**Title:** Preparing High-Need Children for Standards-Based Math Instruction in Elementary School Through a Two-Year Math Intervention: Evidence from a RCT at a State Level of Scale

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## Background and Context

American students' performance on international and national assessments of mathematics achievement is well below what is desired and needed (NMAP, 2008; Provasnik et al., 2012; NCES, 2016), especially among students from low-income backgrounds (NCES, 2011). Furthermore, this income-related gap in math achievement is evident in early childhood before children enter school (Duncan, et al., 2013; Starkey & Klein, 2008). In response, national organizations have recommended that American schools adopt world-class math standards such as the Common Core State Standards for Mathematics.

A major challenge that educators face in implementing higher math standards, however, arises in grade K. Since many children from low-income backgrounds already enter kindergarten unprepared for math instruction, learning expectations associated with new math standards are being raised even higher. Some early math interventions have been shown to be effective in increasing children's math knowledge during the pre-kindergarten (pre-K) year (e.g., Clements et al. 2013; Thomas et al., 2018), but approaches for sustaining these gains in later grades are not established. To address these policy issues, the current study tested the efficacy of an innovative, two-year math intervention designed to prepare high-need children for standards-based math instruction in elementary school.

## Objectives and Research Questions

The overall objective of the study was to implement a two-year math intervention in pre-K and K on a statewide scale, and to evaluate its impact on children's math achievement at the end of one year, and then two years, of math support. We will focus on two research questions in this paper. First, how does the pre-K component of the intervention, *Pre-K Mathematics* (PKM), impact children's mathematics achievement on the ECLS-B, at the end of the pre-K year? Second, how does the cumulative effect of receiving the pre-K component followed by the Common Core-aligned K component, *Early Learning in Mathematics* (ELM), impact children's math achievement on the ECLS-K:2011 at the end of the kindergarten year?

## Setting and Study Sample

The sample consisted of 1,373 pre-K children (687 treatment; 686 control; 663 boys; 710, girls; mean age, 4.44 years, range 3.99-4.96). Up to 12 randomly selected children per pre-K classroom were included. Child participants were from low-income families and were age-eligible for kindergarten in the subsequent year. They were enrolled in pre-K classrooms in public preschool programs in urban and rural areas of Northern and Southern California. These programs served a racially, ethnically, and linguistically diverse population of low-income families.

## Intervention

PKM is a What Works Clearinghouse-rated math intervention that targets the classroom and home learning environments of young children, especially those from families experiencing economic hardship. It consists of math activities with concrete manipulatives that teachers deliver in small groups in the pre-K classroom and home activities that parents can use with the child. Teachers receive professional development (PD), through workshops and on-site coaching., focused on implementation with adequate fidelity and dosage levels and use of progress monitoring. ELM is a kindergarten math curriculum that is aligned with the Common Core math standards, provides a daily math segment lasting 45 minutes and in-class opportunities for individual practice by children. Aligned, structured homework is sent home each week. Classroom observations were used to monitor for treatment diffusion, and none was found.

## Research Design

This study used a cluster RCT design in which units (pre-K/K classroom clusters) were randomly assigned to the treatment or control condition. Children remained in their condition for two years and were tracked longitudinally. Treatment children received PKM in pre-K and ELM in K and control children received business-as-usual math instruction in both pre-K and K. Overall child attrition was 4.4% in pre-K and 11.3% in K; differential child attrition was 1.2% in pre-K and 1.6% in K.

## Data Collection and Analysis

Child outcome data were collected by an independent evaluator, whose assessors were blind to condition and certified in the instruments they administered. Math outcomes were examined using the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B - Math) and the ECLS-K:2011 - Math. Children were assessed at baseline (prior to implementation onset) and at the end of the pre-K and K years in English or Spanish, based on their language proficiency. Demographic characteristics (age, gender, race/ethnicity, and assessment language) were also collected at baseline. Extensive implementation data were collected on the PD provided to teachers and on teachers' intervention fidelity and dosage delivery in pre-K and K.

We report regression-adjusted means for the treatment and control groups from a hierarchical linear model in which children are nested within pre-K/K classroom clusters, the unit of random assignment. The model includes the full set of child-level covariates (ECLS-B and TOPEL pre-tests, age, gender, race/ethnicity, language, and cohort). Effect sizes were calculated using Hedges' *g* formula.

## Findings / Results

Criteria set at baseline were used to rate components of fidelity of implementation as high, adequate, or inadequate in each classroom. Ratings across all components of fidelity of implementation were found to be high in both pre-K and K (Table 1).

ECLS-B math scores of T and C children at baseline, 19.8 and 19.9, respectively, were found to be equivalent. Findings supported confirmatory research questions 1 and 2 (Table 2). Impacts were comparable for children in different racial/ethnic categories and across geographic regions.

