacher's aide was doing with children. Also, children working independently were observed whenever possible.

Data Analysis

This study examined five a priori hypotheses regarding the relationship between exposure to professional development and preschool teachers' math instruction. Independent variables consist of four categories: condition (treatment and control), teacher background characteristics, structural characteristics of professional development (exposure to facilitation, exposure to workshops, and exposure to BBLT), and teacher satisfaction with the intervention (satisfaction with the BB components and satisfaction with the professional development models). Dependent variables include the teachers' reports of the implementation level of the BB components, the average number of specific math activities observed, and the overall average quality score of specific math activities.

Since teacher behaviors within each school/site may be more similar to each other than they are to teacher behaviors at other schools/sites, it was necessary to employ

multilevel modeling as the best data analysis method for this study. For this purpose, the statistical package SPSS (SPSS version 15.0 Inc., Chicago, Illinois) was chosen and two-level multilevel modeling was used. Variables specific to teachers were used at level one. Each school was given an identification number and school ID used as a second level variable. Although the nature of the data involved teachers nested within schools, with a sample size of fifty-seven teachers for the first hypothesis and with a sample size of thirty one teachers for the rest of the hypotheses, statistically significant effects could be difficult to detect. Therefore, the magnitude of effects was examined and a more generous significance level was utilized ($p > .10$).

Hypothesis Testing

1. *Pre-kindergarten teachers who have received professional development in an early childhood math curriculum will implement mathematics activities more often and with higher quality than teachers who have not had the training.* The first hypothesis involves an investigation of the effects of the TRIAD professional development program on teachers' math instruction. For Hypothesis 1, a multiple regression analysis was conducted while taking into account the fact that teachers were nested within schools. The aim of this analysis was to compare the teachers in the treatment group with the teachers in the control group in terms of the average number of specific math activities and the overall quality score of specific math activities. The teacher characteristics variable was used as a covariate in the analysis.

2. *Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development will implement mathematics activities more often and with higher quality than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure, they will be more receptive to the professional development support they received.*

Hypothesis 2 suggests that, within the group of teachers who received professional development in the TRIAD project, teachers who received more professional development would implement mathematics activities more often and with higher quality than those teachers receiving less support. Hypothesis 2 was tested using a multiple regression analysis while taking into account the fact that teachers were nested within schools. More specifically, the multiple regression analysis was used to investigate the contribution of the professional development support to the average number of specific math activities and the overall quality score of specific math activities. The teacher characteristics variable was used as a moderator.

3. *Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development support will implement more components of the curriculum than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure, they will*

implement more components of the BB curriculum. For Hypothesis 3, a multiple regression analysis was carried out in order to examine the association between the professional development treatment teachers received and their implementation level of the BB curriculum. For this analysis, classrooms were considered as nested within schools. The teacher characteristics variable was used as a moderator.

4. *Teachers' implementation of the components of a curriculum as well as quality and quantity of mathematics activities will be associated with their satisfaction with the curriculum. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure and are also satisfied with the curriculum, they will implement more components of the BB curriculum and will conduct math activities more often and with higher quality.* For Hypothesis 4, taking into account the fact that classrooms were nested within schools, a multiple regression analysis was carried out in order to examine the association between teachers' satisfaction with the curriculum and their mathematics instruction and implementation level. The teacher characteristics variable was used as a moderator.
5. *Increase in the quantity and quality of math instruction and in curriculum implementation will be associated with teachers' satisfaction with the professional development support they receive. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure and are also*

satisfied with the professional development, they will provide math instruction more often and with higher quality and implement more components of the curriculum. Hypothesis 5 implies that an increase in teachers' satisfaction with the professional development support they received will be associated with an increase in the quantity and quality of mathematics instruction they provide for their students as well as in their curriculum implementation level. In order to test the hypothesis, a multiple regression was carried out, while taking into account the fact that teachers were nested within schools/sites. While the predictor was teachers' satisfaction scores of the professional development support, the outcome variables were the average number of specific math activities, the quality score of specific math activities, and the curriculum implementation level. In addition, the teacher characteristics variable was used as a moderator.

CHAPTER IV

RESULTS

Descriptive Analyses

Classroom Observations of All Teachers

Classrooms were observed once in fall, once in winter, and once in spring. The focus of the observations was on the mathematics instruction. As described in Chapter III, the observer recorded each mathematics activity if the activity was directed by the classroom teacher or the teacher's aide, and it lasted longer than thirty seconds. Also, the observer rated the activity using a five-point Likert scale. Table 3 displays the means and standard deviations of the number of specific mathematics activities observed and the quality scores those activities received. Across fifty-seven classrooms over three time points across the school year, the mean number of mathematics activities observed was 2 (SD = 1.01) and the mean quality of mathematics activities on a 5-point scale was 3.15 (SD = .51). Note that when teachers were informed about the observation days, they were asked to make the observation days "a typical math day." The average number of math activities and the average quality score show that a typical math day for the pre-kindergarten teachers in this study consisted of only a few mathematics activities with moderate quality. One of the differences between two groups of teachers is that while all treatment teachers conducted at least one math activity, some of the control group

teachers did not provide any math related activities for their students during three observation periods.

Table 3

Descriptive Statistics for Number of Mathematics Activities and their Quality Scores Across the School Year

Source	N	Mean	Minimum	Maximum	SD
Overall					
Number of SMAs	57	2.00	.00	4.33	1.01
Quality Score for SMAs	57	3.15	1.70	4.04	.51
Treatment Group					
Number of SMAs	31	2.42	1.00	4.00	.87
Quality Score for SMAs	31	3.35	2.38	4.04	.41
Control Group					
Number of SMAs	26	1.50	.00	4.33	.95
Quality Score for SMAs	26	2.91	1.70	3.59	.52

Treatment Teachers' Report on Curriculum Implementation

During the implementation year, the teachers in the treatment classrooms were asked to report which activities they completed from among all of the activities required by the curriculum. More specifically, teachers were asked to report which whole-group, hands-on, and math-throughout-the-year activities they completed, and whether they shared newsletters with their families. There were different requirement numbers for each of these activities; in order to compare them, a proportion of completed activities was calculated for each one. For example, the curriculum required that a teacher conduct 180 whole-group activities throughout the school year. If a teacher reported that she performed 160 of those whole-group activities, a proportion of .89 was obtained for that teacher by dividing the number of whole-group activities reported having been completed by the total number of whole-group activities required by the curriculum ($160 / 180 = .89$).

Descriptive data for the proportions of teachers' implementation of the separate components of the Building Blocks curriculum are presented in Table 4. According to the teachers' reports, they implemented the family letters with the greatest fidelity and mathematics-throughout-the-year activities with the least fidelity; they reported implementing .64 of the whole-group activities and .56 of the hands-on activities.

Table 4

Descriptive Statistics for Curriculum Implementation for Treatment Teachers (N=31)

Source	Number Possible	Mean	Minimum	Maximum	SD
Overall					
Implementation of whole-group activities	180	.64	.07	.94	.28
Implementation of hands-on activities	111	.56	.07	.87	.24
Implementation of family letters	30	.85	.00	1.00	.26
Implementation of math-throughout-the-year activities	85	.36	.00	.85	.28
Public School Pre-kindergarten Teachers (N=16)					
Implementation of whole-group activities	180	.70	.37	.87	.13
Implementation of hands-on activities	111	.58	.32	.79	.14
Implementation of family letters	30	.95	.77	1.00	.06
Implementation of math-throughout-the-year activities	85	.28	.04	.64	.15
Head Start Teachers (N=15)					
Implementation of whole-group activities	180	.59	.07	.94	.38
Implementation of hands-on activities	111	.54	.07	.87	.31
Implementation of family letters	30	.75	.00	1.00	.34
Implementation of math-throughout-the-year activities	85	.45	.00	.85	.36

Treatment Teachers' Participation in Professional Development

Teachers implementing the Building Blocks Curriculum participated in professional development workshops, received in-class facilitation, and had access to online resources to assist their implementation of the curriculum. Six workshops were organized prior to the implementation year. The workshops consisted of whole-group lectures, small-group discussions and activities, computer training, and coffee and lunch breaks. Excluding the coffee and lunch breaks, as shown in Table 5, teachers averaged about 35 hours of participation in workshops.

In addition, teachers received in-class facilitation during the implementation year. The goals of the facilitation were to help teachers strengthen their professional development in mathematics as well as their understanding of the curriculum. Teachers received an average of 43 hours of facilitation. Also, teachers were encouraged to log on to online resources provided by the curriculum developers (BBLT) in order to enrich their mathematics instruction and to provide video illustrations of exemplary Building Blocks lessons. The project teachers accessed the BBLT an average of 10.1 times.

Table 5

Descriptive Statistics for Teachers' Participation in Professional Development Program

Source	N	Mean	Minimum	Maximum	SD
Hours in Workshops	31	35.34	.00	56.16	16.28
Public Schools	16	29.17	.00	48.16	17.17
Head Start	15	41.93	16.00	56.16	12.74
Hours of Facilitation	31	43.27	26.09	77.67	13.74
Public Schools	16	53.25	34.83	77.67	11.39
Head Start	15	32.62	26.09	45.46	5.48
Number of BBLT Access	31	10.06	.00	44.00	12.30
Public Schools	16	14.25	0	44.00	14.83
Head Start	15	5.60	0	25.00	6.81

Treatment Teachers' Ratings of Curriculum and Professional Development

At the end of the implementation year, the project teachers rated the curriculum and professional development support using a four-point Likert scale. Table 6 shows teachers satisfaction with the curriculum as well as the professional development support they received. Overall teachers appeared to be satisfied with each, but there was a range, making these two ratings appropriate to use in further analyses.

