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INTERVENTION, EVALUATION, AND POLICY STUDIES

Effects of a Pre-Kindergarten Mathematics Intervention: A Randomized Experiment

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Abstract: Research indicates that a socioeconomic status-related gap in mathematical knowledge appears early and widens during early childhood. Young children from economically disadvantaged families receive less support for mathematical development both at home and in preschool. Consequently, children from different socioeconomic backgrounds enter elementary school at different levels of readiness to learn a standards-based mathematics curriculum. One approach to closing this gap is the development and implementation of effective mathematics curricula for public preschool programs enrolling economically disadvantaged children. A randomized controlled trial was conducted in 40 Head Start and state preschool classrooms, with 278 children, to determine whether a pre-kindergarten mathematics intervention was effective. Intervention teachers received training that enabled them to implement with fidelity, and a large majority of parents regularly used math activities teachers sent home. Intervention and control groups did not differ on math assessments at pretest; however, gain scores of intervention children were significantly greater than those of control children at posttest. Thus, the intervention reduced the gap in children's early mathematical knowledge.

Keywords: Preschool, mathematics intervention, economically disadvantaged, randomized experiment, school readiness

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All citizens need a broad range of basic mathematical understanding to make informed decisions in their jobs, households, communities, and politics (Glenn Commission, 2000; U.S. Department of Labor, Bureau of Labor Statistics, 2006). The ongoing development of a knowledge-based economy places increasing numbers of citizens at risk for having insufficient mathematical, scientific, and technological sophistication for full participation in this economy (Committee on Prospering in the Global Economy of the 21st Century, 2007). More than 80% of occupations that are growing most rapidly in the United States require a substantial base of scientific and mathematical knowledge (Coble & Allen, 2005). Yet since the 1970s, a series of assessments of U.S. students' performance has revealed an overall level of mathematical proficiency well below what is desired and needed (Kilpatrick, Swafford, & Findell, 2001; Mullis et al., 1997; Mullis et al., 2000).

In recent years, the National Council of Teachers of Mathematics (NCTM) and several state departments of education have addressed these challenges with new standards to improve mathematics education (Massachusetts Department of Elementary & Secondary Education, 2000; NCTM, 2000, 2006), and progress has been made at the elementary and middle school levels, especially in schools that have instituted reforms (e.g., Fuson, Carroll, & Drueck, 2000; International Association for the Evaluation of Educational Achievement, 2001; Riordan & Noyce, 2001). However, children who live in poverty and who are members of linguistic and ethnic minority groups continue to demonstrate significantly lower levels of achievement (Denton & West, 2002; Johnson & Kritsonis, 2006; Natriello, McDill, & Pallas, 1990).

These achievement differences have roots in early childhood. Children from different sociocultural backgrounds enter elementary school at different levels of readiness for a standards-based mathematics curriculum (Clements, Sarama, & DiBiase, 2004; Klein & Starkey, 2004a; West, Denton, & Germino-Hausken, 2000). Economically disadvantaged kindergarten children have less extensive mathematical knowledge than their middle-income peers (Denton & West, 2002; Griffin, Case, & Siegler, 1994; Jordan, Huttenlocher, & Levine, 1992). The same has been found for economically disadvantaged preschool children (e.g., Ginsburg & Russell, 1981; Hughes, 1986; Jordan, Huttenlocher, & Levine, 1994; Starkey & Klein, 1992; Starkey, Klein, & Wakeley, 2004). Recent cross-cultural research on early mathematical development in China, Japan, and the United States found that a socioeconomic status (SES)-related gap in early mathematical knowledge is present at preschool entry at age 3 years in all three countries (Starkey & Klein, 2008). This gap, however, narrows and eventually closes over the preschool years for children in China and Japan, where preschools (in China) or a combination of preschools and home environments (in Japan) provide relatively rich support for mathematical development for children beginning at 3 years of age. In contrast, the SES-related gap widens for American children during the preschool years. These early SES-related differences in mathematical development are conceptually broad, encompassing informal knowledge of number, arithmetic, patterns, space/geometry, and measurement (Starkey et al., 2004). Furthermore, they are persistent. SES-related differences in math achievement, which have been identified at the outset of elementary school, persist and become more pronounced with time (e.g., Entwisle & Alexander, 1989, 1990; Rathbun & West, 2004). The consequences of these early differences for children's school achievement are underlined by findings from the Early Childhood Longitudinal Study (Rathbun & West, 2004). A mathematics achievement gap was found between entering kindergartners with family risk factors, including family income, and their more advantaged peers. This gap widened over the first 4 years of elementary school.

The reason for the early SES-related gap in mathematical knowledge appears to stem, at least in part, from differential levels of support for early mathematical development that children receive in their early learning environments. Economically disadvantaged American children receive less support for mathematical development both at home and in preschool. Parents' mathematics beliefs and practices vary with socioeconomic status. Middle SES parents tend to believe the home environment plays a role as great or greater than preschool in preparing young children for school mathematics, whereas more lower SES parents believe the preschool environment plays the greater role (Starkey & Klein, 2008; Wakeley, 2002). Economically disadvantaged mothers expect that preschool teachers will provide instruction in numeracy skills to prepare their children for school (Holloway, Rambaud, Fuller, & Eggers-Pierola, 1995). With respect to practices, the frequency with which 4- to 6-year-old children engage in number-related activities at home is positively correlated with the extent of their developed numerical knowledge (Blevins-Knabe & Musun-Miller, 1996). Middle SES parents, in comparison to lower SES parents, provide mathematics support that is more frequent, mathematically broader, accompanied by scaffolding, and richer in mathematical language (Hart & Risley, 1995; Saxe, Gubermen, & Gearhart, 1987). In contrast, many economically disadvantaged parents provide a comparatively narrow base of support (Starkey & Klein, 2000, 2008). This variation in young children's home learning environments is a likely source of the SES-related differences in early mathematical knowledge.

Children from economically disadvantaged families also receive less support for mathematical development in their preschool classrooms. Many preschool programs provide a paucity of developmentally appropriate supports for early mathematical development (Bryant, Burchinal, Lau, & Sparling, 1994; Graham, Nash, & Paul, 1997). The amount of mathematical language used by preschool teachers is correlated with the amount of mathematical knowledge present in their preschool children (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). Pre-kindergarten teachers often use no systematic mathematics curriculum, receive little or no training in early childhood mathematics, are unfamiliar with the mathematics curriculum taught in local elementary schools, and know little about mathematics standards (Copley, 2004; Copley & Padròn, 1999). American preschool programs provide less support than

Chinese preschools for children at 3 and 4 years of age. Within the United States, a variety of public preschools for lower SES children have been found to provide less mathematics support than private preschools enrolling higher SES children (Starkey & Klein, 2008). Many public preschool teachers report that they did not know how to support children's developing numerical abilities (Farran, Silveri, & Culp, 1991) and are providing children with an uneven base of support for mathematical development (Starkey & Klein, 2003).

