

Abstract Title Page

Title:

Stages in the Development of a Mathematics Intervention for Public Preschool Programs

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Background/context:

Description of prior research and/or its intellectual context and/or its policy context.

All citizens need a broad range of basic mathematical understanding to make informed decisions in their jobs, households, communities, and politics; in addition, careers require an increasing level of proficiency. 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 et al., 2001; Mullis et al., 2000). Economically disadvantaged children demonstrate significantly lower levels of achievement (Bowman, Donovan, & Burns, 2001; Denton & West, 2002).

These differences have roots in the earliest years. Preschool children from low socioeconomic status (SES) families possess less extensive mathematical knowledge than their peers from higher SES families (e.g., Jordan, Huttenlocher, & Levine, 1994; Starkey, Klein, & Wakeley, 2004). Moreover, this SES-related gap is present as early as 3 years of age, and widens during the preschool years in the United States (Starkey & Klein, 2007). As a consequence, children from different socioeconomic backgrounds often enter elementary school at different levels of readiness to learn a standards-based mathematics curriculum (Clements, Sarama, & DiBiase, 2004; Starkey, 2007). The source of the early SES-related gap in mathematical knowledge is twofold. Children from low-income families receive less support for mathematical development both at home and in their school environments. Many low-income American parents provide a narrower range of mathematical learning opportunities than middle-income parents provide (Blevins-Knabe & Musin-Miller, 1996). They are also more likely to expect preschool teachers to provide instruction in number-related skills (Holloway et al., 1995). Many public preschool programs serving low-income families, as compared to private programs serving middle-income families, provide fewer learning opportunities and supports for mathematical development (e.g., Bryant, et al., 1994; Starkey, 2003). In general, pre-kindergarten teachers do not use a systematic math curriculum, receive little or no training in early childhood mathematics, are unfamiliar with the math curriculum taught in local elementary schools, and know little about math standards (Copley, 2004). In summary, both the home and school learning environments of low-income American children are less rich mathematically than learning environments of middle-class children. This lack of support for mathematical development results in a SES-related gap in mathematical knowledge that appears early and widens during early childhood.

The long-term success of low-income children requires high-quality experiences during their early "years of promise" (Carnegie Corporation, 1998). Research shows that such experiences result in greater school readiness upon entry into kindergarten (Bowman et al., 2001; National Center for Educational Statistics, 2002; Shonkoff & Phillips, 2000). Furthermore, focused early math interventions help prevent later learning difficulties in mathematics for all children (Fuson, Smith, & Lo Cicero, 1997). Unfortunately, most American children are not in high-quality preschool programs (Hinkle, 2000). Therefore, if progress in improving the mathematical proficiency of our citizens is to encompass *all* children, much greater attention must be given to *early* mathematics experiences. This education must begin in preschool, and it must be improved – especially for low-income children.

To attempt to close the SES-related gap in mathematical knowledge, we have spent several years developing a mathematics intervention for economically disadvantaged preschool children. Development has gone through the following phases:

Stage 1. A home mathematics intervention was developed to enable low-income parents to enhance their support of their preschooler's mathematical development. Dyadic (parent-child) math activities were created primarily by adapting tasks from the basic research literature on early mathematical development. Head Start families were randomly assigned to an Intervention (I) Group (home math curriculum) or a Comparison (C) Group (no home curriculum). Parents then used these activities at home with their 4-year-old. An assessment of children's mathematical knowledge revealed that children in the I Group developed more knowledge during the pre-k year than their peers in the C Group (Starkey & Klein, 2000).

Stage 2. A conceptually broad pre-kindergarten mathematics curriculum for use by teachers in a variety of programs (Head Start, state preschools, and private preschools). A sample of 163 pre-k children in 10 classrooms (5 in programs serving low-income families and 5 serving middle-income families) was included. Teachers learned to implement the curriculum in two multi-day workshops with on-site technical assistance. I children received the mathematics curriculum during their pre-k year. Comparison children did not receive the math curriculum. An assessment instrument, the Child Math Assessment, was developed to assess children's mathematical knowledge. ANOVAs revealed that children in the I Group developed significantly more mathematical knowledge than children in the C Group did (Starkey, Klein, & Wakeley, 2004).

