Abstract Title Page

Title: Establishing and Sustaining an Effective Pre-Kindergarten Math Intervention at Scale

Authors and Affiliations:
Alice Klein, WestEd
Prentice Starkey, WestEd
Lydia DeFlorio, University of Nevada, Reno and WestEd
E. Todd Brown, University of Louisville

Abstract Body

Background / Context:

      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 insufficient preparation for mathematics standards, such as the Common Core State Standards. 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. Cross-cultural research on children's early mathematical development in China and the United States has found that cross-SES differences within each country are present at 3 years of age. The SES gap, however, narrows in China during the preschool years but widens in the United States (Starkey & Klein, 2008). One contributing factor is that preschools in urban areas of China implement a mathematics curriculum for all children beginning at age 3, whereas many public preschool programs in the United States do not implement effective mathematics curricula (e.g., Preschool Curriculum Evaluation Research Consortium, 2008; U.S.DHHS/ACF, 2010). It is also known from a recent meta-analysis of several large longitudinal studies that children's mathematics knowledge in kindergarten is the strongest predictor of their later school achievement – stronger than early literacy knowledge, attention skills, or socioemotional development (Duncan, et al., 2007). If this gap is not addressed early, it persists and increases over time (e.g., Bodovski & Farkas, 2007; Morgan, Farkas, & Wu, 2009). Thus, it is clear that the acquisition of early mathematics knowledge by all children must be a major educational priority.

      To address this educational priority, our research group has developed an early mathematics intervention, *Pre-K Mathematics* (Klein & Starkey, 2004). With collaborators, we have rigorously evaluated it over multiple studies and have found it to be highly effective at improving mathematical knowledge in economically disadvantaged pre-kindergarten children relative to a control group (Klein, et al., 2008; also see What Works Clearinghouse website, http://ies.ed.gov/ncee/wwc). However, testing the scale-up of an early mathematics intervention already shown to have beneficial effects shifts the focus from the effectiveness of the curriculum per se to the effectiveness of the proposed process by which public preschool and Head Start programs can be assisted to implement the curriculum well enough to attain its benefits. The level of scale used in this project – school district preschool programs and grantee-operated Head Start programs – is the customary level at which preschool curricular adoptions are made.

      Our scale-up project was comprised of two studies. First, a Main Study was conducted to evaluate the effectiveness of *Pre-K Mathematics* when implemented at scale. Second, a Sustainability Study was conducted to determine whether programs could sustain an effective implementation of *Pre-K Mathematics* beyond the initial year in which intensive professional development was provided. In this presentation, we will review the principal child outcomes and mediation model from the Main Study, and then focus on the Sustainability Study and a comparison between the findings of the two studies. Finally, we will discuss the policy implications of these findings for establishing partnerships with preschool programs in order to help them implement and sustain effective early mathematics curricula.

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 school 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. 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* (Klein & Starkey, 2004), the curricular intervention used in this project, included classroom, home, and professional development components. The classroom component provided conceptually broad support for the development of children's informal mathematical knowledge. It consisted of a set of 27 *small-group math activities* with concrete manipulatives, *math software*, and a *math learning center* in the classroom. The mathematical content of the small-group activities was based on based on developmental research about the nature and extent of early mathematical knowledge. Teachers typically conducted small-group math activities twice a week with groups of 4 children for 20 minutes, plus a review day for absent or struggling children. The home component of the intervention provided parents with activities to support their children's mathematical development and complemented the math support children were receiving at preschool. A Spanish version of the home math activities was used with Spanish-speaking families. Finally, the professional development component utilized a trainer-of-trainers model to implement the math curriculum on the scale of a Head Start program or school district preschool program. Program trainers or coaches attended a Facilitators Institute to learn *Pre-K Mathematics* as well as to learn how to conduct fidelity visits and support teachers implementing the math curriculum in their classrooms. The program trainers, in turn, helped train the teachers and monitored their fidelity of implementation of the math curriculum in their classrooms.

Research Design:
The basic research design was a cluster randomization in which 94 classrooms at 63 sites were randomly assigned to the intervention and control conditions in accordance with the prior power analysis. 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 early mathematical knowledge. The Child Math Assessment (CMA) was used to provide a measure of children's informal mathematical knowledge across a broad range of skills and concepts. The TEMA-3 was used along with the CMA as a standardized measure of children's developing mathematical knowledge. Classroom

observation (EMCO) and curriculum fidelity instruments were also administered to collect data on potential mediators and moderators of intervention effects.

Findings / Results:
The fidelity of teachers' implementation of *Pre-K Mathematics* small-group activities was measured 6 times across the school year. Observed fidelity was high both in California (.92) and in Kentucky/Indiana (.90). This indicates that, in general, teachers implemented small-group math activities as intended by the developers. Children's mathematical knowledge was assessed at pretest and posttest of the pre-k year using the CMA and TEMA-3. Nested analyses found that significantly greater gains in mathematical knowledge were experienced by treatment children, relative to control children, on both the CMA (ES=.83) and the TEMA-3 (ES=.45). Moreover, the intervention effect was consistent across states and program types. 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 *Pre-K Mathematics* intervention was robust across the varied preschool contexts included in this study.

Classroom observations of teachers' math practices were conducted in both intervention and control classrooms. Analyses revealed that treatment teachers, relative to control teachers, learned to use a set of best math practices – small-group activities that were mathematically focused and scaffolded by teachers. Consistent with the proposed mediation model, it was found that this set of best math practices indirectly mediated the intervention by engaging children's developing mathematical cognition.

