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Title: Scaling Up An Effective Pre-K Mathematics Intervention: Mediators and Child Outcomes

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Abstract Body

Background / Context:

All citizens need a broad range of basic mathematical understanding to make informed decisions in their jobs, households, and communities; in addition, careers require an increasing level of proficiency in mathematics (Glenn Commission, 2000; Kilpatrick, Swafford, & Findell, 2001). Yet, since the 1970s, a series of assessments of American 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). In recent years, the National Council of Teachers of Mathematics (NCTM, 2000; NCTM, 2006) and others have addressed these challenges with new standards and reforms to improve mathematics education, and some progress has been made at the elementary and middle school levels (National Mathematics Advisory Panel, 2008; Fuson, Carroll, & Drueck, 2000). Nevertheless, economically disadvantaged children continue to demonstrate significantly lower levels of math achievement in school (Bowman, Donovan, & Burns, 2001; Denton & West, 2002).

These achievement differences have roots in early childhood. A recent meta-analysis of data from several national studies of school achievement found that the strongest predictor of academic achievement in elementary school is mathematical knowledge at school entry (Duncan et al., 2007). Despite the importance of mathematical knowledge at school entry, however, children from different socioeconomic backgrounds enter elementary school at different levels of readiness to learn a standards-based mathematics curriculum (Clements, Sarama, & DiBiase, 2004; Starkey, 2007). 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, l994; Starkey, Klein, & Wakeley, 2004). Moreover, this SES-related gap is present as early as three years of age, and widens during the preschool years in the United States (Starkey & Klein, 2008). 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 preschool. Many low-income American parents provide a narrower range of mathematical learning opportunities than middle-income parents provide (Blevins-Knabe & Musin-Miller, 1996). Furthermore, public preschool programs serving low-income families, as compared to private programs serving middle-income families, typically provide fewer learning opportunities and supports for early mathematical development (e.g., Bryant, et al., l994; Starkey, 2003). In general, public preschool programs do not use a systematic math curriculum, and preschool teachers receive little training in early childhood mathematics (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.

Due to the SES-related gap in early mathematical knowledge and the need to improve low-income children's readiness for school mathematics, we developed an intervention, *Pre-K Mathematics*, and rigorously evaluated it over several studies. This math intervention has been found to be highly effective at improving pre-k children's mathematical knowledge relative to a control group (Klein, et al., 2008; also see What Works Clearinghouse website, http://ies.ed.gov/ncee/wwc). In this presentation, we examine the pre-k mathematics intervention implemented at a customary level of scale and at a distance from the developer. Analyses will examine (1) effectiveness at scale across varied contexts, and (2) classroom practices that mediate, at least in part, effective math outcomes for young children.

Experiment 1 - Main Study

Purpose / Objective / Research Question / Focus of Study:

The Main Study of the Pre-K Mathematics Scale-Up Project was a randomized controlled field trial that had two principal objectives: (1) to determine whether and how the pre-k mathematics intervention continues to be effective when implemented at a customary level of scale and at a distance from the developer, and (2) to document the process of implementing the math intervention in varied contexts in order to understand under what conditions the intervention is effective.

Setting:

The Main Study was conducted in varied contexts, which included Head Start and state-funded public preschool programs in California, Kentucky, and Indiana. Teachers from 94 classrooms at 63 sites (Head Start Centers or public preschools) were included in the experiment.

Population / Participants / Subjects:

The sample for the experimental field trial included 744 children in 94 classrooms at 63 preschool sites. The California sample was comprised of ethnically diverse, low-income urban children. The Kentucky/Indiana sample was comprised of predominantly Caucasian, low-income rural children. Attrition during the pre-k year was 10.1%.

Intervention / Program / Practice: *Pre-K Mathematics*, the curricular intervention used in this project, has been given the highest rating of effectiveness by the What Works Clearinghouse.