Children enrolled in Head Start make minimal improvement in mathematical knowledge over the pre-kindergarten year. In the Head Start Impact Study (Administration for Children and Families, 2005), economically disadvantaged children were randomly assigned to either a Head Start condition or a control condition in which enrollment was denied. Most children in the control condition either stayed home or went into family day care or other informal care arrangements. It was found that children in the Head Start group experienced no gains in mathematical knowledge relative to that of the control group. Thus, enrollment in Head Start and exposure to the general curricula used in most Head Start classrooms, the most common being Creative Curriculum and High Scope, had no measurable impact on mathematical development relative to staying home or informal care arrangements. Many Head Start teachers appear not to engage in intentional teaching of mathematics; consequently, Head Start teachers and programs need effective curricula and professional development in the area of mathematics (Starkey, 2007; U.S. Department of Health and Human Services, 2007).

In summary, both the home and classroom learning environments of low-income American children are less rich than the learning environments of their middle-class peers. An SES-related gap in mathematical knowledge is already present at 3 years of age when many children enter preschool. This gap widens during the preschool years in the United States. An SES-related gap is also present in China and Japan by 3 years of age, but in contrast to the United States, the gap narrows and is closed by the end of the 2nd year of preschool. Preschool is universal in China, and Chinese preschools provide standards-based mathematics curricula for 3-year-olds as well as for 4-year-olds. American preschools serving low-income families provide less support.

The long-term success of low-income children requires high-quality experience during their early "years of promise" (Carnegie Task Force on Learning in the Primary Grades, 1998). Research shows that such experiences result in greater school readiness upon entry into kindergarten (Bowman, Donovan, & Burns, 2001; National Center for Education Statistics, 2002; Shonkoff & Phillips, 2000). Unfortunately, most American children are not in high-quality programs (Hinkle, 2000). If progress in improving the mathematics proficiency of our citizens is to encompass *all* children, much greater attention must be given to *early* mathematics experiences.

In summary, there is a national need for effective curricula that support mathematical development in preschool children, especially those from economically disadvantaged families. There is also a corresponding need for professional development for preschool teachers to learn about the foundations of mathematics in early childhood, how young children learn mathematics, and how to facilitate that learning. Thus, the objective of this research was to evaluate the effects of a pre-kindergarten mathematics intervention, including a research-based curriculum, on economically disadvantaged children's mathematical development and the amount of support for mathematics provided in their classroom and home environments.

OVERVIEW

The evaluation of a pre-kindergarten mathematics curriculum was conducted as part of the national Preschool Curriculum Evaluation Research program, using a randomized controlled experiment. The curriculum, Pre-K Mathematics, was implemented in two types of preschool programs serving low-income families—Head Start and state-funded public preschools—in California and New York. A sample of pre-kindergarten children was randomly selected from each classroom to participate in the research. The evaluation of Pre-K Mathematics included both locally developed, math-specific measures and a national battery of cross-program measures in literacy, mathematics, and social skills. In this article, we focus primarily on math-specific measures, but results from the cross-program measures are discussed where appropriate.

METHOD

Participants

Child Sample. Eight children were randomly selected in each classroom from the total number of consented children, balanced for age and gender, to participate in the experiment. All children were in the age range eligible for entrance into public kindergarten the following year. The pretest sample consisted of 316 normally developing pre-kindergarten children from low-income families. During the intervention year, 38 children left the study (12% attrition) primarily because of family mobility, resulting in a final study sample of 278 children (134 girls and 144 boys). Their mean age was 4.4 years (range = 3.8–4.9 years) at pretest at the beginning of their pre-kindergarten year. Mean age was 4.4 years for intervention children and 4.4 years for control children. Ethnic composition of the children was 53% African American, 22% White, 22% Hispanic, 4% Asian American, and 4% interracial/other. Children enrolled in state-funded preschools comprised 52% of the sample; Head Start children comprised the remaining 48% of the sample.

Teacher Participants. All 40 teachers who participated in the experiment were female. The ethnic composition of the teachers was 38% White, 33% African American, 13% Hispanic, 10% Asian American, and 5% interracial/other. Teachers had an average of 12.4 years experience teaching preschool. State-funded preschool teachers had significantly more teaching experience (16 years) than Head Start teachers (10 years), $F(1, 32) = 4.69$, $p < .05$. The majority (73%) of teachers had a bachelor's degree or higher; 27% had an associate's degree or less. State-funded preschool teachers were more highly educated than Head Start teachers ($p < .02$), and state-funded preschool teachers in New York were more highly educated than their counterparts in California ($p < .001$).

Design

The pre-kindergarten mathematics intervention was conducted in both Head Start and state-funded preschool programs in the San Francisco Bay Area of California and in Buffalo, New York. Four California programs participated (two Head Start and two state-funded preschool programs) and two New York programs participated (one Head Start and one state-funded preschool program). Teachers in each program volunteered to participate in the intervention, and then their classrooms were randomly assigned to either the intervention condition (Pre-K Mathematics curriculum) or the control condition (existing classroom curriculum/business as usual). A total of 40 preschool classrooms (10 Head Start and 10 state-funded classrooms in each state) were randomly assigned at the beginning of the school year using block randomization. Blocks were formed at the program level (four programs in California and two in New York), with teachers from Head Start and state-funded programs balanced by curriculum condition in each state.

Protections Against Treatment Diffusion. To minimize the potential for treatment diffusion (e.g., curricular contamination) of control classrooms by intervention activities, intervention and control classrooms were located in different buildings. Furthermore, programs were asked to ensure that intervention and control teachers did not substitute in classrooms assigned to a condition different than theirs. Finally, observations of intervention and control classrooms were made using the Early Mathematics Classroom Observation (EMCO) instrument, which has sufficient sensitivity to detect use of Pre-K Mathematics activities in a classroom. Neither the EMCO nor periodic unannounced classroom visits in treatment and control classrooms by project staff revealed any evidence of contamination.

Characteristics of Classrooms at Baseline. Teachers in intervention and control classrooms were instructed to continue their use of curricula in place prior to their agreement to participate in the research project. The general-purpose curricula used in these classrooms included Creative Curriculum, High Scope, Montessori, and locally developed curricula such as Buffalo Public Schools Benchmarks. Control teachers were instructed not to alter their classroom practices or curricular choices from business as usual. Intervention teachers added the math intervention to their current set of classroom curricula. The Early Childhood Environment Rating Scale–Revised was used to measure the general quality of classrooms included in the experiment. Examination of Early Childhood Environment Rating Scale scores in the fall did not indicate an unhappy randomization. Overall classroom quality scores of intervention classrooms (3.4) and control classrooms (3.7) did not significantly differ.

