Paper 5: Closing the Socioeconomic Gap: An Efficacy Study of a Mathematics Curriculum to Support the Youngest Preschool Children

Background / Context:
There is a national need for effective interventions to improve school readiness and subsequent achievement in mathematics for students from low-income families. A cross-socioeconomic gap in mathematical knowledge is present in American and Chinese children by 3 years of age (Starkey & Klein, 2008). The gap closes over the preschool years for Chinese children, who receive a systematic math curriculum at age 3 years in preschool. By contrast, this gap widens over the preschool years for American children, because many public preschool programs such as Head Start do not use curricula that effectively support early mathematical development. The Head Start Impact Study (ACF, 2005) found that gains in math by intervention children enrolled in Head Start were not significantly different from gains by control children who were denied enrollment. Recent intervention research has found that early mathematics enrichment can significantly enhance low-income children’s mathematical knowledge. However, providing a mathematics intervention during the pre-kindergarten year does not entirely close the socioeconomic gap in early mathematical knowledge.

Purpose / Objective / Research Question / Focus of Study:
This study will evaluate the efficacy of a 2-year preschool mathematics intervention that begins at preschool entry when children are 3 years of age and continues through the end of the pre-K year. The overarching objective of this study is to determine whether a 2-year preschool mathematics intervention can close the SES-related gap in mathematical knowledge by entry into kindergarten. This objective cannot be addressed in the proposed presentation because the efficacy study is still underway. An objective that will be addressed, however, is whether a new mathematics curriculum for 3-year-olds, Pre-Pre-K Mathematics, was effective for low SES children. This was the first early math intervention that focused on 3-year-olds. In addition, we will investigate whether a set of self-regulation (SR) competencies, which have been considered to be important components of school readiness, are related to children’s developing mathematical knowledge. One possible relation that is being studied is whether these self-regulation competencies appear to moderate growth in mathematical knowledge.

Setting: The study was conducted in 63 classrooms in 3 Head Start programs in Northern California. All classrooms are mixed-age, including both 3- and 4-year-old children. Approximately half are full-day classrooms and half are half-day classrooms. All of these Head Start programs serve an urban, ethnically diverse, low-income population.

Population / Participants / Subjects:
The study sample includes 526 preschool children (274 females and 252 males. The ethnic composition is 58% Latino, 18% African-American, 7% Caucasian, 6% Asian-American/Pacific Islander, and 11% multi-ethnic/other. Mean age of the sample was 3.38 years at pretest in fall of the first year (pre-pre-k) of preschool. Eight to 10 children per classroom were randomly selected for participation at the beginning of their pre-pre-k year of preschool. Attrition over the pre-pre-kindergarten year was 8.5%.
**Research Design:**
The basic research design was a cluster randomization in which 63 Head Start classrooms at 43 sites were randomly assigned to one of three conditions: Intervention-2 (I-2) condition, Intervention-1 (I-1) condition, or Control (C) condition. There were 21 classrooms assigned to each condition. By recruiting the sample when children entered preschool at age 3 and following them for two years through the end of preschool, children were equated for number of years of preschool across experimental conditions.

The experimental design includes three conditions: (1) I-2, a 2-year intervention in which children received a math intervention (*Pre-Pre-K Mathematics* and *Pre-K Mathematics*) during both years of preschool; (2) I-1, a 1-year intervention in which children received a math intervention (*Pre-K Mathematics*) during the final (pre-k) year of preschool; and (3) C, a business-as-usual control condition for both years of preschool.

One specific aim is to test whether the math curriculum for 3-year-olds has an impact on the math outcomes during the preschool entry year. Another aim is to test on math outcomes at the end of pre-k are greater when children receive two years of math curricula in preschool than when they receive one year. We hypothesize that both interventions will be effective and that the 2-year intervention will be more effective than the 1-year intervention.

A third aim is to determine whether a set of self-regulation competencies, child competencies that are considered to be important components of school readiness, act as moderators of child outcomes in a preschool mathematics intervention.

**Intervention / Program / Practice:**
The math interventions we are testing in this study include a pre-kindergarten mathematics curriculum (*Pre-K Mathematics*) for 4-year-olds that has already been found to be effective, relative to a business-as-usual control condition, in a randomized controlled trial. In addition, a preschool mathematics curriculum (*Pre-Pre-K Mathematics*) for 3-year-olds that has not previously been evaluated in a randomized controlled trial was included in the 2-year intervention condition. Both curricula include developmentally appropriate math activities with concrete manipulatives. Children engage in these activities in small groups with teacher scaffolding as needed. The curricula also include home math activities that teachers send home for use by parent-child dyads. The effects of the 1-year and 2-year interventions will be compared with one another and with a business-as-usual control condition.

Teachers in the I-2 condition participated in an introductory math workshop (2 days) that provided overviews of early mathematical development and the classroom and home activities in the math curriculum for 3-year-olds. Following the introductory workshop, teachers in the I-2 condition received the full professional development component consisting of two math workshops and biweekly on-site facilitation by professional development staff.