Table 6

Descriptive Statistics for Teacher Satisfaction with the Curriculum and Professional Development Support (N = 31)

Source	Mean	Minimum	Maximum	SD
Satisfaction with the curriculum (1-4 scale)	3.55	2.80	4.00	.34
Satisfaction with the professional development support (1-4 scale)	3.59	2.50	4.00	.43

Summary of Descriptive Results

The previous section provides descriptive data related to the quality and quantity of observed math instruction throughout the implementation year, teachers' reports on curriculum implementation, their participation in professional development, and their satisfaction level with the curriculum and the professional development. According to those findings, teachers carried out a few mathematics activities with medium ratings of effectiveness, and they reported implementing the curriculum at about a 60% rate. To achieve this level of implementation, teachers in the treatment group received 43 hours of facilitation on average and had about 35 hours of participation in workshops. They accessed online resources nearly 10 times across the school year, with wide variation in the use of this professional development medium. Teachers seemed pleased overall with both the curriculum and the program. In the next section, analysis strategies and the models to test the hypotheses are discussed.

Hypothesis Testing

Analysis Strategy

Because the data consisted of teachers nested in schools, multilevel modeling was used to analyze the data. Although the details of the analyses are discussed in Chapter III, the following section reviews the details of the models and the analyses.

In this study, a two-level model was examined to address each hypothesis. Specifically, hypotheses were tested by using a multiple regression analysis while taking into account the fact that teachers were nested within schools. Eleven models were estimated. The between-school variance was treated as a fixed effect; that is, the differences between school means were not assumed to involve sampling error. The reason is that the small number of schools in this particular study means little expectation that the results generalize statistically to a larger population of classrooms. Therefore, the statistical model, with schools as a fixed effect, does not assume that these schools are sampled from a universe to which the findings can be generalized but, rather, attempts only to describe findings for these specific schools.

In order to help readers critique the study, it is important to clearly explain the data analysis process. Specifically, there exist assumptions underlying the multilevel modeling. The following paragraphs address these assumptions. One of the assumptions of multilevel modeling is related to linearity between the outcome variables and the predictors. Linearity tests were run in order to assess linear and non-linear relationships. The test results showed that the significance values for the non-linear component were

above the critical value of .05, indicating that there was no significant non-linearity between the outcome variables and the predictors.

Another assumption is that the data need to be normally distributed. One data set related to teachers' satisfaction with the professional development support they received had a negatively skewed distribution. In order to normalize the distribution, a square root transformation was employed. First the scores were reversed by subtracting each score from the highest score obtained. Then, square roots of the values were calculated. As a final step, the scores were reversed back and coded into a new variable. This new satisfaction variable was used as a predictor in related analyses.

The data were also examined for outliers. There were no outliers in any of the variables.

Another assumption of multilevel modeling is independent errors, meaning that the residual terms should not be correlated. This assumption may be tested with the Durbin-Watson test. While it varies between 0 and 4, test results with a value closer to 2 indicate that the residuals are uncorrelated. Based on the test results, this assumption was met for the models in this study.

Independent Variable: Creating a Professional Development Analytic Variable

Prior to the main analyses, the correlations among three variables related to teachers' exposure to each professional development support (exposure to workshops, exposure to facilitation, and exposure to BBLT) were examined to determine whether the variables should be tested individually or used as a composite "total relative exposure" variable. These correlations are presented in Table 7. The test results showed a positive,

moderate, and significant correlation between teachers' access to BBLT and exposure to facilitation ($r = .58, p < .01$). A negative but not significant correlation between the exposure to workshop and the exposure to facilitation was observed. Also, the correlation of exposure to workshop with exposure to BBLT was negative but not significant. In order to condense the number of variables due to the sample size and to avoid confounding due to the inter-correlations, the variables were not tested individually. A composite *total relative exposure* variable was created. As discussed in Chapter III, each variable represents low, low-medium, medium-high, and high exposure to each type of professional development support. In order to create a composite variable, the scores across the three variables for each teacher were summed. This allowed each form of professional development to count equally towards the total professional development received. The *total relative exposure* variable was treated as a continuous variable and used as a predictor in related analyses.

Table 7

Correlations among Exposures to Different Types of Professional Development Support (N = 31)

Source	Exposure to facilitation	Exposure to workshop	Exposure to BBLT
Exposure to facilitation	-	-.24	.58***
Exposure to workshop		-	-.09
Exposure to BBLT			-

Note. *** $p < .01$, ** $p < .05$, * $p < .10$.

Treatment of Missing Data

Teachers in both groups were informed about the observation days and asked to make the observation day “a typical math day.” There were two teachers who did not conduct any math activities during three observation periods. Although they were given zero as their score for the average number of specific math activities, they could not have a score for the overall average quality score relating to the specific math activities.

Although dropping those two teachers from the study was an option, it was decided to keep them in the analyses due to the small sample size. The decision was to give them a low score that was distinctly lower than that of the lowest score among the rest of the teachers’ scores. However, this score should not be as extreme as a literal zero would be in order to avoid outliers that would skew the distribution. In order to calculate a quality score for those two teachers, the interval between the highest and next highest scores and the interval between the lowest and next lowest scores were both calculated. While the interval between the two highest scores was 0.18 ($4.04 - 3.86 = 0.18$), the interval between the two lowest scores was 0.23 ($2.22 - 1.99 = 0.23$). Thus, the average interval obtained was 0.21 ($((0.18 + 0.23) / 2 = 0.21)$). The interval between the lowest score and those two teachers’ scores should be at least that big or a little bigger than that of the average interval. Since the lowest score was 1.99, the teachers who conducted no math activities should be given a score of 1.78 ($1.99 - 0.21 = 1.78$) at most or little lower. Based on these calculations, those teachers who conducted no math activities were each given a score of 1.70 as their quality score.

Dependent Variables: Creating the Outcome Analytic Variables

The outcome variables in the models related to teachers' mathematics instruction were the average number of SMAs and the overall quality score of SMAs. Correlations between the two variables were examined. The test result showed a moderate and significant correlation between the average number of SMAs and the overall quality score of SMAs ($r = .52, p < 0.01$). However, because the two variables are conceptually distinct, separating quantity and quality of math activities, the dependent variables were analyzed separately in the analytical models.

Correlations among the proportions of teachers' implementation of each of the four curriculum components are presented in Table 8. The test results show high correlations among the proportions of the implementation levels for all components. Due to the high correlations, rather than using each implementation level separately, the proportion of overall curriculum implementation was obtained. As noted previously, the curriculum requires teachers to complete 180 whole-group activities, 111 hands-on activities, and 85 math-throughout-the-year activities. Also, it asks teachers to send 30 family letters to parents on a regular basis. Since the required number of activities for each component is different from the others, the one that requires the most is expected to make a larger contribution to the total and therefore to carry more weight in determining the overall proportion of curriculum implementation. In order to calculate the weighted overall proportion of curriculum implementation, first, the sum of all activities reported having been completed was obtained for each teacher. Then, it was divided by the total sum of all activities required by the curriculum. This variable was used as a dependent variable in related analyses.

Table 8

Pearson Correlations among Teachers' Implementation of the Curriculum Components (N = 31)

Source	Whole-group Activities	Hands-On Activities	Family Letters	Math-Throughout-the-Year Activities
Whole-group Activities	-	.91***	.85***	.78***
Hands-On Activities		-	.81***	.86***
Family Letters			-	.59***
Math-Throughout-the-Year Activities				-

Note. *** $p < .01$, ** $p < .05$, * $p < .10$.

Centering the Moderator Variables and Predictors

In order to properly test interactions with the moderator variables, it was necessary to center the variables including predictors and moderators prior to running analyses. Therefore, the teacher characteristics, exposure to professional development, and teachers' satisfaction variables were centered so that the mean of these variables became zero. First, the overall mean values were obtained for each variable. Then, a new variable for each was computed by subtracting the original value from its mean. This transformation does not affect the original shape of the distribution.

Final Analytic Model

For eleven multilevel models that were used to test all five hypotheses, multiple outcomes and predictors were employed, depending on the hypothesis and model. Overall, outcomes included the average number of specific math activities, the overall quality score of specific math activities, and the overall curriculum implementation level. Final predictors were the total relative exposure to professional development, satisfaction with the curriculum, and satisfaction with the professional development program. Also included were the variables for the school system and teacher characteristics. While the system was used as a blocking factor in the first model examining the effect of participation in professional development on teachers' mathematics instruction, it was not included in the other models. On the other hand, the teacher characteristics were used as a covariate for Hypothesis 1 and as a moderator for the rest of the hypotheses. Covariates were included to control for specific factors in order to improve the precision of the model.

Examining the Effect of Participation in Professional Development on Math Instruction: Control Group vs. Treatment Group

Of fifty-seven teachers, thirty-one were assigned to receive professional development support. The rest of the teachers were in the control group. In this section, the effect of participation in a professional development program on the quantity and quality of mathematics instruction is examined.

Hypothesis 1. Pre-kindergarten teachers who have received professional development in an early childhood math curriculum will implement mathematics activities more often and with higher quality than teachers who have not had the training.

The hypothesis examines the curriculum condition differences (i.e., treatment group vs. control group) in terms of quality and quantity of math activities. The outcome variables were 1) the average number of specific math activities and 2) the overall quality score of specific math activities. The predictor for this model was the group to which teachers had been assigned. Since the analysis involves comparison of the randomized conditions and randomization was done separately within each system (i.e., public schools pre-kindergarten programs administered by an urban school system and local Head Start administered by a metropolitan non-profit agency), it was a blocked design with system as a blocking factor. Therefore, system was included in the model as a blocking factor. The teacher characteristics variable² was treated as a covariate in the analysis. All fifty-seven teachers were treated as nested within the schools or sites.

Table 9 provides the fixed effects estimates for the examination of the relationship between professional development participation and quantity of math activities. In this model, the regression coefficient associated with condition indicates that the teachers who received professional development support with emphasis on math instruction conducted math activities more often than those teachers who were in the comparison group. In order to describe the magnitude of the effect of condition, standardized mean difference was constructed by dividing the differences between the treatment group and the control group by between classroom standard deviation. An effect size of 1.25

² The *teacher characteristics* variable represents teacher's educational background, teaching experience, and licensing status. The variable is in an ordinal sequence from less to more. For more information, see Chapter III.

indicates that the mean of the treatment group is at the 90th percentile of the control group.