Intervention

A pre-kindergarten mathematics intervention was implemented in public preschools in California and New York. The purpose of the intervention was to enrich mathematically children's preschool and home learning environments.

Components. The intervention included the classroom and home components of *Pre-K Mathematics* (Klein & Starkey, 2002, 2004b) and DLM Express math software for classroom use (Clements & Sarama, 2003). Teachers implemented these components according to a curriculum plan that explicitly linked the small-group classroom activities to the home and computer activities.

Pre-K Mathematics consists of small-group mathematics activities with concrete manipulatives for use by teachers and children in preschool classrooms as well as home mathematics activities and materials for use by parents and their preschool-age children in home settings. A teacher's manual provides a curriculum plan that links small-group classroom activities to home activities. The curriculum includes the following units: (a) Counting and Number, (b) Understanding Arithmetic Operations (Fall Activities), (c) Spatial Sense and Geometry, (d) Patterns, (e) Understanding Arithmetic Operations (Spring Activities), (f) Measurement and Data, and (g) Logical Reasoning. Teachers presented 29 small-group mathematics activities in accordance with a curriculum plan at a rate of approximately one new math activity per week. Teachers conducted the weekly math activity with each child in a group of four to six children twice during the week for approximately 20 min per group. Thus, barring child absences, target dosage was 58 small-group sessions per child. The small-group activities were designed to be sensitive to the developmental needs of individual children. Suggestions were provided for scaffolding children who experienced difficulty with a part of the activity. Furthermore, downward (less challenging) extensions were provided for children who were not ready for the initial (easiest) part of the activity, and upward (more challenging) extensions were suggested for children who completed the activity with relative ease. Finally, Assessment Record Sheets, specifically tied to small-group activities, were provided for teachers to keep a record of the progress of individual children during each activity. The curriculum plan provided time (e.g., review weeks) for teachers to review small-group math activities with children who had been absent or were continuing to experience difficulty with a particular activity.

Teachers sent 18 Pre-K Mathematics home activities home to parents at a rate of approximately one activity every 1 to 2 weeks. Home activities included manipulatives for parents to use with children, a brief narrative describing the activity and stating its purpose, and picture strips depicting how to conduct the activity. Similar mathematical content was covered during the same week by home and small-group classroom activities.

In addition to the teacher-guided small-group activities and parent-guided home activities of Pre-K Mathematics, the intervention also included 27 supplementary computer-based mathematics activities and a math learning center. Math software for young children, DLM Express, was installed on a computer in each classroom. Teachers were also encouraged to enhance the math learning center in their classroom or, if they did not have a math center, to create one. Teachers were encouraged to provide some materials from Pre-K Mathematics small-group activities that had been completed as well as math manipulatives gathered from elsewhere in the classroom.

Professional Development Provided. During the 1st year of implementation, treatment group teachers participated in a 4-day training workshop focusing on Units 1 to 3 of the curriculum and participated in another 4-day workshop focusing on Units 4 to 7 in winter. Ongoing on-site training was provided in teachers' classrooms by facilitators approximately twice per month, for an average of 15 on-site training sessions per teacher. Throughout the preschool year, facilitators observed and rated the implementation fidelity of small-group activities in each intervention classroom one to two times per month, with formative feedback given at the end of each observation. Facilitators also observed children during use of the computer-based mathematics activities, examined computer records of children's use of these activities, confirmed that home mathematics activities were being sent home as scheduled, and provided feedback and training to teachers as needed.

Implementation Fidelity. To measure the quality of each intervention teacher's implementation of Pre-K Mathematics, a fidelity instrument, the Fidelity of Implementation Record Sheet, was administered (see the appendix). Fidelity was evaluated for each intervention teacher on five dimensions: (a) adherence to the schedule of activities set in the curriculum plan, (b) preparation of all materials needed to conduct the activity, (c) delivery of the principal parts of small-group mathematics activities, (d) provision of developmental adjustments (scaffolding, downward extensions, and upward extensions) needed by individual children in the group, and (e) making written assessments of individual children during the course of activities. Fidelity observations were made during bimonthly facilitation visits throughout the year. During these visits, a trainer observed as a teacher conducted a small-group math activity and provided feedback afterward regarding any departures from fidelity.

Information on parents' use of Pre-K Mathematics home activities was obtained through a parent questionnaire. Parents were asked to report whether they had received these activities from their child's teacher and, if so, how often they used the activities with their child.

Teachers' use of the supplemental DLM Express mathematics software was also monitored during fidelity visits. Fidelity of use of this software was evaluated for each intervention teacher in regard to (a) adherence to the schedule of computer-math activities set in the curriculum plan, (b) introduction of the activity to children, and (c) provision of the opportunity for children to engage in the activity and to receive assistance with activities or with turn-taking as needed.

Assessment Procedures

Two sets of measures were administered—a set of math-specific measures administered by the research teams at Berkeley and Buffalo and a set of cross-program measures administered by RTI International. Use of the cross-program measures was required by the funding agency, the Institute of Education Sciences, as part of the Preschool Curriculum Evaluation Research program. The battery of local and cross-program measures included parent and home environment measures, teacher and classroom measures, and child assessments. Several cross-program measures were drawn from the Family and Child Experiences Survey battery used in prior evaluations of Head Start programs (Administration for Children and Families, 2006).

Parent and Home Environment Measures. A locally administered parent questionnaire obtained information about parents' support for children's mathematical development at home as well as their knowledge and beliefs about preparing children for school mathematics. A parent interview conducted as part of the cross-program assessment elicited demographic information about children and parents, children's health and disability status, parent judgments of children's accomplishments and social skills, family–child activities, parenting practices, use of child care, and parental depression. The interview drew questions primarily from the Family and Child Experiences Survey.

Teacher Practice and Classroom Measures. An instrument from the local battery, the EMCO, was used to assess teachers' mathematics practices. Administration began during arrival and ended during departure (half-day classrooms) or lunch (full-day classrooms). An observation was made of all teacher–participant activities in which there was mathematical content. The observer recorded the mathematical content, number of children present, and duration of the activity. Activities were categorized as (a) *focal* math activities in which the primary goal of the activity was children's mathematics learning (e.g., an activity focused on the names of numerals) or (b) embedded math activities in which the primary goal was nonmathematical (e.g., a cooking project in which children measured ingredients at one point). EMCO was administered twice (fall and spring) in all classrooms.