Each teacher received a math curriculum book and manipulative materials to accompany the 14 small-group classroom activities in the math curriculum. Each classroom activity and a related home activity were implemented for two weeks, with reviews of classroom activities provided as indicated by a progress-monitoring instrument.
Teachers implemented the math intervention from October to May (allowing for pretest and posttest assessments) according to a weekly curriculum plan. Over the course of Year 1, project professional development staff conducted fidelity of implementation observations of the I-2 teachers (6 fidelity observations per teacher, one for each unit of the math curriculum) in order to provide formative feedback to the teachers and to prevent fidelity drift.

Teachers in the I-1 and C classrooms continued with whatever math practices constituted business-as-usual. The nature of the math practices in I-1 and C classrooms were documented through classroom observations by research staff. However, no changes were introduced in the math practices in these classrooms during the first intervention year of the study.

Data Collection and Analysis:
Outcome data on all children in the I-2, I-1, and C conditions included measures of their mathematical knowledge, Child Math Assessment – Downward Extension (CMA-DE) and the Test of Early Mathematics Ability (TEMA-3). Furthermore, data on classroom and child mediators and moderators were collected. These included measures of child self-regulation (effortful control), classroom observation measures of teachers’ math practices, and a measure of implementation fidelity.

Findings / Results:
Impact of the intervention on children’s mathematical knowledge. Three-year-old children’s math knowledge at the beginning of the pre-pre-k year of preschool was very limited. Children were correct on fewer than 25% of the CMA-DE items, and more than half of the sample reached ceiling within 5 items on the TEMA.

Our principal hypothesis tested in the initial year of the study was that implementing a mathematics curriculum during the pre-pre-k year would have a significant impact on 3-year-old children’s mathematical development. Specifically, it was predicted that I-2 children would have more extensive mathematical knowledge than I-1 and Control children at the end of the pre-pre-k year. A hierarchical model with children nested within classrooms was used to fit the data for the analyses. Composite scores on the CMA-DE for I-2, I-1, and Control children in the fall (pretest) and the spring (posttest) were examined in a 3 (condition) X 2 (time) repeated measures ANCOVA. Analyses revealed that the CMA-DE scores of all children increased from the fall to the spring, $F(1, 414) = 241.70, p < .0001$. However, in the spring, I-2 children demonstrated more extensive knowledge on the CMA-DE than the I-1 and Control children, $F(2,414) = 26.65, p < .0001$, effect size .79 between I-2 and Control, .78 between I-2 and I-1 (see Figure).

The same analytic procedure was used for the TEMA, using both Raw Scores and Experimental Scores. Similar to the findings for the CMA-DE, I-2 children demonstrated more extensive knowledge on the TEMA than the I-1 and Control Children did in the spring, using both Raw Scores $F(2,414) = 26.65, p < .0001$ (effect size .73 between I-2 and Control, .58 between I-2 and I-1), and Experimental Scores, $F(2,414) = 26.04, p < .0001$ (effect size .70 between I-2 and Control, .62 between I-2 and Control).

Proximal effects on teachers’ mathematics practices. The Early Mathematics Classroom Observation (EMCO) was used to observe teacher math practices in all classrooms during the baseline year preceding the initial year of implementation. Math
practices were categorized as focal (intentional, focused math content) or embedded (incidental, embedded math content), scaffolded or non-scaffolded, and whole group or small group math activities. The mean minutes of math (MOM) support provided per child per day were calculated. ANOVAs of MOM support provided by teachers revealed no differences among the three conditions at baseline. During the pre-pre-k year, however, I-2 teachers provided significantly more MOM through small-group activities than I-1 or C teachers did ($p < .01$). The greatest differences between I-2 teachers’ MOM and I-1 and C teachers’ MOM was found in small-group, focal, scaffolded math activities, $p < .005$.

**Fidelity of implementation.** Analysis of data collected using our fidelity measure indicated that fidelity scores of I-2 teachers were acceptably high (>0.9 of 1.0).

**Children’s self-regulation (effortful control) and mathematical knowledge.** Three-year-old children’s performance on several self-regulation tasks were related significantly to their math knowledge (CMA-DE and TEMA) at the beginning of the pre-pre-k year ($p < .01$).

**Conclusions:**
It was found that 3-year-old children’s math knowledge at the beginning of preschool was very limited. However, over the pre-pre-k year, children who received a math curriculum exhibited significantly more growth in their mathematical knowledge than children who did not receive a focused math curriculum. Furthermore, teachers’ math practices were changed by the professional development provided as part of the math intervention. Teachers in the I-2 condition provided significantly more support to their children through small-group and home math activities than teachers in the other two conditions did. Thus, providing a focused math curriculum to 3-year-old children from low-income families during their first year of preschool significantly enhances mathematical development and helps reduce the SES gap in young children’s mathematical knowledge.
Appendices

Appendix A. References


Appendix B. Tables and Figures

Effects of the Intervention on Children's Mathematical Knowledge Over the Pre-Pre-Kindergarten Year

- I-2
- I-1
- Control

Time of Assessment

Fall (Pretest)        Spring (Posttest)

Composite CMA-DE Score

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0