As noted previously, the schools/sites were nested within two types of programs. The regression coefficient for the system shows that the pre-kindergarten public school teachers completed math activities more often than the Head Start teachers did. The coefficient associated with teacher demographic characteristics was not significant, meaning that teacher characteristics were not related to the quantity of teachers' mathematics activities.

Hypothesis 1 is supported for the average number of specific math activities. Teachers who received professional development in mathematics instruction carried out more mathematics related instructional activities in their classrooms than the teachers who did not have such support.

Table 9

Results for the Influence of Condition on Average Number of Specific Math Activities (N = 57)

Fixed Effect	Coefficient β	SE	p-value
Condition:			
Treatment = 1	-1.02	.38	.020
Control = 0			
System:			
Public schools = 1	-1.11	.29	.003
Head Start = 0			
Teacher characteristics	-.07	.15	.658

Table 10 provides the fixed effects estimates for the examination of the relationship between professional development support and quality of math activities. The regression coefficient associated with condition indicates that the mathematics activities provided by the teachers who received professional development support with emphasis on math instruction were of a higher quality than that provided by the comparison teachers. An effect size of 1.21 indicates that the mean of the treatment group is at the 88th percentile of the control group.

In addition, the regression coefficient for system shows that public school pre-kindergarten teachers provided math activities whose quality was higher than the activities carried out by the Head Start teachers. The coefficient for teacher demographic characteristics was not significant.

Hypothesis 1 is also supported in predicting an increase in the overall quality of specific math activities provided by teachers who have professional development related to mathematics instruction.

Table 10

Results for the Influence of the Condition on the Quality Score of Specific Math Activities

Fixed Effect	Coefficient β	SE	p-value
Condition:	-.55	.11	.000
Treatment = 1			
Control = 0			
System:	-.66	.14	.000
Public schools = 1			
Head Start = 0			
Teacher characteristics	-.09	.07	.209

In sum, Hypothesis 1, stating that pre-kindergarten teachers who received professional development support in an early childhood math curriculum would implement mathematics activities more often and with higher quality than teachers who did not have the training, was supported. Moreover, the results showed that disparities between the two types of programs in terms of their teachers' mathematics instruction. The preschool teachers in public schools pre-kindergarten classrooms provided math instruction more often and with higher quality for their students than Head Start teachers did in theirs. Teacher characteristics contribute to either the quality or quantity of teachers' mathematics instruction.

Examining the Effect of Professional Development Exposure within the Treatment Group

Although the first hypothesis dealt with both the control and treatment groups, the following analyses focus only on the treatment group and examine the effect of

professional development on the quality and quantity of mathematics instruction as well as teachers' curriculum implementation.

Hypothesis 2. Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development will implement mathematics activities more often and with higher quality than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure, they will be more receptive to the professional development support they received.

In Hypothesis 2, the teachers were considered as nested within the schools or sites. The outcome variables were 1) the average number of specific math activities and 2) the overall quality score of specific math activities. The predictor for this model was teachers' total relative exposure to professional development. The teacher characteristics were used as a moderator in the model. In other words, the interaction effects between the exposure to professional development and teacher characteristics was examined. In the models, the variables involved in the interaction were included separately as main effects plus the interaction.

Results of the first analysis examining the quantity of math activities are displayed in Table 11. In this model, after controlling for teacher characteristics, the regression coefficient associated with main effect of teachers' exposure to professional development was not significant. Thus teachers who received more professional development support were not significantly different from the teachers who received less

professional development support in terms of the quantity of mathematics activities they conducted in their classrooms. In addition, the coefficient associated with the interaction effect of teacher characteristics and exposure to professional development was not significant. Hypothesis 2 was not supported for the average number of specific math activities for the treatment group.

Table 11

Results for the Influence of Exposure to Professional Development on the Average Number of Specific Math Activities (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Main effect of exposure to professional development	.04	.07	.600
Main effect of teacher characteristics	-.10	.19	.613
Interaction effect of teacher characteristics and exposure to professional development	.01	.08	.942

Results of the second analysis that examined the quality of math activities are displayed in Table 12. In this model, the coefficient associated with teachers' exposure to professional development was not significant, which means that within the treatment group the total amount of professional development support was not significantly related to the quality of mathematics activities they provided for their students. In addition, the coefficient associated with the interaction effect of teacher characteristics and exposure to professional development was not significant. Hypothesis 2 was not supported for the overall quality score of specific math activities.

Table 12

Results for the Influence of Exposure to Professional Development on the Quality Score of Specific Math Activities (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Main effect of exposure to professional development	.01	.04	.746
Main effect of teacher characteristics	.03	.09	.729
Interaction effect of teacher characteristics and exposure to professional development	-.02	.04	.709

In sum, total relative exposure to professional development was not a significant predictor of either the quality or quantity of math instruction that teachers provided for their students. Nor were teacher characteristics a moderator of the effects.

Therefore, Hypothesis 2, stating that teachers who received more professional development support would implement mathematics activities more often and with higher quality than those teachers who received less professional development support and that teacher characteristics would be a moderator of such effects, was not supported.

Hypothesis 3. Within the group of teachers who received professional development in an early math curriculum, teachers who received more professional development support will implement more components of the curriculum than those teachers who received less professional development. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational

background, more teaching experience, and teaching licensure, they will implement more components of the BB curriculum.

This hypothesis focuses on implementation of the Building Blocks curriculum components; curriculum implementation is a separate issue from specific math instruction activities tested in the previous hypothesis. Again in this analysis, teachers were considered nested within schools/sites. The outcome variable for this model was the curriculum implementation proportion score. The predictor was teachers' total relative exposure to professional development. The teacher characteristics were used as a moderator in the model. In other words, the interaction effects between the exposure to professional development and teacher characteristics was examined. In the models, the variables involved in the interaction were included separately as main effects plus the interaction.

Results of the analysis that examined the curriculum implementation level are displayed in Table 13. For this model, the coefficient for teachers' exposure to professional development was not significant. This means that the curriculum implementation proportions for teachers who received more professional development support were not different from the ones for the teachers who received less support. In this analysis, however, the coefficient for the interaction effect of teacher characteristics and exposure to professional development was significant, meaning that curriculum implementation was predicted by a combination of teacher characteristics and amount of professional development.

Table 13

Results for the Influence of Exposure to Professional Development on the Curriculum Implementation Level (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Main effect of exposure to professional development	-.01	.01	.431
Main effect of teacher characteristics	-.01	.03	.633
Interaction effect of teacher characteristics and exposure to professional development	-.02	.01	.055

It is important to examine what moderating effects teacher characteristics and exposure to professional development have on curriculum implementation level. Thus, Figure 1 was created to graphically demonstrate the interaction between curriculum implementation level and exposure to professional development in the presence of teacher characteristics. While the blue line represents teacher characteristics below the median, the green line stands for the teacher characteristics above the median. Within the group of teachers who were less exposed to professional development, teachers with stronger backgrounds implemented the curriculum with greater fidelity than the teachers with weaker backgrounds. However, greater professional development appeared to diminish the implementation of the teachers with stronger backgrounds. In addition, the graph suggests that teachers with weaker backgrounds implemented the curriculum at the same rate as those teachers with stronger backgrounds when they were more exposed to professional development.

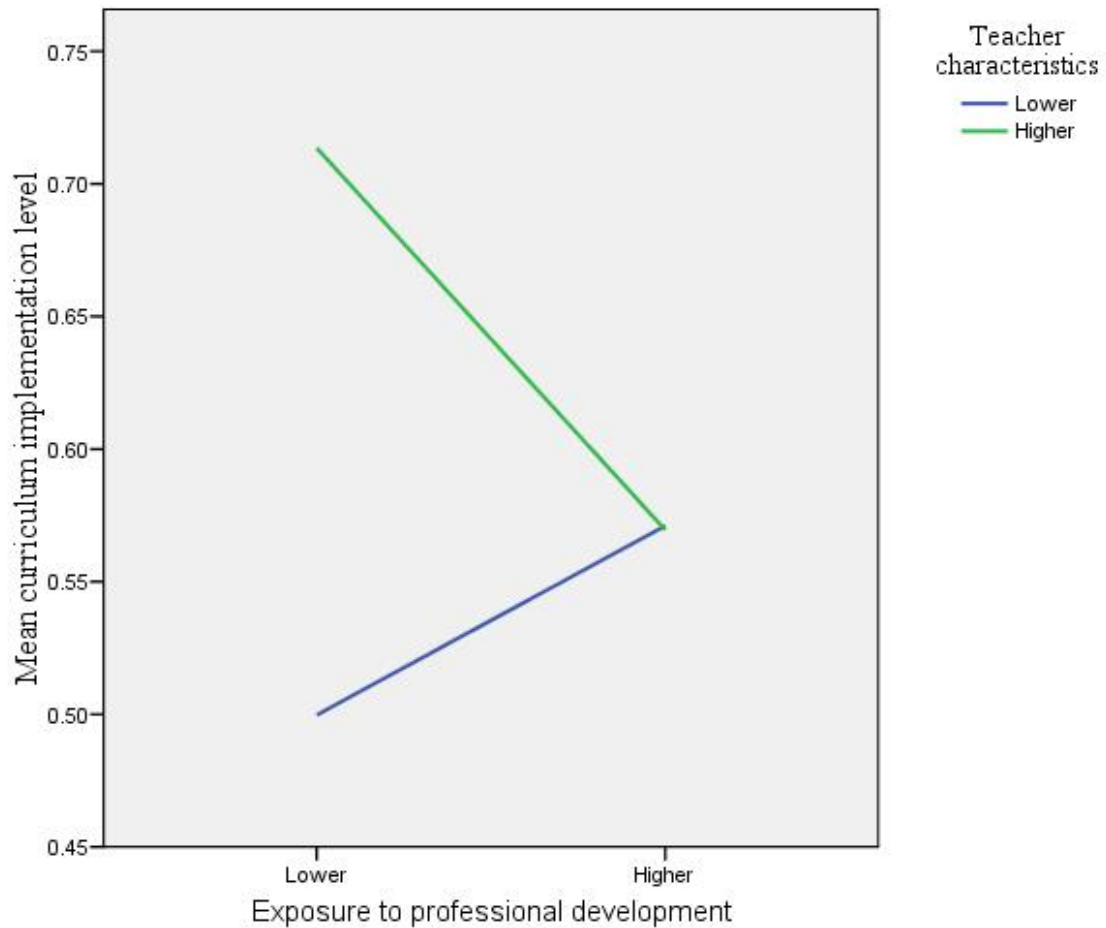


Figure 1. Interaction graph for exposure to professional development and teacher characteristics

In short, Hypothesis 3, stating that in general teachers who received more professional development support would implement curriculum components more than those teachers who received less professional development support and that teacher characteristics would be a moderator of such effects, was partially supported.