Child Assessments. To test the hypothesis that intervention children will develop more extensive mathematical knowledge than control children, the child assessment instrument should be sufficiently broad to include the diverse knowledge structures that comprise early mathematical cognition and are supported by the pre-kindergarten math curriculum. The Child Math Assessment (CMA) is a researcher-developed measure that assesses informal mathematical knowledge across a broad range of skills and concepts appropriate for preschool and kindergarten children. The CMA comprises 15 tasks, with multiple problems per task, that measure children's knowledge in the areas of number, arithmetic, space and geometry, measurement, and patterns. The tasks involve concrete objects and encompass a range of problem difficulty. The specific mathematical tasks included in the CMA are described in more detail in Starkey et al. (2004). It should be noted that although the CMA was designed to be sensitive to the development of some concepts supported by the pre-kindergarten mathematics intervention, it was not overaligned with the intervention (i.e., it did not use the same tasks or materials presented in the intervention).

The psychometric properties of the CMA are very good for children in this age range. Test–retest reliability over a 2-week interval is .91, and Cronbach's alpha over all tasks is .90. Moreover, as evidence of convergent validity with a standardized measure of children's math knowledge, CMA scores were found to be positively related to Test of Early Mathematics Ability–3 scores ($r = .74$, $p < .01$) for a diverse sample of 4- to 5-year-old children.

The CMA was used to assess intervention and control children's early mathematical knowledge at pretest and posttest. The pretest assessment was conducted prior to the time teachers began implementing the curricular intervention in treatment classrooms. The posttest assessment was conducted after the curricular intervention had been completed in treatment classrooms. The CMA was administered individually to children in two 20- to 30-min testing sessions that were conducted on separate days. Session order was counterbalanced across children, with half in each classroom receiving Session A first, and half receiving Session B first. Testing took place at children's preschools. Individual children were escorted from their classroom to a quiet room for the testing sessions. All sessions were videotaped.

The cross-program battery included individually administered measures of mathematical knowledge, language and early literacy knowledge and skills, social skills, and classroom behavior. Math measures included the Woodcock–Johnson (WJ) Applied Problems, CMA–Abbreviated (CMA–A), and the Shape Composition Task. Language development, phonological awareness, and beginning reading and writing skills were assessed by the WJ Letter Word Identification and WJ Spelling subscales, the Preschool Comprehensive Test of Phonologic and Print Processing, the Test of Language Development, the Peabody Picture Vocabulary Test, and the Test of Early Reading Ability. Teachers provided information on children's social skills by completing the Social Skills Rating System.

RESULTS

Parent and Home Environment Findings

Family Demographics. Mothers of participating children reported the highest level of education they had completed. The percentages at each education level were as follows: less than high school (15%), high school or vocational school but less than bachelor's degree (60%), bachelors degree or higher (11%), declined to state (14%). The primary home language was English (84%), Spanish or Spanish and English (10%), and other (Cantonese, Fanti, Hindi, Laotian, Mandarin, Pushto, Tagalog, Tonga) or other and English (6%). Parents reported that their pre-kindergartners engaged in a mean number of 7.7 math-related activities (range = 1–13) at home at least once per week during a typical week. Examples of some to these activities were playing store-bought games involving math (e.g., games with dice), playing with math-related toys (e.g., toy cash register with play money), block construction activities, paper cutting or folding activities (e.g., origami), art activities involving patterns or symmetry, reading number or shape books, math workbook activities, use of educational software, and watching educational television programs.

Parents were also asked about their beliefs and home practices related to children's early mathematical development. The following belief question was asked: "Consider the relative contribution of the home environment and the preschool environment in preparing children for math in kindergarten. Please indicate in percentages how much you think each contributes (please total to 100%)." It was found that 18% of parents believed the home environment was of greater importance, 39% believed the preschool environment was of greater importance, and 43% thought the two environments were equally important.

In fall, near the beginning of the school year, intervention and control families did not significantly differ in their beliefs about mathematics readiness or in the amount of support they were providing at home for mathematical development in their children. Parental beliefs and home practices pertaining to mathematical development were significantly correlated. Specifically, parents who tended to believe that the home learning environment was more important than the preschool environment as a place to foster mathematical knowledge, also tended to engage in more math-related home activities with their child ($r = .32$, $p < .0001$). Parents' tendencies to believe in the importance of the home learning environment and to engage in math activities with their children at home predicted children's CMA scores at the beginning of the intervention in fall. Specifically, children of parents both who believed that home was more important than preschool as a place for children to learn math and who provided more math activities at home tended to have higher CMA scores in the fall, $F(1, 232) = 9.57$, $p < .005$. This finding suggests that both parental beliefs and practices may have played a significant role in children's early mathematical development prior to their participation in this project.

Teacher Practice and Classroom Environment Findings

Implementation Fidelity. Fidelity of teachers' implementation of Pre-K Mathematics small-group activities ranged from 0–1 on each of the five dimensions of fidelity. An overall fidelity score, ranging from 0–1, was calculated for each visit by averaging fidelity across the five dimensions. Overall fidelity scores for Pre-K Mathematics small-group activities across the year were found to be, on average, high (.90 or higher) for Head Start teachers in both states and for state-funded preschool teachers in California and moderate (.70–.89) for state-funded preschool teachers in New York. Fidelity scores ranged from .70 to .99 for individual teachers (Table 1). Overall scores did not vary significantly by program type or location. A series of univariate 2 (Program location: California or New York) $\times$ 2 (Program type: Head Start or state-funded preschool) analyses of variance (ANOVAs) of overall scores and scores on particular dimensions of fidelity revealed no overall differences between program types, duration of program day (half-day or full-day classes), or program locations. Lower fidelity

Table 1. Mean fidelity scores for implementation of small group mathematics activities

	California		New York	
Dimension of Fidelity	Head Start	State Pre-K	Head Start	State Pre-K
The teacher stays on schedule	.88	.93	.65	.60
Is prepared	.93	.93	1.00	.94
Delivers the basic activity	.91	.95	.94	.87
Makes developmental adjustments	.88	.92	.93	.78
Assesses all children	.95	.85	.98	.95
Overall fidelity mean	.91	.92	.90	.83
Overall fidelity range	.84–.99	.81–.98	.84–.99	.70–.96

Note. Fidelity scores can range from 0 to 1.

Table 2. Mean fidelity scores for implementation of computer mathematics activities

	California		New York	
Dimension of Fidelity	Head Start	State Pre-K	Head Start	State Pre-K
Overall fidelity mean	.83	.87	.95	.65
Overall fidelity range	.67–1.00	.63–.96	.92–.98	.00–.89

Note. Fidelity scores can range from 0 to 1.

scores were found on only one dimension (staying on schedule) in classrooms in New York than in California, $F(1, 16) = 17.77$, $p < .0001$. No other differences were found. Overall fidelity scores were also unrelated to teachers' education level and years of preschool teaching experience. Thus, Pre-K Mathematics fidelity did not vary significantly by program location, program type, duration of program day, teacher education level, or years of teaching experience.

