Title: A Randomized Study of the Efficacy of a Two-Year Mathematics Intervention for At-Risk Pre-Kindergarten and Kindergarten Students

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Abstract

Background: Educators are increasingly concerned about the low level of mathematics performance of U.S. students on the TIMSS and other international assessments of mathematics (National Mathematics Advisory Panel, 2008) as well as their preparation for mathematics standards, such as the Common Core State Standards for Mathematics (CCSSM). Furthermore, students from low-income and minority backgrounds demonstrate lower levels of mathematics achievement than their peers from more advantaged backgrounds, and there is compelling evidence that this SES-related achievement gap in mathematics emerges prior to school entry (e.g., Starkey & Klein, 2008). Research has shown that math intervention in the prekindergarten (PK) year reduces but does not completely close this early SES-related math gap (insert Figure 1 here). Also, effects of PK math interventions persist, but are diminished, in kindergarten (K) and beyond (insert Figure 2 here; Starkey, Klein, & DeFlorio, 2014). We will report a multi-year (PK and K) intervention, which is a relatively new and innovative approach to reducing the early math gap. This intervention spans an education and life cycle transition – from informal preschool education to formal elementary education. It addresses potential effects of and challenges posed by education policies, including public preschool program quality and the higher learning expectations of the CCSSM, beginning in K.

Objective: The objective of this IES-supported project was to test the efficacy of two years of continuous mathematics intervention for economically disadvantaged children. Both the PK and the K interventions, when implemented alone, were previously found in IES-supported efficacy studies to be effective with this population (Klein, et al., 2008; Clarke, et al., 2011). In the present project, their combined impact on low-income students’ mathematical knowledge was measured in an RCT.

Setting: This experimental field trial was conducted in categorical public preschools and Head Start programs in California. Teachers from 41 classrooms were included in the RCT.

Participants: The sample for the experimental field trial included 389 economically disadvantaged PK children (8-12 per classroom) who were age-eligible for K during the next school year. Mean age at PK pretest was 4.47 years. Sample composition was 179 boys, 210 girls, 76% Latino, 7% white, 4% black, 3% Asian-American, 8% multi-ethnic, 3% unknown, 48% English speaking, 40% Spanish speaking, 12% bilingual (English and Spanish). Children who spoke neither English nor Spanish were excluded.

Intervention: A two-year curricular intervention was implemented using Pre-K Mathematics, when treatment (T) children were in PK, and Early Learning of Mathematics, the following year when T children were in K. Curriculum activities and PD, aligned with the Common Core State Standards in Mathematics, were conducted by students’ regular teachers following extensive PD. A business-as-usual control (C) condition was included as the counterfactual.

Research Design: A two-condition (T and C) RCT was conducted, with clusters of PK and K classrooms as the unit of randomization. Most children from a PK classroom in a cluster flowed into 1-2 K classrooms in the cluster. The design was a three-level experimental design with observations nested within children and children nested within PK-K classroom clusters. Within
each participating PK classroom, children who were age eligible for K in the next school year were randomly selected.

**Data Collection, Analysis, and Findings:** The Child Math Assessment (CMA) and Test of Early Mathematics Ability (TEMA-3) were used to assess child outcomes in fall (pretest) and spring of PK, and the TEMA-3 was used in spring (posttest) of K and grade 1 (follow up). The Early Mathematics Classroom Observation (EMCO) and Classroom Observations of Student-Teacher Interactions (COSTI) were used to measure classroom mathematics practices in PK and K classrooms, respectively. Implementation measures included fidelity and dosage measures in PK and K.

ANCOVAs of math outcomes at the end of the first year of intervention (fall of PK to spring of PK) revealed significant Condition X Time interactions, with more mathematical knowledge acquired by T children than by C children: CMA, $F(1,38)=14.86$, $p<.001$, ES=0.64; TEMA-3 raw scores, $F(1,35)=7.80$, $p<.01$, ES=0.46. ANCOVAs of math outcomes at the end of the second year of intervention (fall of PK to spring of K) revealed significant Condition X Time interactions, favoring T children: TEMA-3 raw scores, $F(1,36)=3.85$, $p<.05$, ES=0.32 (Figure 3). Math outcomes at the end of K were greater for children with lower TEMA raw scores at PK entry than for children with higher TEMA scores: lower entry scores, ES=0.50; higher entry scores: raw, ES=0.21. Analyses of grade 1 follow-up data will be conducted and presented.

Classroom observations revealed differences in math practices of T and C teachers. T teachers, relative to PH C teachers, spent more time on math instruction overall, $F(1,39)=25.33$, $p<.0001$, and spent more time engaged in instruction that utilized a set of best math practices, $F(1,39)=286.32$, $p<.0001$. This set of best practices included greater use of (1) small-group math activities, rather than individual or whole-group activities, (2) mathematically focused activities, rather than embedding math in other activities such as art, and (3) individualized scaffolding by teachers, rather than providing no scaffolding or general scaffolding to whole class. Amount of use of these practices predicted child math outcomes. It was also found the K T teachers, relative to C teachers, provided children with more math practice opportunities, $F(1,261)=23.23$, $p<.0001$.

**Conclusions:** The 2-year curricular intervention had intermediate effects on teachers’ mathematics practices. PD changed math practices quantitatively (more time was spent on math) and qualitatively (some new practices were relied on more than BAU practices). The intervention improved mathematics achievement, especially for children who entered PK with the lowest level of mathematical knowledge. The 2-year intervention maintained, in grade K, the effects produced in PK, and thus it better prepared children for the CCSSM. This pattern contrasts with prior 1-year (PK) interventions in which partial fade out occurred in K (Figures 2 and 3). Fade out in grade 1, if any, will be addressed. Interventions that span early childhood programs and elementary education programs are challenging methodologically and institutionally. They have the potential, however, of preparing a greater proportion of young children to meet the higher learning expectations of the CCSSM.
Appendices
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Appendix A. References
References are to be in APA version 6 format.


Appendix B. Tables and Figures

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The intervention significantly improved low-SES children’s mathematical knowledge.
TEMA-3 Raw Scores of Treatment and Control Children in Pre-K and K (Pre-K Scale-Up Study)
TEMA-3 Raw Scores of Treatment and Control Children in Pre-K and K

![Graph showing TEMA-3 Raw Scores of Treatment and Control Children in Pre-K and K](image-url)