Examining the Effect of Teachers' Satisfaction with Curriculum and Professional Development

As noted in Chapter III, the treatment teachers were asked to evaluate the effectiveness of the BB components on student's mathematical understanding and the effectiveness of professional development models on their instruction. They used a four-point Likert scale to evaluate both. The first part of this section examines the association between teachers' satisfaction with the curriculum and their implementation level as well as their mathematics instruction. The latter part deals with the relationship between teachers' satisfaction with the professional development program and the quality and quantity of mathematics instruction they provided for their students and their curriculum implementation level.

Hypothesis 4. Teachers' implementation of the components of a curriculum as well as quality and quantity of mathematics activities will be associated with their satisfaction with the curriculum. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure and are also satisfied with the curriculum, they will implement more components of the BB curriculum and will conduct math activities more often and with higher quality.

For this model, the teachers were considered nested within schools/sites. The outcome variables were 1) the average number of specific math activities, 2) the overall quality score of specific math activities, and 3) the curriculum implementation level. The predictor was teachers' satisfaction with the curriculum. Also, the teacher characteristics

variable was used as a moderator. In other words, the interaction effects between the teachers' satisfaction with the curriculum and teacher characteristics was examined. In the models, the variables involved in the interaction were included separately as main effects plus the interaction.

Table 14 provides the fixed effects estimates for this model. The main effects of teacher satisfaction with the curriculum on the quantity and quality of mathematics activities were not significant. Nor were teacher characteristics a moderator of the effects.

On the other hand, the coefficient for the main effect of teachers' satisfaction with the curriculum was statistically significant in terms of teachers' curriculum implementation level. The coefficient of .16 indicates that, while holding other variables constant, for every one-unit increase in teachers' satisfaction with the curriculum, the curriculum implementation level increases by .16. Also, the coefficient for the interaction effect of teacher characteristics and teachers' satisfaction with the curriculum on teachers' curriculum implementation level was significant. The coefficient of .09 indicates that, curriculum implementation level increases as teachers' satisfaction with the curriculum increases in the presence of teachers' characteristics.

Table 14

Results for the Effects of Teacher Satisfaction with the Curriculum on the Average Number of Specific Math Activities, Quality Score of Specific Math Activities, and Curriculum Implementation Level (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Average number of specific math activities			
Main effect of teachers' satisfaction with the curriculum	.20	.40	.619
Main effect of teacher characteristics	-.11	.18	.522
Interaction effect of teacher characteristics and teachers' satisfaction with the curriculum	.03	.35	.926
Quality scores of specific math activities			
Main effect of teachers' satisfaction with the curriculum	.22	.22	.315
Main effect of teacher characteristics	.03	.09	.775
Interaction effect of teacher characteristics and teachers' satisfaction with the curriculum	-.21	.19	.271
Curriculum implementation level			
Main effect of teachers' satisfaction with the curriculum	.16	.05	.008
Main effect of teacher characteristics	.00	.03	.958
Interaction effect of teacher characteristics and teachers' satisfaction with the curriculum	.09	.05	.079

It is important to examine the effects of teacher background characteristics on the nature of their satisfaction with the curriculum and curriculum implementation level. Thus, Figure 2 was created to graphically demonstrate the interaction between curriculum implementation level and teacher satisfaction with the curriculum in the presence of teacher characteristics. While the blue line represents teacher characteristics below the median, the green line stands for the teacher characteristics above the median. Figure 2 indicates a positive linear pattern. The combination of higher teacher characteristics and higher satisfaction with the curriculum resulted in greater implementation than lower teacher characteristics and lower satisfaction with curriculum. For lower teacher satisfaction, higher teacher characteristics resulted in somewhat greater implementation than weaker teacher backgrounds.

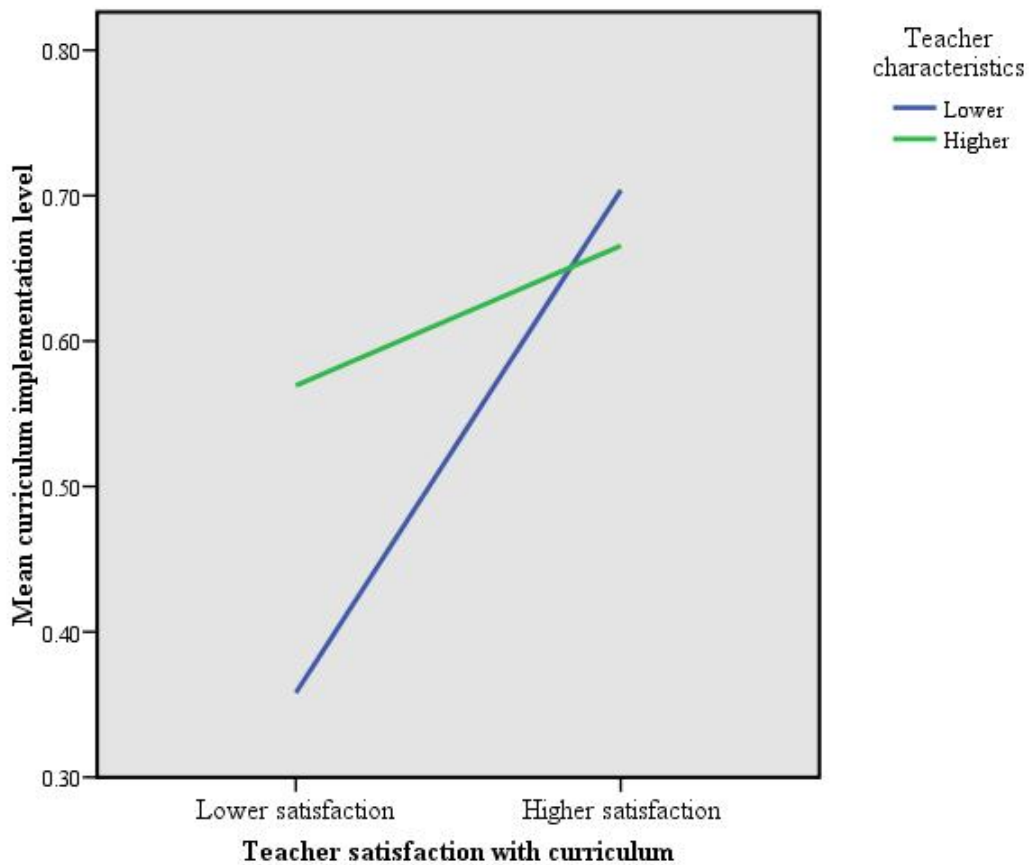


Figure 2. Interaction graph for teacher satisfaction with the curriculum and teacher characteristics

These results suggest that a strong contributor to how much these teachers implemented the curriculum was the degree to which they liked the curriculum and were satisfied with it. In addition, these results suggest that for these teachers, it was more important for implementation for teachers with weaker backgrounds to like it. In short, Hypothesis 4, stating that teacher satisfaction with the curriculum would be associated with the quantity and quality of mathematics activities and curriculum implementation level, and teacher characteristics would be a moderator of such effects, was supported for

proportion of curriculum activities implemented but not for the quantity or quality of their math instruction.

Hypothesis 5: Increase in the quantity and quality of math instruction and in curriculum implementation will be associated with teachers' satisfaction with professional development support they receive. Moreover, teacher characteristics will be a moderator of the effects, such that if teachers have higher educational background, more teaching experience, and teaching licensure and are also satisfied with the professional development, they will provide math instruction more often and with higher quality and implement more components of the curriculum.

For this model, the outcome variables were 1) the average number of specific math activities, 2) the overall quality score of specific math activities, and 3) the curriculum implementation level. The predictor was teachers' satisfaction with the professional development program. Also, the teacher characteristics variable was used as a moderator. In other words, the interaction effects between the teachers' satisfaction with the curriculum and teacher characteristics were examined. In the models, the variables involved in the interaction were included separately as main effects plus the interaction.

Results of the analysis that examined the average number of specific math activities, the quality score of specific math activities, and curriculum implementation level are displayed in Table 15. For this model, the coefficients for the main effect of teachers' satisfaction with the professional development program were not significant for any of the outcomes. Also, the coefficients for the interaction effects of teacher

characteristics and teachers' satisfaction with the professional development for all outcomes were not significant.

In sum, Hypothesis 5, stating that teachers' quantity and quality of mathematics instruction and curriculum implementation level would be associated with their satisfaction with the professional development and teacher characteristics would be a moderator of such effects, was not supported.