Teachers' overall fidelity of use of the supplemental computer math software was moderate (.80) and ranged from .00 to 1.00 (Table 2). Most teachers were able to follow the schedule of computer-math activities and to ensure that children received a turn. Several teachers, however, were unable to monitor closely the computer area while children were using it, and a small number of teachers were resistant to using computer-based activities. Fidelity to DLM Express computer-based mathematics activities did not vary significantly by program location, program type, duration of program day, teacher education level, or years of teaching experience.

Regression analyses of relations between CMA scores and both small-group math fidelity and computer-based math fidelity were also conducted. These analyses found that neither fidelity score significantly predicted change in children's CMA scores.

Costs prohibited direct observations of parents' use of Pre-K Mathematics home activities with their children. Consequently, measurement of implementation fidelity was limited to parental report of frequency of use of these activities. Teachers reported that they sent Pre-K Mathematics home activities to parents as scheduled in the curriculum plan. A large majority (95%) of parents reported that they had received home activities and had used the activities every 1 to 2 weeks (81% of parents) or at least monthly (92%). Most (95%) parents reported a positive reaction to receipt of math activities from their child's teacher and felt the activities helped their child learn about math.

Proximal Effects on Teachers' Mathematics Practices. Teacher math practices observed during administration of the EMCO were categorized as focal or embedded math activities. The mean number of minutes of math support that was provided per child per day was calculated. The ANOVAs of minutes of math support provided by teachers revealed no differences between teachers of different education levels (less than bachelor's degree vs. bachelor's degree or higher) or with different amounts of preschool teaching experience. Likewise no differences were found when math support in half-day and full-day classrooms was compared.

Control teachers provided 21 min of math per day, of which 7 min was focal math and 14 min was embedded math. In contrast, intervention teachers provided 36 min of math per day, of which 24 min was focal math and 12 min was embedded math. Intervention teachers provided significantly more minutes of focal math support than did control teachers, $F(1, 32) = 13.32$, $p < .001$. Intervention and control teachers did not differ in the amount of embedded math support that they provided.

A final set of analyses was conducted to determine whether the number of minutes of focal or embedded math that teachers provided predicted change in children's mathematical knowledge. The amount of focal math support children received significantly predicted positive change in children's CMA scores, $F(1, 270) = 15.32$, $p < .0001$. Amount of embedded math, however, did not significantly predict change in these scores.

Impact of the Intervention on Children's Mathematical Knowledge

CMA. Children's performance on the CMA was coded from videotape, and then coded responses were scored for accuracy. Interrater reliability, calculated on approximately 20% of the coded data, was high (>97% agreement). For each task on the CMA, individual problems were scored for accuracy (possible range = 0–1). Because the numbers of problems varied across tasks, a mean proportion correct on individual tasks was computed. Then a composite mathematics score for each child was obtained by averaging across the mean scores for all 15 tasks. Composite scores on the CMA provided an overall measure of children's early mathematical knowledge, and composite scores were used in the impact analyses described next.

The principal hypothesis of this study was that implementing a pre-kindergarten math curriculum would have a significant impact on the mathematical development of intervention children as compared to control children. Specifically, it was predicted that intervention children would demonstrate more extensive mathematical knowledge on the CMA than control children across the pre-kindergarten year. A hierarchical model with children nested within classrooms and time nested within child was used to fit the data for the repeated measures analysis. Composite CMA scores for intervention and control children in the fall (pretest) and the spring (posttest) were examined in a 2 (group) $\times$ 2 (site) $\times$ 2 (program type) $\times$ 2 (time) repeated measures ANOVA. Analyses revealed that the CMA scores of both groups increased over time, $F(1, 270) = 699.17$, $p < .0001$. In addition, there was a significant Group $\times$ Time interaction, $F(1, 270) = 39.61$, $p < .0001$. The CMA scores of

Table 3. Child Math Assessment scores of intervention and control groups

Group	Fall	Spring
Intervention	0.35 (0.15)	0.55 (0.13)
Control	0.34 (0.13)	0.47 (0.14)

Note. Child Math Assessment scores are combined across site, because no significant effect for site was found.

intervention children and control children did not differ in the fall ($p = .95$). However, in the spring, intervention children demonstrated more extensive knowledge on the CMA than control children ($p < .0001$; Table 3). Thus, the significant interaction reflected a greater increase in CMA scores across the pre-kindergarten year for intervention children than for control children (Figure 1). The effect size (Cohen's *d*; Cohen, 1988) for the change in CMA scores from fall to spring was 0.89 for the control group and 1.43 for the intervention group with the difference of 0.55 representing the effect size of the curricular intervention.[1] No other main effects or interactions were significant.

A second set of analyses using children's gain scores on the CMA from fall to spring revealed the same pattern of results. A hierarchical model with children nested within classrooms was used to fit the data in this analysis. For each child, a gain score between their fall CMA score and their spring CMA score was computed. Then CMA gain scores for intervention and control children were examined in a 2 (group) $\times$ 2 (site) $\times$ 2 (program type) ANOVA. The effect of group emerged as significant, $F(1, 32) = 34.73$, $p < .0001$, but no other main effects or interactions were found to be significant. As hypothesized, children in the intervention group ($M_{\text{change}} = 0.20$) improved significantly more on the CMA from fall to spring than children in the control group ($M_{\text{change}} = 0.12$), and this improvement on the CMA was statistically significant for both sites (NY, $p < .0001$; CA, $p < .01$).

Cross-Program Assessment. A math composite, consisting of the CMA–A, the Shape Composition task, and the WJ Applied Problems, was formed. Correlations between individual tests ranged from .39 to .63, and Cronbach's alpha was .75. Intervention children exhibited greater gains in their math-composite scores than did children in control classrooms, $F(1, 1405) = 7.02$, $p < .01$, $d = 0.23$. This difference in gains made by intervention children, relative to control

[1]The What Works Clearinghouse calculated an effect size of 0.58 for the impact of Pre-K Mathematics on intervention children's math performance as compared to a control group. Additional information can be found in the intervention report for Pre-K Mathematics at the What Works Clearinghouse Web site (http://www.whatworks.ed.gov/).