The impact found at the end of pre-K did not fade in K (mean normed score≥national average). Analyses found that the PD provided to T teachers impacted their math practices (Figures 1 and 2). Amount of math instruction (or associated variables associated) by teachers, in small groups or overall, appeared to mediate causal influences of the intervention (Figures 1 and 2).

**Conclusions**

Consistent with the conference theme, these findings and implications for education policy will be discussed. We conclude that (1) math intervention in pre-K can be effective at a state level of scale, and (2) impacts in pre-K can be maintained in K when children receive a Common Core-aligned math curriculum. The income-related gap in early math achievement can be reduced by providing effective math intervention in pre-K followed by a Common Core-aligned math curriculum in kindergarten.

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**Table 1. Fidelity of Implementation in Pre-K and K Treatment Classrooms**

| Grade Level | Component of Fidelity of Implementation | Mean Score [1] | Rating |
|---|---|---|---|
| Pre-K | Workshop Attendance | 5.00 | High |
| Pre-K | Coaching Visits | 4.46 | High |
| Pre-K | Intervention Fidelity | 4.67 | High |
| Pre-K | Curriculum Dosage | 4.94 | High |
| K | Workshop Attendance | 4.98 | High |
| K | Coaching Visits | 4.60 | High |
| K | Intervention Fidelity | 4.67 | High |
| K | Curriculum Dosage | 4.76 | High |

[1] Maximum score = 5.00
[2] Rating: High (≥4.00), Adequate (3.00-3.99), Inadequate (<3.00)

**Table 2. Child Math Outcomes in Pre-K and K**

| Outcome measure (grade) | N (ITT) | Effect size (ITT) | N (TOT) | Effect size (TOT) | Mean Normed Score (T)[1] |
|---|---|---|---|---|---|
| ECLS-B (spring pre-K) | 1,313 | 0.30*** | 921 | 0.31*** | |
| ECLS-K (spring K) | 1,218 | 0.24*** | 919 | 0.33*** | 50.6 |

[1] ECLS-B Math has no spring norms; ECLS-K Math has spring norms: national mean is 50.0

*** Treatment and control means are significantly different, $p < 0.01$.

The TOT sample consists of treatment children who received at least 75 percent of dosage in the pre-K and K years, and control children who attended pre-K and K at least 75 percent of the time.

Results adjusted for clustering using a two-level model: children within pre-K classrooms. We used the following baseline control variables: ECLS-B and TOPEL pre-tests, age, gender, race/ethnicity, assessment language, and cohort. We calculated effect sizes using Hedges' $g$ formula: $\frac{\widehat{mean}_T - \widehat{mean}_C}{SD_{pooled}}$, where $\widehat{mean}_T$ equals the adjusted treatment group mean, $\widehat{mean}_C$ equals the adjusted control group mean, and $SD_{pooled}$ is the pooled SD. We used the following formula to calculate the pooled SD: $SD_{pooled} = \sqrt{\frac{(N_T-1)SD_T^2+(N_C-1)SD_C^2}{N_T+N_C-2}}$, where $N_T$ equals the treatment group sample size, $N_C$ equals the control group sample size, $SD_T$ equals the unadjusted treatment group SD, and $SD_C$ equals the unadjusted control group SD.