Table 15

Results for the Effects of Teacher Satisfaction with the Professional Development on the Average Number of Specific Math Activities, Quality Score of Specific Math Activities, and Curriculum Implementation Level (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Average number of specific math activities			
Main effect of teachers' satisfaction with the professional development	.45	.31	.162
Main effect of teacher characteristics	-.12	.17	.475
Interaction effect of teacher characteristics and teachers' satisfaction with the professional development	.38	.30	.216
Quality scores of specific math activities			
Main effect of teachers' satisfaction with the professional development	.12	.18	.507
Main effect of teacher characteristics	.05	.09	.607
Interaction effect of teacher characteristics and teachers' satisfaction with the professional development	-.13	.18	.479
Curriculum implementation level			
Main effect of teachers' satisfaction with the professional development	.07	.05	.184
Main effect of teacher characteristics	.01	.03	.761
Interaction effect of teacher characteristics and teachers' satisfaction with the professional development	.05	.05	.330

Secondary Analyses

Individual Contribution of Professional Development Models

Although the total relative exposure to professional development was not a significant predictor of quality and quantity of mathematics instruction and curriculum implementation level, it is informative to examine what each professional development type (i.e., workshops, facilitation, and online support) contributed individually relative to the others. There were compensatory relationships among the professional development types as demonstrated by the negative correlations between participation in workshops and facilitation as well as between participation in workshops and access to BBLT. To investigate the components of professional development individually, three models were estimated. The outcomes were 1) the average number of specific math activities, 2) the overall quality score of specific math activities, and 3) the curriculum implementation level. The predictors were 1) exposure to workshops, 2) exposure to facilitation, and 3) exposure to BBLT. The covariate used in these models was the teacher characteristics variable (educational background, experience, and licensure status). The teachers were considered nested within schools/sites.

Results of the analysis that examined the average number of SMAs are displayed in Table 16. For this model, after controlling for the others, the coefficient for the exposure to workshops was negatively significant. The negative coefficient indicates that one-unit increase in teachers' participation in workshops results in decrease in the average number of specific math activities by .30. On the other hand, the coefficient for the exposure to facilitation was positive and significant. The interpretation of the positive

coefficient is that for every one-unit increase in teachers' exposure to facilitation, the average number of specific math activities increases by .39. Also, the coefficient for the exposure to BBLT was positively significant. The positive and significant coefficient means that for every one-unit increase in teachers' exposure to BBLT, the average number of specific math activities increases by .25. The main effect of teacher characteristics was not significant for the number of specific math activities.

In addition, the effects of exposure to professional development models were examined for quality of math instruction and curriculum implementation level. The coefficients for the exposure to workshops, facilitation, and BBLT were not significant for the quality score of specific math instruction and curriculum implementation level. Nor were an interaction effect of teacher characteristics.

Table 16

Results for the Influence of Professional Development Models on the Average Number of Specific Math Activities, Quality Score of Specific Math Activities, and Curriculum Implementation Level (N = 31)

Fixed Effect	Coefficient β	SE	p-value
Average number of specific math activities			
Main effect of exposure to workshops	-.30	.12	.019
Main effect of exposure to facilitation	.39	.17	.030
Main effect of exposure to BBLT	.25	.13	.060
Main effect of teacher characteristics	-.26	.19	.183
Quality scores of specific math activities			
Main effect of exposure to workshops	.04	.07	.600
Main effect of exposure to facilitation	-.03	.10	.787
Main effect of exposure to BBLT	.05	.08	.515
Main effect of teacher characteristics	.08	.12	.520

Table 16, continued

Results for the Influence of Professional Development Models

Fixed Effect	Coefficient β	SE	p-value
Curriculum implementation level			
Main effect of exposure to workshops	.01	.02	.833
Main effect of exposure to facilitation	.02	.03	.603
Main effect of exposure to BBLT	-.02	.02	.512
Main effect of teacher characteristics	.00	.04	.991

In sum, the contribution of each professional development model on quantity and quality of math instruction and teachers' curriculum implementation level was examined. The results indicated that more exposure to facilitation and online support positively influenced the number of specific math activities teachers carried out in their classrooms. On the other hand, there was a negative and significant relationship between exposure to workshops and the average number of specific math activities, indicating that as teachers participated in workshops more, the average number of math activities they conducted in their classrooms decreased. But, oddly enough, the results showed that the three different professional development models (i.e., workshops, facilitation, and BBLT online) influenced neither the quality of teachers' mathematics instruction nor their level of curriculum implementation.

CHAPTER V

SUMMARY, DISCUSSION, AND CONCLUSIONS

This study examined the effects of a professional development program on teachers' mathematics instruction under three broad aspects. First, the study looked at the effect of participation in the TRIAD professional development program on teachers' mathematics instruction implementing a pre-kindergarten mathematics curriculum and compared their instructional behaviors to control teachers teaching as they usually did. Second, the study examined the effects of varying amounts of exposure to professional development on the treatment teachers' mathematics instruction as well as their curriculum implementation. Third, this study sought to examine the association between the treatment teachers' satisfaction with the curriculum and with professional development and their mathematics instruction. This chapter provides a summary of the analytical results, a discussion about the implications of the findings, and a depiction of the strengths and limitations of the study³.

³ Note that due to the small number of classrooms, test coefficients that would be considered statistically significant at the often-used criteria of .05 or .01 were not expected. Rather, p-values at or below 0.10 were considered to indicate relationships that should be explored further in a larger study.

Summary of Results

The Effect on Instruction of Participation in Professional Development on Mathematics

The first hypothesis focused on the effect of a professional development program (TRIAD) on preschool teachers' mathematics instruction. The hypothesis predicted that participation in an intensive program of professional development focused on a pre-kindergarten mathematics curriculum would result in increased quantity and quality of mathematics instruction for teachers who participated compared to a randomly assigned control group of teachers engaged in their usual practices. This hypothesis was confirmed for both the quality and quantity of mathematics instruction. When pre-kindergarten teachers were provided instruction in the mathematics areas young children need to develop and the quality with which they should be taught, both the quantity and quality of their mathematics instruction increased significantly. Given the documentation of how little math instruction occurs in early childhood classrooms, but how important skill in mathematics is for later achievement, this is an important finding.

The Effect of Exposure to Professional Development within the Treatment Group

Given the group differences in instruction as a function of participation in the TRIAD training, the next two hypotheses dealt with the contributions of the degree of exposure to the professional development activities of TRIAD (i.e., from low to high) to teachers' mathematics instruction as well as their curriculum implementation level. Two hypotheses pertaining to exposure to the professional development program on three outcomes of math instruction were tested. Neither of the hypotheses was. In other words,

the results showed that greater amounts of exposure to professional development were not associated with the quantity or the quality of mathematics activities. Nor was the amount of professional development related to the curriculum implementation level. However, as will be explored later, it should be remembered that for the test of these hypotheses all professional development activities were combined into one variable. It turns out that not all professional development activities were equivalent in their effects. Combining them may have contributed to the lack of positive results on these two hypotheses.

In addition, for these two hypotheses, it was conjectured that teacher background characteristics would moderate the relationship between exposure to professional development and mathematics instruction as well as the relationship between the exposure to professional development and the curriculum implementation. More experienced and educated teachers were predicted to be more receptive to the curriculum training. The findings showed that teacher characteristics did not have a significant impact on the relationship between exposure to professional development and quality and quantity of mathematics instruction. However, the results demonstrated that greater professional development appeared to lessen the curriculum implementation of the teachers with stronger backgrounds.

The Effect of Teachers' Satisfaction with Curriculum and Professional Development

The last two hypotheses pertained to the association between teacher satisfaction with the curriculum and the professional development they received and their mathematics instruction. They also examined the possible moderating effects of teacher

characteristics. The first hypothesis focused on the relationship between teachers' satisfaction with the curriculum and their mathematics instruction as well as curriculum implementation level. Although teacher satisfaction with the curriculum was not related to the quality and quantity of their mathematics instruction, teachers who were more satisfied with the curriculum implemented more components of the curriculum than the teachers who were less satisfied with it. Also, teacher characteristics moderated the relationship between teacher satisfaction and curriculum implementation level such that teachers with higher levels of education and experience implemented more of the curriculum when they personally liked the curriculum.

The second hypothesis related to teachers' satisfaction with the professional development support and the quality and quantity of mathematics instruction and curriculum implementation and was not confirmed. Teachers' satisfaction with the professional development they received did not predict their instruction or their implementation of the curriculum.

Summary of Secondary Analyses

Although the total relative exposure to professional development was not a significant predictor of quality and quantity of mathematics instruction and curriculum implementation level, as mentioned earlier, the variable used in the analyses was a composite one. With only 31 teachers in the treatment group, it was important to reduce the number of variables in the analyses, hence the creation of composite variables for both professional development types and for teacher background factors. But it is important to examine what each professional development type (i.e., workshops,

facilitation, and online support) contributed individually to teacher mathematics instruction and curriculum implementation. This secondary analysis demonstrated non-significant but negative relationships among the three types of professional development offered in this study. Greater participation in workshops was negatively correlated with the amount of facilitation a teacher received and with participating in the online BBLT. The negative correlations could indicate “compensation;” teachers who could not attend the workshops could have been more motivated to examine the materials online. Coaches would certainly have spent more time with teachers who did not get the basic training.

To explore the contribution of each of the professional development components relative to the others, a secondary analysis examined the relationship of each with teachers’ math instruction as well as their curriculum implementation. The results indicated that more exposure to *in-classroom facilitation* positively influenced the number of specific math activities teachers carried out ($r = .39, p < .030$). In addition more participation in the *online support (BBLT)* was positively related to enacting more mathematics activities ($r = .25, p < .060$). In contrast, a negative and significant correlation was found between exposure to workshops and the average number of specific math activities teachers carried out ($r = -.30, p < .019$). This relationship indicated that as teachers participated more in workshops, the average number of math activities they conducted in their classrooms decreased.

The results did not demonstrate any significant differential contribution of exposure to the three different professional development models (i.e., workshops,

facilitation, and BBLT online) on teachers' quality of mathematics instruction or their level of curriculum implementation.