Classroom component of intervention. 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* (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. Activities with closely related mathematical content were organized into units in order to help children make connections among related concepts. Furthermore, units were explicitly linked with the National Council of Teachers of Mathematics standards for pre-K – grade 2.

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 the 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.

Home component of intervention. The home component of the intervention provided parents with activities to support their children's mathematical development and complement the math support children were receiving at preschool. A Spanish version of the home math activities was used with Spanish-speaking families.

Professional development component. A trainer-of-trainers model that was used to implement the math curriculum on the scale of a Head Start program or school district pre-k program. Internal facilitators (PD staff from or contracted for the preschool programs) attended a Facilitators Institute to learn *Pre-K Mathematics* 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. Teachers had, on average, 14 years of teaching experience, and 56% had BA degrees or higher; the remainder had AA degrees or less.

Research Design:
The basic research design was a cluster randomization in which the 63 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 were similar with regard to 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 children's knowledge outcomes. 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 9 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 ages 3 to 5 years of age (preschool to K). The TEMA-3 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) were also administered to collect data on potential mediators and moderators of effects in the classroom and home learning environments.

Findings / Results:

Fidelity of implementation. The fidelity of teachers' implementation of *Pre-K Mathematics* small group activities was measured periodically across the school year. Overall fidelity could possibly range from 0.00 (low fidelity) to 1.00 (high fidelity). Observed fidelity was high both in California (state-funded preschool classrooms, .96; Head Start, .94) and in Kentucky/Indiana (state-funded preschool classrooms, .94; Head Start, .96). This indicates that, in general, teachers implemented small group activities as intended by the developer. This implies that the amount and quality of the professional development that was provided was sufficient for teachers to implement with fidelity.

Curriculum dosage. Curriculum dosage that intervention children received in the classroom and at home was recorded. Summary statistics and moderator analyses are underway and will be presented in the paper.

Child outcomes. Children's mathematical knowledge was assessed at pretest and posttest using the CMA and TEMA-3. A 3-level repeated measures ANOVA of CMA composite scores, with children nested within classrooms within sites, revealed no significant difference in pretest scores between conditions. A significant Condition X Time interaction, $F(1,666)=171.28$, $p<.0001$ indicated greater change in intervention children's scores across time. An ANCOVA model revealed converging findings. There was a significant difference in adjusted posttest scores between the intervention and control conditions on the CMA, $p<.0001$. Intervention children's scores increased from 0.29 at pretest to 0.61 at posttest, an increase of 102%; control children's scores increased from 0.32 at pretest to 0.48 at posttest, an increase of 50%. Thus, intervention children's gains were approximately double those of control children. 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.

A parallel set of analyses of children's raw scores on the TEMA-3 at pretest and posttest revealed a significant Condition X Time interaction, $F(1,663)=47.66$, $p<.0001$. The effect size was moderate, .45 standard deviations. Intervention children's scores increased from 7.0 at pretest to 14.8 at posttest, an increase of 111%; control children's scores increased from 7.4 at pretest to 12.5 at posttest, an increase of 69%.

A parallel set of analyses of children's raw scores on selected subscales of the Woodcock-Johnson-III (Understanding Directions; Letter-Word Identification; Spelling) at pretest and posttest found no significant Condition X Time interaction for any of these subscales.

The intervention effect was consistent across states and program types (Head Start or state-funded public preschool). There was no significant effect of state or program type and no significant interaction of time with state or program type. This indicates that the intervention was robust across varied preschool contexts: Head Start vs. state-funded public preschool programs, and California programs serving urban, ethnically diverse families vs. Kentucky/Indiana programs serving predominantly rural white families. There was a marginally significant main effect for gender, with girls scoring higher on the CMA, in general, than boys $F(1,666)=5.45$, $p<.02$. Gender did not interact with time or condition.