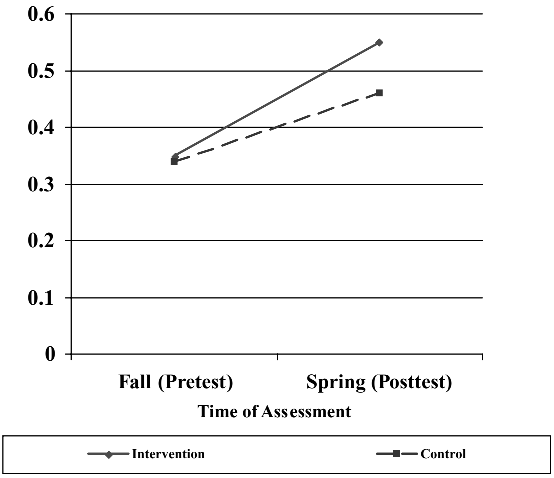

Figure 1. Child Math Assessment scores of intervention and control children at pretest and posttest.

children, was sufficiently large to reveal differences between intervention and control children's math scores in spring, $F(1, 208) = 20.91$, $p < .0001$, effect size = 0.62.

A reading composite, consisting of Test of Early Reading Ability, WJ Letter Word, and WJ Spelling, was created. Gains in reading skills by intervention and control children did not differ.

A language composite, consisting of the Peabody Picture Vocabulary Test and Test of Language Development–Grammatic Understanding, was also created. Language gains by intervention and control children did not differ. Likewise, intervention and control children's gains in social skills, as measured by the Social Skills Rating System, did not differ. In summary, analyses consistently revealed that the mathematics intervention had a positive impact on children's mathematical knowledge but no measurable impact on their early reading, language, and social skills.

DISCUSSION

The principal objective of the present randomized field trial was to evaluate the effectiveness of a mathematics intervention when implemented in public preschool programs. The curricular intervention, Pre-K Mathematics, was found to be effective, both by the authors and by the external evaluator. Furthermore, the evidence met the What Works Clearinghouse standards for effectiveness. Economically disadvantaged pre-kindergarten children experienced significantly more growth in mathematical knowledge when teachers used this curriculum than when they engaged in their usual practices.

Robustness of the Intervention

The training model that was followed ensured that teachers both participated in multiday curriculum workshops and received on-site facilitation by trainers who knew the curriculum. This training was sufficient to enable teachers to implement the intervention with a moderate to high degree of fidelity. Teachers found staying on schedule to be the most challenging dimension of fidelity. It is noteworthy that the training provided was sufficient to overcome any potential disadvantages stemming from variations in teacher characteristics (teacher education level, amount of preschool teaching experience) or program characteristics (state in which program was located, program type—Head Start or state-funded pre-kindergarten, or duration of program day—half-day or full-day classes). Furthermore, these teacher and program characteristics were not related to the gains seen in children's mathematical knowledge. Thus, when trained in accordance with our training model for 1 year, teachers with a variety of characteristics were able to implement in a variety of preschool settings with a sufficient degree of fidelity to produce positive child outcomes in mathematics.

The parent questionnaire revealed that parents differ in regard to their beliefs about the importance of the home environment in preparing children for kindergarten mathematics. Parents also differ in the number of math activities they engage in with young children. Furthermore, parental beliefs and practices predicted children's CMA scores in fall prior to the beginning of the intervention. This set of findings is noteworthy because it suggests that early differences in the extent of children's mathematical knowledge may stem from differences in parental beliefs and home practices. Despite these differences, it is encouraging that most intervention parents used and liked the home math activities that teachers sent home to them. This suggests that there was not a strong resistance in the parent community to engaging in math activities with their children at home. In summary, teachers implemented the intervention with fidelity, despite variation in teacher and program characteristics. Moreover, parents' used the home activities, despite variation in their math readiness beliefs. From this, it can be concluded that the intervention was robust.

Strengths of This Randomized Experiment

There is a need in early childhood intervention research to measure the intervention more completely than has been done in the past. In particular, our research suggests that there is value in using a fidelity measure that is directly tied to indispensable dimensions of the curriculum. A curriculum-dependent fidelity measure can be used by on-site trainers to formatively evaluate individual teachers' implementation of specific dimensions of a curriculum. This measure enables teachers rapidly to improve their implementation. For example, on-site trainers quickly noticed when teachers in our experiment were falling behind the schedule called for in the curriculum plan. Trainers then attempted to understand why the schedule was slipping and to help teachers get back on schedule.

A related strength was the use of the CMA, because it is a conceptually broad assessment of children's mathematical knowledge. The content validity of other measures of early mathematical knowledge, such as the WJ Applied Problems, is inadequate for the range of mathematical knowledge that is developing during early childhood. Finally, the developmentally broad cross-program battery found that the math intervention apparently had no adverse effect on the other domains of development that were examined.

Limitations of This Randomized Experiment and Next Steps

The present experiment examined effects of the intervention during teachers' initial year of implementation. Teachers' fidelity of implementation was moderate to high, but perhaps it could be improved during a 2nd year of implementation. With more experience, teachers may also attain greater familiarity with the range of small-group management issues and math-specific learning difficulties that can arise as they conduct small-group math activities. This experiment does not establish whether teachers will raise the fidelity of their implementation and accrue useful experience during a 2nd year of implementation. If they do, will a consequence be greater gains in children's mathematical knowledge?

Another limitation of this experiment is its sample of classrooms of volunteer teachers. The magnitude of effects obtained with volunteer teachers could possibly differ from that obtained with all teachers in a program. It will be important to study implementation and effectiveness at a customary level of scale, such as an entire Head Start program or a school district's early childhood program, because curriculum adoptions often apply to an entire program. A randomized experiment conducted at this level of scale would include all teachers in the program—reluctant or resistant teachers as well as those who would have volunteered.

Both of these limitations are being addressed in our current work. Teachers from this experiment have implemented for a 2nd year with another cohort of children. Findings will be reported in a subsequent article. Another experiment is being conducted at the program level of scale in varied program contexts (e.g., urban vs. rural programs).

Recommendations for Preschool Programs

Continued reliance on general-purpose curricula to support children's mathematical development is pedagogically risky. Some curricula have not been evaluated rigorously. Others that have been evaluated rigorously, relative to a randomly assigned control group, have not been found to have an impact on mathematical development (e.g., Lambert, O'Donnell, & Abbott-Shim, 2008). Instead, programs should consider adoption of special-purpose mathematics curricula of proven effectiveness. Adoption of effective new curricula, however, will require many programs to change in fundamental ways. First, a training model like the one used in the present intervention—multiple days of workshops plus on-site facilitation—will require a greater investment in professional development than many programs usually make. Research shows that this investment can pay immediate dividends in the quality of teachers' implementation. Second, curricula that include activities for programs to send home to parents to conduct with their young children are expecting programs to reach out to parents more than many currently do. Research has shown that when schools implement specific practices, parents, regardless of ethnicity or SES, become more involved in those practices (Epstein & Dauber, 1991; Hiatt-Michaels, 2001). Thus, preschools should consider ways to encourage parents to engage in mathematics activities with their children. The study presented here demonstrates that change in programs' approach to professional development and change in their relationship with the parent community can have positive effects on children's developing mathematical knowledge.