Discussion

The results of this study highlighted a number of important points to explore further. The first point of discussion is professional development and the impact of attendance at the TRIAD project on preschool teachers' mathematics instruction. The second point deals with the individual contributions of each professional development component. The next point concerns the impacts of colleagues from a single school/site on the effectiveness of the professional development program. The next point is related to teachers' satisfaction and its impact on their instruction. The last point focuses on the impact of teacher characteristics on mathematics instruction.

Attendance at the TRIAD project

At first glance, the central finding of this study corresponds to the findings of the other studies examining whether or not teacher attendance at a professional development program affected their instruction (see Bruce & Rose, 2008; Ponticell, Olson & Charlier, 1995). This work demonstrates a strong and significant relationship between professional development and teachers' mathematics instruction. More specifically, participation in a professional development program that is a combination of content-specific workshops, mentoring, and online support proved to be effective in increasing the amount and quality of mathematics instruction that preschool teachers provided for their students, compared with the teachers who did not participate in such program.

Although it was expected to see a further relationship between the quantity and quality of instruction and deeper and more sustained professional development for teachers (Supovitz & Turner, 2000), the findings of this study did not confirm this expectation. In this study, wide variation in teachers' exposure to different types of professional development allowed an examination of whether more exposure to professional development in general resulted in math activities occurring more often and with higher quality in preschool classrooms. Simply, more exposure to professional development was not related to the degree of teacher implementation or their enactment of mathematics instruction. In other words, teacher classroom behaviors of those who received more professional development were not different from those in the training group who received less professional development support. But it turns out that the type of professional development helps explain this general finding.

Individual Contributions of Professional Development Components

Workshop participation, common to many professional development programs, was negatively correlated with the number of mathematics activities teachers conducted in their classrooms. One possible explanation for this unexpected finding is that workshops might not help the teachers transfer the new knowledge they were taught during the workshops to their classroom practices, something Wolfe and Snyder also found (Wolfe & Snyder, 1997). Such action requires new knowledge to be integrated with previous knowledge, beliefs, and skills. Because of their context, workshops were group-focused and did not target each teacher's knowledge, beliefs, and skills (Lieber et al., 2009); thus, workshops might not be able to help teachers identify and resolve

contradictions between their existing knowledge and newly learned knowledge. This may have implications for professional development providers. Workshops are appealing because they are efficient and cheaper. However, to achieve classroom results, trainers may need to focus more on the ways to make effective connections with the workshop content and teachers' classroom practices.

Another possibility is related to the way the workshops were set up. In designing workshops, it is critical to organize them in a way that engages teachers in mathematical experiences that are similar to the ones that the professional development designers expect from the participating teachers to provide for their students. The TRIAD workshops were organized for adult learners (Bransford et al., 1999). For instance, during the small group discussions, the TRIAD team elicited teachers' understanding of teaching and learning mathematics by using a range of question types to challenge their thinking and by encouraging them to explain their reasoning. This type of learning environment was like that expected from the treatment teachers in their classrooms while teaching mathematics. Despite the TRIAD team's best effort to organize the workshops for adult learners and the teachers' expressed satisfaction with the workshop format and content, it was possible that the workshops might have not sufficiently communicated with the teachers to make connections with their own classroom practices.

Ratings of workshops at the end may not provide enough evidence to determine their effectiveness; teachers provided high ratings but no measures were taken to ascertain whether the workshops had been successful in the ways the developers intended. One possibility to explore in the future is the construction of summative measures in order to determine whether teachers actually learned the goals of the

workshops. These sorts of measures are difficult to construct and require the providers of workshops to be more precise about the goals than they may be accustomed to. Teachers also are unused to being quizzed on the specific content they were to gain from workshops. Going in this direction would be a change for both providers and participants, but could yield more information about workshop effectiveness than is currently available.

In addition, providers could try to make their workshops more directly related to the participants' needs right from the outset. More specifically, the providers could design a test that allows them to discover the important aspects of teaching and learning mathematics with which teachers need help and to re-organize the context of the workshops based on such needs. Another way is to ask participants to give advice about the better approaches to provide professional development support. In other words, it might be helpful to provide the teachers with an opportunity to have more control over their own development and to assess the workshops for their effectiveness in doing so.

Also, future research should examine the ways to increase teachers' interest in participating in professional development. Not unlike what happens in many school systems and Head Start agencies, the group of Head Start teachers in this study was required to participate in the workshops by their agency; attendance was taken. If teachers had not attended, they would have had to take a personal leave day. These are the same teachers who did not seek one-on-one facilitation or online support as much as the other teachers. Moreover, these teachers conducted fewer math activities with lower quality. While the public school pre-kindergarten teachers were also required to attend the workshops, in fact, they had more discretion about choosing not to. Head Start

teachers work more days during the year than public school teachers. Some workshops occurred during times of optional professional leave days for the public school teachers, something not available to Head Start teachers. The public school teachers appeared to feel more control over their participation in all components of the professional development offered.

Combining these two groups of teachers who work with similar children but in very different professional contexts may not have been wise. Specifically it might be worth considering the creation of school-based mathematics education communities. While taking into account the institutional context, it would be important to examine ways to build communities of teachers as learners, and in particular, to build trust among participants within these communities. However, it is important to keep in mind that creating an education community does not mean that dramatic changes would occur in those teachers' instruction. Therefore, it is critical to continue providing follow-up support for the teachers within the communities.

Another important finding of this study is related to the non-significant effects of facilitation and online support on the quality of mathematics instruction. Note that the treatment group conducted math activities more often and with higher quality than the teachers in the control group. However, when examining the individual contributions of each professional development types on the quantity and quality of mathematics instruction, the results showed that while receiving more facilitation and online support resulted in increase in the amount of mathematics activities, more exposure to those professional development types did not influence the quality. Such finding might be because of the compensatory relationships among the professional development types. If

teachers did not participate in a workshop, they received more facilitation. Also, those teachers received more encouragement to log on to the website to get online support.

In addition, during the meetings of the project staff with the facilitators, a certain amount of time was spent on discussions about what had been observed in the treatment classrooms. The facilitators were informed about specific issues related to treatment teachers' mathematics instruction such as a lack of inferential questions, lack of content knowledge, and so on. Also, when necessary, the facilitators were given names of teachers who seemed to need more facilitation. As a result, it appears that teachers with weakest knowledge, skills, and attitude might have received professional development support, especially facilitation and online support, the most. These forms of professional development might have helped those teachers to increase the quantity of math instruction; however, these efforts were not associated with differences among the teachers in the quality of their instruction.

Moreover, although the facilitators were encouraged to focus on how to provide high quality math instruction as they met with their teachers, there were no data showing what happened during the facilitation time. In regard to the findings, it could be suggested that increasing the quality of instruction should be the primary goal of the coaches. Specifically, coaches could focus on how to create a classroom environment that does not limit any child's access to challenging mathematics instruction, how to enhance classroom discourse, how to choose materials/tasks to increase students' motivation, and how to assess children to obtain information about students' skills and potential. After ensuring that teachers developed understanding of how to provide excellent math activities and transferred it into their practice, then, coaches could focus more on

increasing the quantity of mathematics activities. In this study, the quality of instruction for treatment teachers was higher than control teachers, but it still averaged only in the mid range. There was room for improvement.

Also, there might be mentor-related factors that influenced the effectiveness of facilitation. There were four facilitators who worked with the treatment teachers in this study – two facilitators for Head Start teachers and two facilitators for public school pre-kindergarten teachers. Each facilitator provided different amounts of facilitation for their teachers. One of the Head Start facilitators reported an average of 30.8 hour-facilitation per teacher and the other reported 33.8 hours of facilitation. On the other hand, one of the public school facilitators provided 50.3 hours of facilitation and the other one provided 55.5 hours of facilitation for each of their teachers. Perhaps as a consequence there were differences among the teachers in terms of the number of mathematics activities they provided for their students, qualities of those activities, and their curriculum implementation. Note that there were no significant effects of facilitation and online support on the quality of mathematics instruction and curriculum implementation; however, it might be informative to examine the groups of teachers who received the least/most amount of facilitation in terms of the quantity and quality of math instruction they provided for their students and their implementation level. Specifically, while teachers who received the least facilitation conducted an average of 1.5 math activities with an average quality score of 3.29, teachers who received the most facilitation conducted an average of 3.3 math activities with an average quality score of 3.68. Also, while teachers who received the least facilitation implemented 15% of the curriculum components, teachers who received the most facilitation completed 60% of the

curriculum components. Because of facilitators' assignment to schools/sites, further examination could not be completed; otherwise, the results would be misleading because of the factors such as system/school differences. Thus, future research should focus on understanding mentor-related factors as support or barrier during professional development.

Certain patterns in teachers' use of the online resource BBLT also have implications for further work. Although the project teachers chose to access the BBLT an average of 10 times throughout the implementation year, there was a considerable range in their usage levels. While six teachers never logged on to the website, other teachers accessed it as much as 44 times across the school year. Differential usage could have been due to differences in motivation and interest in the curriculum, but usage could also have been related to how comfortable teachers felt with technology. As more information is put online for teachers, significant research is needed to ensure that all teachers benefit from online resources as much as others who have more technological skills.

Different access could also be related to characteristics of the website itself, in other words, how rewarding it was for teachers when they first logged on. For instance, Downer and colleagues (Downer et al., 2009) have suggested that regularly updated websites with more interactive opportunities and new video-clips of teachers employing curriculum activities would ensure more consistent and long-term usage. Also, it would be helpful to allow interactions between the participating teachers and the providers through e-mails, discussion boards, and chat sessions.