Stage 3. The combined home and classroom intervention was evaluated in a randomized field trial. Classrooms were randomly assigned to intervention and control conditions. Objectives of the project were to determine whether the curricular intervention, when implemented with fidelity, would increase the amount of mathematics support provided by intervention children's teachers and parents and, if so, enhance intervention children's mathematical knowledge. A classroom observation instrument, Early Mathematics Classroom Observation (EMCO), was developed in order to measure proximal effects of the mathematics intervention on the classroom learning environment. Findings supported the hypothesis that the curricular intervention would have a greater impact on the amount of intentional mathematics support provided by intervention teachers than by control teachers. The principal hypothesis of the study was that the curricular intervention would have a significant impact on intervention children's mathematical development as compared to control children. Hierarchical models (children nested within classrooms and time nested within each child) were used to fit the data for two sets of analyses. The first set analyses examined children's composite CMA scores from the beginning (pre-test) to the end (post-test) of the pre-kindergarten year in a repeated measures analysis. A conditional model was created using Time (Fall or Spring), Group (Control or Intervention), Site (CA or NY), Preschool Type (Head Start or State preschools), and all possible interactions as independent variables. A second set of analyses used children's gain (difference) scores on the CMA from pre-test to post-test as the outcome measure. The first set of repeated measures analyses revealed that CMA Scores increased significantly over time, $F(1,270)=699.17$, $p<.0001$. Gain score analyses revealed the same pattern of effects, with the intervention children demonstrating significantly greater gains in mathematical knowledge on the CMA than the control children. Effect size (Cohen's d) was .84. This effect size value shows that the math curriculum produced a 62% increase in math knowledge for the intervention children relative to what the control children gained over the pre-kindergarten year (Klein, Starkey, Clements,

Sarama, & Iyer, 2008). Thus, the combined home and classroom intervention is effective. It enhances mathematical development in low-income pre-kindergarten children.

Stage 4. Currently, a scale-up project is being conducted at a customary program-wide level of scale in varied contexts, including different types of public preschool programs in multiple states. This research is described below.

Purpose/objective/research question/focus of study:

The Scale-Up Pre-K Mathematics project, was conducted at a customary program-wide level of scale in Head Start and state-funded preschool programs in California and Kentucky/Indiana. The objectives of this randomized field trial were twofold: (1) to determine whether the intervention, the Pre-K Mathematics curriculum, continues to be effective when implemented on this level of scale and at a distance from the developer, and (2) to document the process of implementing a pre-kindergarten math intervention in varied preschool settings in order to better understand the barriers to scalable interventions.

Setting:

The field trial was conducted in varied contexts, which included Head Start and state preschool programs in California, Kentucky and Indiana. Teachers from 94 classrooms at 62 sites (Head Start centers or public schools) were included in the experiment.

Population/Participants/Subjects:

The sample for the experimental field trial included 744 children in 96 preschool classrooms at 60 sites. The California sample was comprised of ethnically diverse, low-income urban children. The Kentucky/Indiana sample was comprised predominantly of Caucasian, low-income rural children.

Intervention/Program/Practice:

Components of the Pre-K Mathematics Intervention. The pre-K mathematics intervention used in this project included two components that target the learning environments of young children, the classroom and the home, and a third component that provided professional development for facilitators and teachers who implemented the math curriculum in their classrooms.

Classroom component. The classroom component provided conceptually broad support for the development of children's informal mathematical knowledge. It consisted of a set of *small-group math activities* with concrete manipulatives, *math software*, and a *math learning center* in the classroom. The small-group activities have been published as a teacher's manual, Pre-K Mathematics Curriculum (Klein & Starkey, 2004). The mathematical content of the small-group activities were based on developmental research about the nature and extent of early mathematical knowledge (see Geary, 1994 and Ginsburg et al., 1998 for reviews of research). Activities with closely related mathematical content were organized into units in order to help children make connections among related concepts. Furthermore, the units were explicitly linked with the National Council of Teachers of Mathematics 2000 standards for pre-K - grade 2 (NCTM, 2000).

The Pre-K Mathematics Curriculum is comprised of 7 units: (1) Number Sense and Enumeration, (2) Arithmetic Reasoning (less-advanced fall activities), (3) Spatial Sense and Geometric Reasoning, (4) Pattern Sense and Pattern Construction, (5) Arithmetic Reasoning (more-

advanced spring activities), (6) Measurement and Data Representation, and (7) Logical Relations. Each unit begins with a brief overview of the development of the mathematical concepts supported by the unit. There are a total of 32 small-group math activities in the curriculum, and each small-group activity specifies the key mathematical terms, the set up and the materials needed for the activity. Scripting provided an example of what a teacher might say in an activity, however, some alternative phrasing does not compromise implementation fidelity.

Several key features of this curriculum were designed to be sensitive to the developmental needs of young children. Downward (less-challenging) extensions of the small-group activities were provided for children who were not ready for a given activity, and upward (more challenging) extensions were included for children who completed an activity easily. Furthermore, suggestions were provided for scaffolding or supporting children who experienced difficulty with a part of the activity. Finally, assessment sheets that accompanied each small-group activity enabled the teacher to record individual children's learning over the course of the curriculum.