Recommendations for Policymakers

Programs should be encouraged to use math curricula and practices that are of proven effectiveness. Use of effective curricula, however, will require additional resources. There is a need to train trainers as well as preschool teachers to support children's early mathematical development. Forging closer relationships between pre-kindergarten teachers and parents, such as having teachers send math materials home to parents, will also be a new expense. We believe that this investment in teachers and parents will more than pay for itself in good will from teachers and parents and, most important, in the opportunity it will give children to begin to achieve in mathematics.

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REFERENCES

Administration for Children and Families. (2005, July). *Head Start Impact Study: First year findings*. Washington, DC: U.S. Department of Health and Human Services. Retrieved from http://www.acf.hhs.gov/programs/opre/hs/impact_study/reports/first_yr_finds/first_yr_finds.pdf

Administration for Children and Families. (2006, February). *Family and Child Experiences Survey (FACES 2000) technical report*. Washington, DC: U.S. Department of Health and Human Services. Retrieved from http://www.acf.hhs.gov/programs/opre/hs/faces/reports/technical_2000_rpt/tech2k_title.html

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting, 5*, 35–45.

Bowman, B. T., Donovan, M. S., & Burns, M. S. (Eds.). (2001). *Eager to learn: Educating our preschoolers*. Washington, DC: National Academy Press.

Bryant, D. M., Burchinal, M., Lau, L. B., & Sparling, J. J. (1994). Family and classroom correlates of Head Start children's developmental outcomes. *Early Childhood Research Quarterly, 9*, 289–309.

Carnegie Task Force on Learning in the Primary Grades. (1998). *Years of promise: A comprehensive learning strategy for America's children* [Executive summary]. New York: Carnegie Corporation. Retrieved from http://www.carnegie.org/sub/pubs/execsum.html

Clements, D. H., & Sarama, J. (2003). *DLM Express math software*. In *DLM Express math resource package*. Columbus, OH: SRA/McGraw-Hill.

Clements, D. H., Sarama, J., & DiBiase, A. M. (Eds.). (2004). *Engaging young children in mathematics: Standards early childhood mathematics education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Coble, C., & Allen, M. (2005). *Keeping America competitive: Five strategies to improve mathematics and science education* (Document 6219). Denver, CO: Education Commission of the States.

Cohen, J. (1988). *Statistical power for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, Naional Academy of Sciences, National Academy of Engineering, Institute of Medicine. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Copley, J. V. (2004). The early childhood collaborative: A professional development model to communicate and implement the standards. In D. H. Clements, J. Sarama, A. M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 401–414). Mahwah, NJ: Lawrence Erlbaum Associates.

Copley, J. V., & Padròn, Y. (1999). Preparing teachers of young learners: Professional development of early childhood teachers in mathematics and science. In G. D. Nelson (Ed.), *Dialogue on early childhood science, mathematics, and technology education* (pp. 117–129). Washington, DC: American Association for the Advancement of Science.

Denton, K., & West, J. (2002). *Children's reading and mathematics achievement in kindergarten and first grade*. Washington, DC: National Center for Education Statistics. Available from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2002125%20

Entwisle, D. R., & Alexander, K. L. (1989). Early schooling as a "critical period" phenomenon. *Research in the Sociology of Education and Socialization, 8*, 27–55.

Entwisle, D. R., & Alexander, K. L. (1990). Beginning school competence: Minority and majority comparisons. *Child Development, 61*, 454–471.

Epstein, J. L., & Dauber, S. L. (1991). School programs and teacher practices of parent involvement in inner-city elementary and middle schools. *Elementary School Journal, 91*, 289–303.

Farran, D. C., Silveri, B., & Culp, A. (1991). Public preschools and the disadvantaged. In W. Damon (Series Ed.), L. Rescorla, M. C. Hyson, & K. Hirsh-Pasek (Vol. Eds.), *New directions for child development No. 53: Academic instruction in early childhood: Challenge or pressure?* (pp. 65–73). San Francisco: Jossey-Bass.

Fuson, K. C., Carroll, W. M., & Drueck, J. V. (2000). Achievement results for second and third graders using the Standards-based curriculum Everyday Mathematics. *Journal for Research in Mathematics Education, 31*, 277–295.

Ginsburg, H. P., & Russell, R. L. (1981). Social class and racial influences on early mathematical thinking. *Monographs of the Society for Research in Child Development, 46*, (6, Serial No. 193).

Glenn Commission. (2000). *Before it's too late: A report to the nation from the National Commission on Mathematics and Science Teaching for the 21st Century.* Washington, DC: U.S. Department of Education.

Graham, T. A., Nash, C., & Paul, K. (1997). Young children's exposure to mathematics: The child care context. *Early Childhood Education Journal, 25*, 31–38.

Griffin, S., Case, R., & Siegler, R. S. (1994). Rightstart: Providing the central conceptual prerequisites for first formal learning of arithmetic to students at-risk for school failure. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 24–49). Cambridge, MA: Bradford.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore: Brookes.

Hiatt-Michaels, D. (Ed.). (2001). *Promising practices for family involvement in schools.* Greenwich CT: Information Age.

Hinkle, D. (2000). *School involvement in early childhood.* Washington, DC: National Institute on Early Childhood Development and Education, Office of Educational Research and Improvement, U.S. Department of Education.

Holloway, S. D., Rambaud, M. F., Fuller, B., & Eggers-Pierola, C. (1995). What is "appropriate practice" at home and in child care?: Low-income mothers' views on preparing their children for school. *Early Childhood Research Quarterly, 10*, 451–473.

Hughes, M. (1986). *Children and number: Difficulties in learning mathematics*. Oxford, UK: Blackwell.

International Association for the Evaluation of Educational Achievement. (2001). *Mathematics benchmarking report: TIMSS 1999—Eighth grade*. XX: Author. Retrieved from http://timss.bc.edu/timss1999b/mathbench_report/t99bmath_TOC.html

Johnson, C., & Kritsonis, W. A. (2006). A national dilemma: African-American students underrepresented in advanced mathematics courses. *National Journal for Publishing and Mentoring Doctoral Student Research, 3*(1), 1–8.

Jordan, N. C., Huttenlocher, J., & Levine, S. C. (1992). Differential calculation abilities in young children from middle- and low-income families. *Developmental Psychology, 28*, 644–653.