Role of the Colleagues

The role of the colleagues might have an impact on the effectiveness of professional development. Although evidence shows that having several teachers in professional development from a single school may encourage them to implement and to solve problems of practice together (Garet et al., 2001; Little, 1993; Kennedy, 1998), this study showed that teachers from the same school/site may also have shared their negative attitudes with each other. The Head Start teachers in this study present a complex mixture of behaviors. They were nested within two sites and had multiple opportunities to influence each other. As reported earlier, the Head Start teachers attended workshops two times more than the public school pre-kindergarten teachers but without much personal say. These same teachers, however, were provided almost two times less facilitation than the amount of facilitation that the pre-kindergarten teachers were provided. Also, the Head Start teachers chose to access the online resource BBLT three times less than the pre-kindergarten teachers in public schools, despite the fact that the study paid to have special Internet access hard wired for each classroom. Finally, they implemented the curriculum at a lower level than the other teachers and carried out fewer mathematics activities with lower quality for those they did carry out.

This low level of participation in Head Start may be due in part to system related issues. For instance, there are documented high rates of turnover among Head Start teachers (Chafel, 1992; Currie & Thomas, 2000; Gill, Greenberg & Vazquez, 2002), which was similarly found in this study. At the beginning of the implementation year, while only three public school pre-kindergarten teachers were replaced with new teachers, nine Head Start teachers – five teachers in the treatment group and four teachers

in the control group – were replaced with new ones by the system. The notion that teachers do not want to remain in Head Start or are deemed unsatisfactory by their supervisors may cause teachers to have lower morale and then to reduce the quality of service delivery. There were also some administrative issues in Head Start sites. For instance, teachers had to clock in and out at certain times during the school days. This might be an important factor that affected Head Start teachers' access to online resources, especially for the teachers who did not have a computer/internet access at home.

In addition to possible effects of turnover rates and administrative issues in Head Start programs, there are other factors that might have influenced Head Start teachers' mathematics instruction. One factor is related to teacher characteristics. When compared with the public school pre-kindergarten teachers, the Head Start teachers in this study generally were less educated, had less teaching experience, and did not have a teaching license. One of the overall trends of the present study is that the Head Start teachers in the treatment group conducted more math activities with higher quality than the Head Start teachers in the control group. However, perhaps because of their weaker background characteristics, they did not increase the quantity and quality of math activities as much as the public school pre-kindergarten teachers did.

Teacher Satisfaction and Its Impact on Mathematics Instruction

Other studies have also found teacher satisfaction with the professional development to be associated with teachers' willingness to acquire new knowledge and new skills (Nir & Bogler, 2008), and researchers, in general, ask teachers to rate the degree to which they are satisfied with the professional development program through

exit surveys (Frechtling, 2001). However, there are only a limited number of studies that have explored the association between the change in teachers' instruction in relation to the program they participated in and their self-reported satisfaction (Frechtling, 2001). Many studies, in contrast, only ask teachers to express their feelings about the curriculum but the researchers never examine the effects of those feelings on practice. This study, however, examined the association between the preschool teachers' satisfaction with the TRIAD and their mathematics instruction.

In terms of the effect of exposure to professional development on math instruction, one of the important findings of this study is related to the disparity between teachers' self-reported satisfaction level and the observed mathematics instruction. As it was noted by Frechtling (2001), the treatment teachers reported that the professional development program they participated in had positive impacts on their skills, beliefs, and attitudes. However, the results showed that there was no association between teacher rated satisfaction with the professional development and their mathematics instruction – quantity and quality. On the other hand, this study showed that teachers who liked the curriculum more implemented the curriculum components with greater fidelity. One problem with each of these issues is the difficulty of obtaining a range of reactions from teachers, who often appear either reluctant to reveal how they actually feel or who do not see their ratings as reflecting what they intend to practice. In this study, 74% of the treatment teachers' scores for their satisfaction with the program and almost 60% of the teachers' scores for their satisfaction with the curriculum were over 3.5, with the maximum possible rating of 4. The somewhat greater range in ratings for the curriculum itself may explain why those ratings were related to implementation. Ratings of the

professional development, however, may reflect teachers' satisfaction with the days spent in training but not their intention to use the training. Both the failure and the success may call for replication of the study after changing the way of rating satisfaction.

The Impact of Teacher Background Characteristics on Mathematics Instruction

In this study teachers had a wide range of education and experience. Their level of teaching experience ranged from first year teachers to those with decades of experience. Also, there was variation in teachers' educational backgrounds and whether they held a teaching license. The results of this study showed that teacher background moderated the association between teachers' satisfaction with the curriculum and their curriculum implementation. More specifically, within the group of teachers who were more satisfied with the curriculum, the teachers with weaker backgrounds implemented curriculum activities more than the teachers with stronger backgrounds. In addition, teachers' greater exposure to professional development lessened the implementation of the teachers with stronger backgrounds. It seems that the teachers with weaker backgrounds were open to buy-in the Building Blocks curriculum more than the teachers with stronger background. The reason might be that because of their weaker background (i.e., less teaching experience, less education, and/or no teaching license) those teachers might not have been exposed to an organized curriculum previously. On the other hand, teachers with stronger background (i.e., more teaching experience, more education, and a teaching license) have been exposed to curricula before. Thus, they might have thought that they already knew some part of the offered curriculum and, as a result, missed the key points of the curriculum in terms of facilitating students' mathematical understanding. Such

finding warrants future research to find ways to maintain all participating teachers' interest high in learning a new curriculum and in implementing it in their classrooms.

Strengths

The Audience and the Focus of the Professional Development Program

One of the great strengths of this study is both its focus on mathematics instruction and its focus on young children. The majority of the research on effective professional development has been conducted with teachers at elementary or upper grade levels. Moreover, the professional development programs for early childhood teachers are most often concentrated on emergent literacy, classroom management strategies, the importance of play and strategies to improve children's social and emotional development rather than mathematics. Thus, this study contributes to the literature through examining the effects of preschool teachers' exposure to professional development with their subsequent mathematics instruction including both the quantity and quality of mathematics instruction and their curriculum implementation.

Randomization

One of the strengths of the present study was the fact that it was an experiment and that teachers were randomized into comparison groups at the outset. Specifically, the participating sites within each type of program (i.e., public school pre-kindergarten programs and Head Start programs) were grouped into pairs that were similar with regard to the total number of classrooms, number of single-age and mixed-age classrooms, and,

to the extent possible, ethnicity of the pre-kindergarten children. Within each pair, one was then randomly assigned to receive the math intervention and one to participate in the control condition. If teachers shared the same school, they had to share the same informal condition. Random assignment to condition allowed the researchers to better ensure that differences between the treatment and control groups in the outcomes were not due to systematic differences among them at the beginning of the study.

Multi-Faceted Data

The study included data pertaining to the amount of teachers' professional development exposure, teachers' curriculum implementation level, their quantity and quality of mathematics activities, and their satisfaction with the curriculum and the professional development program. Because of the nature of the data collected, the various contributions of professional development exposure could be examined. In contrast, much of the work on professional development is both short term and non-experimental. A great deal of money is spent annually by school systems and Head Start agencies on attempts to improve teachers' practices without any follow up data to determine if changes actually take place. For example, a critical finding from the work presented here involved the diminished effects on the quantity mathematics activities from workshop participation, compared to in-class facilitation and online support.

Duration

One of the common criticisms of professional development activities is their duration. Most of those programs are too short and/or do not allow for follow-up. Since

the TRIAD project encouraged curricular and instructional changes in preschool teachers' mathematics instruction, it provided two years for its teachers. The TRIAD project started with a pilot year with the goal of helping teachers strengthen their professional development in mathematics and learn the Building Blocks curriculum. Then, the teachers were given another year to actually fully implement the curriculum. During the course of two school years, teachers continued to participate in workshops, receive facilitation, and to have the opportunity to access the online BBLT resource. This allowed teachers to have sufficient time to integrate new knowledge into practice. As mentioned before, sustaining their level of implementation may prove difficult for the teachers once the supports are removed.

Limitations

Observations

One of the limitations of this research is that it involves only three observations of each teacher across the school year – once in fall, once in winter, and once in spring. Each of the observations was for a full morning. There is little information available on the number or length of classroom observations necessary to obtain a reliable picture of a teacher's classroom practices. The three observations we conducted might be sufficient, but, on the other hand, the results might have been more reliable if observations had been conducted more frequently. Information on this topic is strongly needed as concerns about fidelity of implementation increase in research.

Self-Reported Data

The satisfaction data and the curriculum implementation level data were self-reported by participating teachers, who may have been subject to providing socially desirable responses. Other data collection methods such as classroom observations may yield more precise data about teachers' curriculum implementation. However, such data collection methods are much more expensive than asking teachers to report their implementation. Self report is a common method in many research studies; more information on the relationship between self reports and actually practices is needed as well as further work on how teachers report. Perhaps more nuanced measures would yield more reliable results and decrease the chance of social desirability affecting the reports.

Conclusion

This dissertation explored the relationship between preschool teachers' mathematics instruction and their exposure to professional development. Analyses examined the effects of preschool teachers' participation in a professional development program on teachers' mathematics instruction. Also, the contributions of how much and what type of professional development teachers were exposed to were investigated. The participating teachers were observed three times during the school year. Teachers in the treatment group reported which curriculum activities they completed and rated the curriculum as well as the professional development program on a weekly basis. In addition, the effects of teacher satisfaction on teachers' mathematics instruction were

investigated by gathering teacher ratings at the end of the year. Multilevel modeling was conducted to test the hypotheses.

The findings of this study showed that participation in the TRIAD project had a positive impact on the quantity and quality of preschool teachers' mathematics activities. The amount of total exposure to professional development within the treatment teachers was related neither to teachers' mathematics instruction nor to their curriculum implementation. This was due, in part, to differential effects for the types of professional development offered. In terms of the individual contributions of each professional development components (i.e., workshops, facilitation, online support), the results showed diminished effects of more participation in workshops on the quantity of mathematics activities teachers conducted; the amount of in-class facilitation and the number of times teachers engaged in online web-based support had positive effects. No effect was found for the individual contribution of each component on quality of mathematics activities or the reported implementation of curriculum components.