Teachers typically conducted small-group math activities twice a week with groups of 4 – 6 children for 20-25 minutes. Small-group activities were presented to pre-K children according to a weekly curriculum plan with one new math activity introduced each week during the school year. Review weeks were also incorporated into the curriculum plan to accommodate children who were absent or had difficulty with a particular activity.

In addition to the teacher-guided small-group activities, two other instructional approaches were included in the classroom component of the math intervention to accommodate children's individual learning styles – math software and a math learning center..

Home component. The home component provided parents with activities to support their children's mathematical development to complement the math support children were receiving at preschool. The Pre-K Mathematics Curriculum (Klein & Starkey, 2004) includes 21 home math activities and materials for families to use with their pre-K. A Spanish version of the home math activities was used with Spanish-speaking families. Teachers sent these activities home to parents according to a curriculum plan that integrated the small-group and computer activities. The home math activities contained many of the same developmental features (e.g., scaffolding, downward and upward extensions) as the small-group activities with the difference that the home activities were represented as picture strips in order to minimize the literacy burden on families.

Professional development component. A key feature of the professional development component was the trainer-of-trainers model that was used to implement the math curriculum in a scale-up context. Internal facilitators (PD staff from or contracted for the preschool programs) attended a Facilitators Institute to learn the Pre-K Mathematics Curriculum and to learn how to provide on-site training and support to teachers implementing the math curriculum in their programs. Internal facilitators, in turn, helped train the teachers and monitored the fidelity of implementation of the math curriculum in their classrooms. Thus, the trainer-of-trainers model insured that the pre-K math intervention was implemented in programs under conditions of routine educational practice.

Research Design:

The basic research design was a cluster randomization in which the 62 sites described above were randomly assigned to the intervention and control conditions. The sites within each type of program (Head Start and state-funded preschool) within each state (CA and KY/IN) were grouped into pairs that are similar with regard to the size of the site (total number of classrooms), type (half-day or full-day classrooms), and, predominant classroom language (English or

Spanish). If there were more classrooms or sites than needed in any grouping, the appropriate numbers were selected randomly.

Data Collection and Analysis:

A set of instruments was used to assess *knowledge outcomes* in children. The CMA (Starkey et al., 2004) was used to provide a measure of children's informal mathematical knowledge across a broad range of skills and concepts. It was administered to children individually in the fall and spring of the pre-K year. The CMA is comprised of 16 tasks, with multiple problems per task, that assess knowledge in the areas of number, arithmetic, space and geometry, measurement, and patterns. The range of difficulty is appropriate for children from 3 to 5 years of age (preschool to K). The TEMA-3 (Ginsburg & Baroody, 2003) was used along with the CMA as a standardized measure of children's developing mathematical knowledge. Instruments (e.g., EMCO, teacher and parent questionnaires, Fidelity of Implementation Record Sheet) were also administered to collect data on potential moderators of effects in the classroom and home learning environments.

Findings/Results:

A 3-level repeated measures ANOVA, with children nested within classrooms within sites, revealed no difference between conditions at pretest but found a strong condition by time interaction, indicating that children in the intervention condition showed a greater increase in mathematical knowledge than children in the control condition, $p < .0001$. The intervention effect was consistent across states. An ANCOVA model revealed converging findings. There was a significant difference in adjusted posttest scores between the intervention and control conditions on the CMA, $p < .0001$.

Children's mathematical knowledge was assessed at pretest and posttest using the CMA and TEMA-3. Mean proportion correct on the CMA by intervention children (.30) and control children (.32) did not differ at pretest. Mean proportion correct by intervention children (.61) and control children (.48), a mean difference of 12.77 or .74 standard deviations. An alternative measure is to take the difference in the adjusted means, 14.31, divided by the pooled standard deviation, which gives .83 standard deviations. By either procedure, the effect sizes are large. Additional child outcome and moderator analyses will be reported.

Conclusions:

Experiment 2 findings indicate that the intervention, Pre-K Mathematics, is still effective when implemented on a broad level of scale (individual school districts or Head Start grantees). Thus, by providing public preschool teachers with a mathematics curriculum like the one used in this study and by training teachers to implement the curriculum with fidelity, the SES-related gap in children's mathematical knowledge can be significantly reduced. These results have implications for the role of curricula in promoting school readiness, and in particular mathematics readiness, for children from low-income families.

Recommendations for policy makers. Programs should be encouraged to recommend or legislate use of math curricula 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 importantly, in the opportunity it will give children to begin to achieve in mathematics.

Appendix A. References

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