Jordan, N. C., Huttenlocher, J., & Levine, S. C. (1994). Assessing early arithmetic abilities: Effects of verbal and nonverbal response types on the calculation performance of middle- and low-income children. *Learning and Individual Differences, 6*, 413–432.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academy Press.

Klein, A., & Starkey, P. (2002). *Pre-K mathematics curriculum*. Glenview, IL: Scott Foresman.

Klein, A., & Starkey, P. (2004a). Fostering preschool children's mathematical knowledge: Findings from the Berkeley Math Readiness Project. In D. H. Clements & J. Sarama & A.-M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 343–360). Mahwah, NJ: Lawrence Erlbaum Associates.

Klein, A., & Starkey, P. (2004b). *Scott Foresman–Addison Wesley Mathematics: Pre-K*. Glenview, IL: Pearson Scott Foresman.

Klibanoff, R. S., Levine, S. C., Huttenlocher, J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical knowledge: the effect of teacher "math talk." *Developmental Psychology, 42*, 59–69.

Lambert, R. G, O'Donnell, M., & Abbott-Shim, M. (2008). *The effect of creative curriculum training and technical assistance on head start classroom quality*. Paper presented at the meeting of the Society for Research on Educational Effectiveness, Washington, DC.

Massachusetts Department of Elementary and Secondary Education. (2000). *Mathematics curriculum framework*. Malden, MA: Author. Retrieved from http://www.doe.mass.edu/frameworks/math/2000/toc.html

Mullis, I. V. S., Martin, M. O., Beaton, A. E., Gonzalez, E. J., Kelly, D. L., & Smith, T. A. (1997). *Mathematics achievement in the primary school years: IEA's third international mathematics and science study (TIMSS)*. Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Gregory, K. D., Garden, R. A., O'Connor, K. M., et al. (2000). *TIMSS 1999 international mathematics report*. Boston: The International Study Center, Boston College, Lynch School of Education.

National Center for Education Statistics. (2002). *Children's reading and mathematics achievement in kindergarten and first grade*. Washington, DC: U.S. Government Printing Office.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics*. Reston, VA: Author.

Natriello, G., McDill, E. L., & Pallas, A. M. (1990). *Schooling disadvantaged children: Racing against catastrophe*. New York: Teachers College Press.

Rathbun, A., & West, J. (2004). *From kindergarten through third grade: Children's beginning school experience*. Washington, DC: National Center for Education Statistics. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2–4–7#

Riordan, J. E., & Noyce, P. E. (2001). The impact of two standards-based mathematics curricula on student achievement in Massachusetts. *Journal for Research in Mathematics Education, 32*, 368–398.

Saxe, G. B., Guberman, S. R., & Gearhart, M. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development, 52*(2 Serial No. 216).

Shonkoff, J. P., & Phillips, D. A. (Eds.). (2000). *From neurons to neighborhoods: The science of early childhood development*. Washington, DC: National Academy Press.

Starkey, P. (2007). Fostering the learning of mathematics in low-income children. *Dialog Briefs*, 10(2), 1–7.

Starkey, P., & Klein, A. (1992). Economic and cultural influences on early mathematical development. In F. L. Parker, R. Robinson, S. Sombrano, C. Piotrowski, J. Hagen, S. Randolph, et al. (Eds.), *New directions in child and family research: Shaping Head Start in the 90s* (pp. 440–443). New York: National Council of Jewish Women.

Starkey, P., & Klein, A. (2000). Fostering parental support for children's mathematical development: An intervention with Head Start families. *Early Education and Development, 11*, 659–680.

Starkey, P., & Klein, A. (2008). Sociocultural influences on young children's mathematical knowledge. In O. N. Saracho & B. Spodek (Eds.), *Contemporary perspectives on mathematics in early childhood education* (pp. 253–276). Charlotte, NC: Information Age.

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly, 19*, 99–120.

U.S. Department of Health and Human Services. (2007). *Final report, Secretary of Health and Human Services Advisory Committee on Head Start Accountability and Educational Performance Measures*. Washington, DC: Author. Retrieved from http://www.acf.hhs.gov/programs/hsb/budget/AdvCmteSep05/SAC_NRS_Report_Jan2007.htm

U.S. Department of Labor, Bureau of Labor Statistics. (2006). The 2004–24 job outlook for college graduates. *Occupational Outlook Quarterly Online, 50*, Number 3.

Wakeley, R. A. (2002). *Early mathematical development in very low birthweight children*. Unpublished doctoral dissertation, University of California, Berkeley.

West, J., Denton, K., & Germino-Hausken, E. (2000). *America's kindergarteners*. Washington, DC: National Center for Education Statistics, U.S. Department of Education.

APPENDIX

Fidelity of Implementation Record (© A. Klein and P. Starkey, 2002)

Part A. Small-Group Activities of Pre-K Mathematics Curriculum

Small-group activity observed: Unit: ____________Activity: ____

A.1. Date scheduled in curriculum plan: __________

Time of activity: Began:_____ Ended:______

B.1. Group Composition (list focal children) Configuration (draw table arrangement)

B.2. Social arrangement of groups: Teams of 2 children vs. Individuals

B.3. Materials are set up correctly and completely? Yes No
If no, explain:

C.1. Does teacher observe children during activity?	Rarely or Not Done (<10%)	Sometimes Done (10-50%)	Usually Done (>50%)	
C.2. Is teacher responsive to children's questions?	Rarely or Not Done (<10%)	Sometimes Done (10-50%)	Usually Done (>50%)	None Asked

C.3. Key mathematical terms used by teacher: ____

C.4. Entire activity completed with group? Yes No
If not, what was not completed and why?

C.5. Any significant substantive departures from script? Yes No If yes, describe: ______________________

____

D.1. Scaffolding Used Choose One:	Not Needed	Needed and… Rarely or Not Done (<10%)	Sometimes Done (10-50%)	Usually Done (>50%)
Usual quality of scaffolding:	Too specific or detailed	About right	Too general or vague	

D.2. Upward Extension: Yes No Not needed

D.3. Downward Extension: Yes No Not needed

Assessment Record Sheet used for today's small group **(attach photocopy)**:

E.1.	Names entered:	Yes	No
E.2.	√ for each problem completed:	Yes	No
E.3.	Comments entered:	Yes	No
E.4.	Incidence of scaffolding recorded?	Yes	No
E.5.	Incidence of downward extensions recorded?	Yes	No
E.6.	Incidence of upward extensions recorded?	Yes	No

Quality of small group management during activity: Low Moderate High

Quality of general classroom management during activity: Low Moderate High

How were children who were not in the small math group managed?