Mediation analyses. Mediation analyses revealed that total minutes of math support per day, as measured by the EMCO, predicted child gains in mathematical knowledge, over and above condition. Specifically, more minutes of math, across all types of math support, were associated with greater gains on TEMA, even with condition controlled, $F(1,575)=7.10$, $p<.01$. Furthermore, more minutes of one particular type of math support (teacher-scaffolded, small-group math instruction), was associated with greater gains on TEMA, even with condition controlled, $F(1,574)=5.84$, $p<.02$. In contrast, minutes of whole-group math instruction was not associated with TEMA gains, $F(1,574)=1.92$, *ns*. Mackinnon's procedure found evidence of mediation for total minutes and small-group minutes of support but not for whole-group minutes of support.

Experiment 2 - Sustainability Study

Purpose / Objective / Research Question / Focus of Study:

The Sustainability Study of the Pre-K Mathematics Scale-Up Project was conducted during the year following the Main Study in the same classrooms. The objective was to determine whether the Head Start and state-funded public preschool programs and their teachers were able to sustain implementation of the math intervention in an effective manner beyond the initial year in which they received professional development.

Setting:

This study was conducted in the same Head Start and state-funded public preschool programs in California and Kentucky/Indiana as in the Main Study.

Population / Participants / Subjects:

The sample for included 326 children in 39 intervention classrooms. The California sample was comprised of low-income, ethnically diverse, urban children. The Kentucky/Indiana sample was comprised of low-income, predominantly Caucasian, rural children. Attrition during the pre-k year was 7.1%

Intervention / Program / Practice:
Intervention teachers from the Main Study continued implementing the classroom and home components of the math intervention with pre-k children during the subsequent year. Fidelity and dosage data will be provided.

Research Design:
The randomization for the Main Study assigned 48 classrooms and their teachers to the intervention condition. Of these, 39 teachers continued teaching in these programs at the pre-k level during the subsequent year of the Sustainability Study. The remaining 9 teachers could not be included, because they were no longer teaching pre-k children in the participating programs.

Data Collection and Analysis:
The measures used in the Main Study were again used the Sustainability Study in order to determine the extent to which the implementation and positive child outcomes could be sustained by programs and to identify any factors associated with changes in implementation.

Child outcomes.
Children's mathematical knowledge was assessed at pretest and posttest using the CMA and TEMA-3. A 3-level repeated measures ANOVA of CMA composite scores, with children nested within classrooms within sites, revealed no significant difference in pretest scores between conditions. A significant Condition X Time interaction, $F(1,527)=68.82$, $p<.0001$ (effect size, .70), indicated greater change in intervention children's scores across time. A parallel set of analyses of children's raw scores on the TEMA-3 at pretest and posttest revealed a significant Condition X Time interaction, $p<.0001$ (effect size, .45).

Conclusions:
The professional development model that was employed in the Main Study enabled teachers to implement with fidelity and effectively. Main impact analyses indicate that the *Pre-K Mathematics* intervention was highly effective when implemented at a customary level of scale, with intervention children experiencing gains in mathematical knowledge about twice as great as control children's gains. The intervention was sufficiently robust that children experienced significant mathematical growth across varied contexts, including Head Start and state preschool programs serving urban, ethnically diverse families in California and predominantly white, rural families in Kentucky and Indiana. Mediation analyses supported our hypothesis that the causal influence was transmitted, at least in part, by teacher-scaffolded small group mathematics activities.

The Sustainability Study findings indicated that Head Start and state-funded public preschool programs and their teachers were able to sustain implementation of the math intervention in an effective manner beyond the initial year in which they received professional development. Gains in mathematical knowledge by intervention children were significantly greater than those of control children.

Recommendations for policy makers. Public preschool programs should be given encouragement and assistance to implement math curricula that are of proven effectiveness. To build capacity in early math, there is a need to provide professional development in early math to program trainers as well as preschool teachers. It is also recommended that programs forge a closer working relationship with parents, such as having teachers send pre-k math materials home to parents. We believe that these changes are necessary to make economically disadvantaged children ready for elementary school mathematics.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

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