Moreover, the results showed that as teachers were more satisfied with the curriculum, they were more likely to implement curriculum components. It is impossible to know whether implementing more of the curriculum led teachers to appreciate and value it more or whether those teachers who liked the concept of the curriculum were more likely to implement it. Also, teacher characteristics positively interacted with the teachers' satisfaction with the curriculum and teachers' curriculum implementation. Specifically, the combination of higher teacher characteristics and higher satisfaction with the curriculum resulted in greater curriculum implementation.

Another finding is that although there was no relationship between the amount of professional development and teachers' curriculum implementation, stronger teacher characteristics resulted in diminished curriculum implementation for teachers with more exposure to professional development. On the other hand, teachers with weaker backgrounds implemented the curriculum components more when they were exposed to more professional development. It is possible that the underlying dynamic for this finding rests on teachers' teaching experience, educational level and their teaching licensure.

Overall, much more research needs to be conducted on the topic of professional development focused on mathematics instruction for preschool teachers. To do so, the following should be considered. First, based on the findings of this study, curriculum companies, researchers, teacher educators, and other entities that deliver mathematics-focused professional development to preschool teachers should keep in mind that there are factors serving as barriers or supports to facilitate the development of preschool teachers' professional knowledge in mathematics: characteristics of teachers, classrooms, schools, and systems. Second, in order to ensure the effectiveness of professional development support, variables that predict effectiveness of such support should be considered. For instance, when providing one-on-one facilitation, it may be critical for designers to ensure what needs to be delivered to the teachers during facilitation and the ways to deliver them. Also, the richness of online resources and teachers' skills in technology may contribute to the effectiveness of online professional development opportunities.

Although emphasis given to professional development has increased dramatically in recent years for every discipline areas, little attention is given to preschool teachers'

professional development in mathematics. Thus, further research should focus on the development of research-based and thoroughly evaluated professional development programs that aim to strengthen preschool teachers' skills, attitudes, and beliefs towards teaching and learning mathematics. This study offers one example of such programs. As a next step, while taking the implications of this study into account, researchers should replicate the study with other preschool teachers to better understand those programs' effects on preschool teachers' mathematics instruction.

Appendix A
Sample Workshop Agenda



Welcome to the Building Blocks
!! Trajectory Game Day !!
Monday, April 30, 2007
Agenda for Game Day



08:00 - 08:15	Welcome & Morning Refreshments
08:15 - 08:45	"Trajectories" by Douglas Clements
08:45 - 09:00	Introduction to the Game Day
09:00 - 09:50	Game 1
09:50 - 10:00	Break (snacks & drinks provided)
10:00 - 10:50	Game 2
10:50 - 11:40	Game 3
11:40 - 12:30	Game 4
12:30 - 13:15	Lunch Time
13:15 - 14:45	Trajectory Jeopardy!
14:45 - 15:00	Closing remarks

Games to be played in small groups
BB Squares (Patterns and Measurement)
BB Millionaire (Counting and Comparing Numbers)
BB Beat the Clock (Geometry)
BB Concentration (Number Composition and Operations)

Everyone grab your Thinking Caps and Good Luck Charm!!!!

We have plenty of prizes!
You have all the right answers!

Appendix B
The Classroom Observation of Early Mathematics - Environment and Teaching
Specific Math Activities

Start _____ **End** _____

Specific Math Activity _____
 # children who participated: _____

Average time _____

watched only:

Math Topic (s) (Check all that apply and Circle the primary topic)
 Counting
 Comparing and Ordering
 Recognizing Number and Subitizing
 Composing Numbers (instantly, e.g., "knowing facts")
 Adding and Subtracting
 Multiplying and Dividing (sharing)
 Shapes
 Composing Shapes
 Comparing Shapes
 Motions and Spatial Sense (position)
 Measuring
 Patterning
 Classifying (sorting)
 Numeral Recognition and writing

Description: _____ # minutes _____

Mathematical Focus					
10. The teacher displayed an understanding of mathematics concepts.	SD	D	N NA	A	SA
11. The mathematical content was appropriate for the developmental levels of the children in this class. <ul style="list-style-type: none"> used task at level of difficulty consistent with children's level of thinking and learning used tasks in sequence corresponding to children's growing level of thinking 	SD	D	N	A	SA
Organization, Teaching Approaches, Interactions					
Check organization(s) used: <input type="checkbox"/> Whole Group <input type="checkbox"/> Individual Activity with Teacher <input type="checkbox"/> Other: Describe organization of activity if not one of the listed, such as, transition, etc. <input type="checkbox"/> Small Group (Teacher) <input type="checkbox"/> Centers (Structured) <input type="checkbox"/> Game <input type="checkbox"/> Play (Unstructured)					
12. The teacher began by engaging and focusing children's <i>mathematical thinking</i> . <ul style="list-style-type: none"> directed children's attention to, invited them to consider, a mathematical question, problem, or idea 	SD	D	N NA	A	SA
13. The <i>pace</i> of the activity was appropriate for the developmental levels/needs of the children and the purposes of the activity.	SD	D	N NA	A	SA
14. The teacher's management strategies enhanced the quality of the activity. <ul style="list-style-type: none"> prepared materials ahead of time organized children effectively orchestrated interaction to maintain children's involvement 	SD	D	N	A	SA
15. The teacher was actively involved in the activity for what percentage of time (<i>beyond</i> setup or introduction)?	0	1-25	26-50	51-75	76-100
If code for #15 was 0— or if the activity called for no extensive discussion of concepts or strategies, then <u>stop</u>.					
Teaching Strategy (ies) Check teaching strategy(ies) used: Other: Describe other strategies. <input type="checkbox"/> Directly Instructing (inc. direct questions, simple Q&A) <input type="checkbox"/> Demonstrating (Counting with) <input type="checkbox"/> Socratic Questioning (leading to point) <input type="checkbox"/> Guided Discovery <input type="checkbox"/> Facilitating <input type="checkbox"/> Acknowledging/Encouraging					
16. The <i>teaching strategies</i> used were appropriate for the development levels/needs of the children and purposes of the activity. <ul style="list-style-type: none"> strategies matched instructional goals strategies provided appropriate level of support strategies maintained all children's engagement with the mathematical ideas 	SD	D	N NA	A	SA

SMA # _____	Specific Math Activity	Teacher Name _____				
Expectations						
17. The teacher had high but realistic mathematical expectations of children. • the teacher asked all children to try to solve problems and attempt various solution strategies.	SD	D	N NA	A	SA	
18. The teacher acknowledged and/or reinforced children's effort, persistence, and/or concentration. • recognized children's actions, implicitly or explicitly, verbally or nonverbally	SD	D	N NA	A	SA	
Eliciting children's solution methods						
19. The teacher asked children to share, clarify, and/or justify their ideas. • used a range of question types to probe and challenge children's thinking • encouraged children to explain their mathematical thinking; e.g., asked "why?", "how did you...?", "could you...?" questions.	SD	D	N NA	A	SA	
20. The teacher facilitated children's responding. • elicited many solution methods for one problem • encouraged elaboration of children's responses • waited for and listened attentively to individual children • responded to errors as learning opportunities	SD	D	N NA	A	SA	
21. The teacher encouraged children to listen to and evaluate others' thinking/ideas. • actively elicited communication between children • stated and reinforced the expectation that children would listen to each other	SD	D	N NA	A	SA	
Supporting children's conceptual understanding						
22. The teacher supported the describer's thinking. • reminded children of conceptually similar problem situations • provided background knowledge • directed group help for an individual child • assisted individual children in clarifying their own solution methods	SD	D	N NA	A	SA	
23. The teacher supported the listener's understanding. • asked a different child to explain a peer's method • encouraged the child to put the explanation in their own words or provide an alternate explanation	SD	D	N NA	A	SA	
24. The teacher provided "just enough" support. • Facilitated children's actions at appropriate level, providing adequate (not too little) but not too much (e.g., doing the task for the child) help or information	SD	D	N NA	A	SA	
Extending children's mathematical thinking						
25. The teacher built on and/or elaborated children's mathematical ideas and strategies. • re-described children's ideas and strategies, adding mathematics content and vocabulary	SD	D	N NA	A	SA	
26. The teacher encouraged mathematical reflection. • drew out key math ideas during and/or towards the end of the activity • helped children make connections to math ideas from other activities and/or real-life experiences	SD	D	N NA	A	SA	
Assessment and Instructional Adjustment						
27. The teacher observed and listened to children, taking notes as appropriate (only need notes in small groups)	SD	D	N NA	A	SA	
28. The teacher adapted tasks and discussions to accommodate the range of children's abilities and development.	SD	D	N NA	A	SA	

Appendix C
Sample Weekly Record Sheet

Name:

School

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Real Math Building Blocks • PreK • Assessment

Weekly Record Sheet

Directions:

- Under the week number, write the date you started that week's activities.
- In the ✓ columns, put a ✓ when the activity is completed.
- For Small Group and Computer Center put the # of children who participated in the activity.
- For Whole Group and Math Throughout the Year, put a ✓ for each time the class does the activity.

Week	✓	Whole Group	✓	Hands On Math Center	#	Computer Center	#	Small Group	✓	Home Connection
17 Date		"Oh Dear, What Can the Pattern Be?" Pattern Strips (The Core) Count and Move In Patterns Cube Patterns Listen and Copy		Pattern Strips (The Core) Stringing Beads Build Cube Stairs Cube Patterns		Pattern Zoo 2 Pattern Planes 2 Marching Patterns 2		Pattern Strips (The Core)		Family Letter
18 Date		Number Jump (Numerals) Snapshots Listen and Copy Guess My Rule Mr. Mixup (Shapes)		Places Scenes Shape Pictures Memory Number		Party Time 3 Memory Number 2		Snapshots Memory Number		Family Letter

Questions and Notes:

Questions and Notes About Computer:

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