Sustainability Study
Purpose / Objective / Research Question / Focus of Study:
The Sustainability Study was conducted in the same intervention classrooms with the same teachers during the year following the Main Study. The principal objective was to determine whether 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 preschool programs in California and Kentucky/Indiana as in the Main Study.
Population / Participants / Subjects:
The sample included 326 children in 39 treatment 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 10%.
Intervention / Program / Practice:
Intervention teachers from the Main Study continued implementing the classroom and home components of *Pre-K Mathematics* with pre-k children during the Sustainability year. Fidelity was similar in the first and second years of implementation, .91 and .93, respectively. Teachers also provided children with similar amounts of the intended dosage of classroom activities in the first and second years of implementation, 85% and 88%, respectively, and children mastered similar percentages of small group activities, 71% and 65%, respectively. Child absences were the most common reason for missing doses.
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 their programs at the pre-k level during the subsequent year in which we conducted 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 same set of instruments was used in the Sustainability Study in order to determine the extent to which the implementation and positive child outcomes could be sustained by programs.

Findings / Results:

Child math outcomes.

Children's mathematical knowledge in pre-kindergarten was assessed at pretest and posttest using the CMA and TEMA-3. A 3-level ANOVA of CMA scores, with children nested within classrooms within sites, revealed no significant difference in pretest scores between conditions. A significant Condition X Time interaction, $F(1,527)=68.82, p<.0001$ (ES=.70), indicated greater change in intervention children's scores across time. A parallel set of analyses of children's TEMA-3 scores at pretest and posttest revealed a significant Condition X Time interaction favoring treatment children, $F=(1, 527) = 34.57, p<.0001$ (ES=.45).

> **Comparison of child math outcomes between teachers' first and second year of implementation.** The next set of analyses compared gains in children's math knowledge between treatment teachers' first year of implementation (Main Study) and their second year of implementation (Sustainability Study). There were no significant differences between implementation years in children's CMA scores or TEMA scores.

> **Kindergarten follow up: TEMA.** Longitudinal follow-up analyses examined whether the positive effects of the intervention on children's math knowledge persisted into kindergarten. TEMA-3 raw scores at pre-k pretest (time 1), pre-k posttest (time 2), and middle of grade K (time 3) were analyzed using a repeated measures mixed model. Treatment children, relative to control children, demonstrated significantly greater mathematical knowledge both at time 2, $F(1, 1398) = 20.37, p < .0001$, and time 3, $F(1,1398) = 38.44, p < .0001$.

> **Kindergarten follow up: Teacher report cards.** Kindergarten teachers, who were blind to children's assigned condition during the pre-k intervention year, rated children's mathematical ability on a Uniform Report Card. These data provide further evidence that the effects of the intervention persisted into kindergarten. Teachers reported that mathematical knowledge was more extensive in treatment children than in control children, $F(1,547)=21.245, p < .0001$.

Teachers' mathematics practices.

> In the first year of implementation, it was found that treatment teachers, relative to control teachers, spent more time on math instruction overall and more time engaged in instruction that utilized a set of best math practices, which had been emphasized in the *Pre-K Mathematics* training provided. This set of best practices included greater use of small-group math activities, focal (mathematically explicit) activities, and scaffolding. In the second year of implementation, treatment teachers, relative to control teachers, continued to spend more time engaged in math instruction compared to control teachers, $F(1,77) = 19.394, p < .0001$. Treatment teachers also continued to use the set of best math practices. Specifically, they devoted more instructional time on small-group math activities, $F(1,77) = 74.176, p < .0001$, focal math activities, $F(1,77) = 24.305, p < .0001$, and provided children with scaffolding for math learning more often, $F(1,77) = 26.040, p < .0001$ compared to control teachers. As in the first year of implementation, there were no significant differences by condition in the amount of

instructional time devoted to whole-group math activities, embedded math activities, or math activities in which children were not provided with scaffolding.

Conclusions:
Public Preschool Programs Can Improve Children's Math Outcomes by Implementing an Effective Math Curriculum Coupled with High Quality Mathematics Practices

A policy implication that can be drawn from these findings is that programs need both an effective math curriculum and teachers who utilize a set of best mathematics practices when implementing the curriculum. It is this combination that helps public preschool programs address the SES-related math gap. Furthermore, significant improvement in children's math outcomes can be obtained in the initial year of implementation as evidenced by the Main Study results.

Public Preschool Programs Can Sustain High Quality Instructional Practices

In the sustainability year, treatment teachers were able to continue to implement *Pre-K Mathematics* with a high degree of fidelity and to deliver a good dosage of small-group math activities in their classrooms. With support from program trainers, teachers sustained their use of a set of best mathematics practices that had been emphasized in their professional development training, and continued to monitor children's math learning across the pre-kindergarten year.

Public Preschool Programs Can Sustain an Effective Implementation with Support from Program Trainers

The principal hypothesis - that the math intervention would lead to increased mathematical knowledge in participating children by the end of the pre-kindergarten year - was clearly supported. Furthermore, treatment effects, as measured by a standardized assessment and by children's kindergarten teachers, persisted into the kindergarten year. Thus, programs were able to sustain an effective implementation when implementing at a customary, program-wide level of scale.

Appendices

Not included in page count.

Appendix A. References

Bodovski, K., & Farkas, G. (2007). Mathematics growth in early elementary school: The roles of beginning knowledge, student engagement and instruction. Elementary School Journal, *108,* 115-130.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428 –1446.

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

Morgan, P. L., Farkas, G., & Wu, Q. (2009). Five-year growth trajectories of kindergarten children with learning difficulties in mathematics. Journal of Learning Disabilities, *42*, 306-321.

National Mathematics Advisory Panel. (2008). *Final report of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education.

Preschool Curriculum Evaluation Research Consortium (2008). Effects of preschool curriculum programs on school readiness. Washington, D.C., U.S. Department of Education.

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

U.S. Department of Health and Human Services, Administration for Children and Families (2010). Head Start Impact Study. Final Report. Washington, DC.