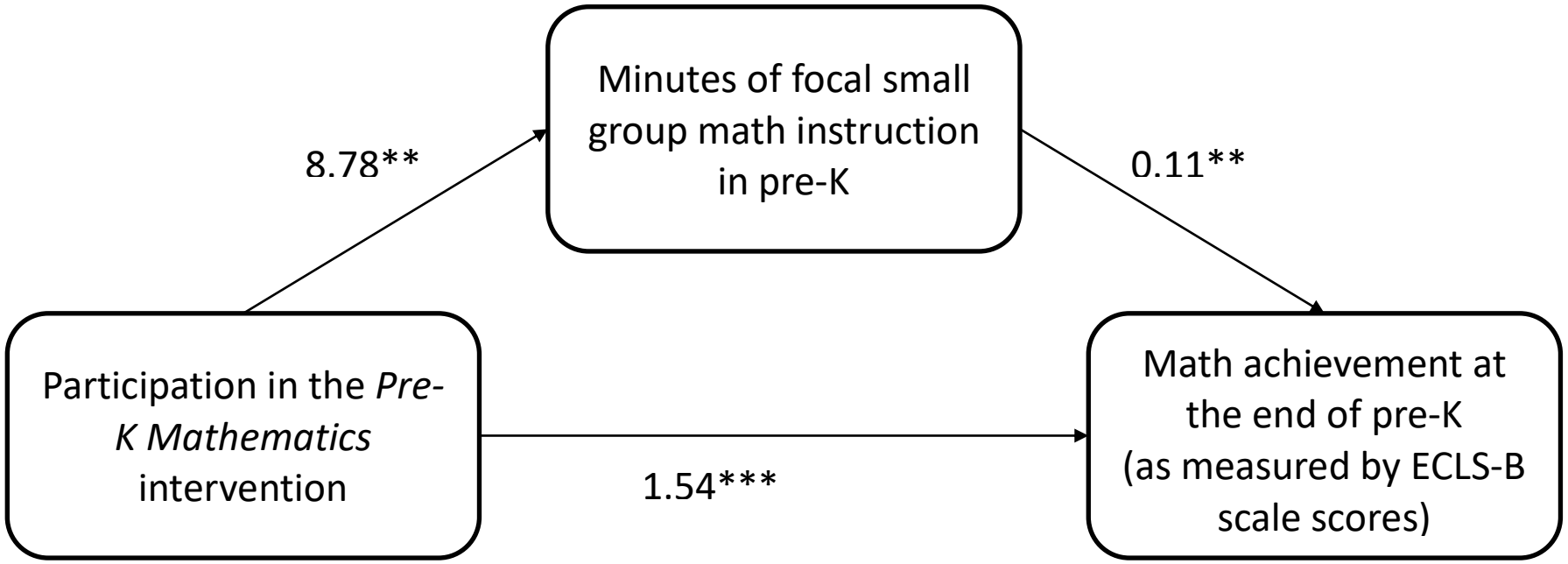


**Figure 1. Minutes of Focal Small Group Math Instruction as Mediator in Pre-K (TOT)**

** Coefficient significantly different from zero, $p < 0.05$.

*** Coefficient significantly different from zero, $p < 0.01$.

The figure shows regression coefficients for the relationship between participating in the intervention and math achievement as mediated by minutes of math instruction. The regression coefficient between participating in the intervention and math achievement, controlling for minutes of math instruction, is in parentheses.

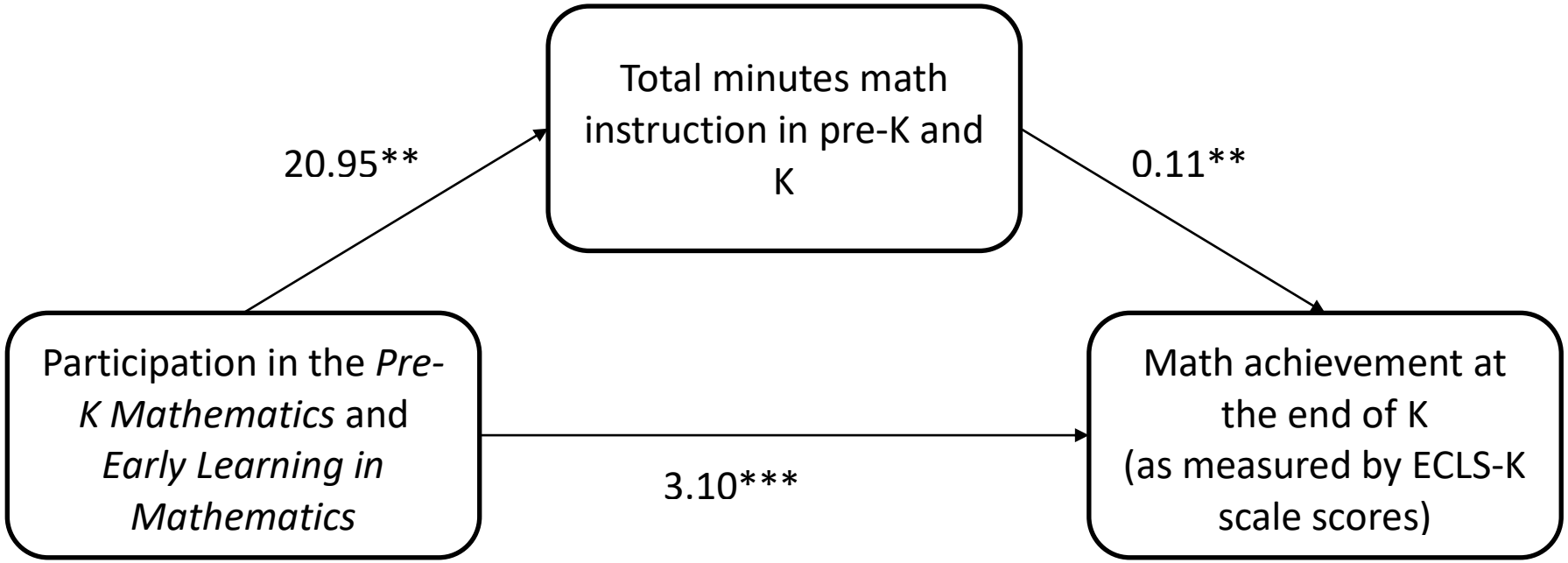


**Figure 2. Total Minutes of Math Instruction as Mediator in Pre-K and K (TOT)**

*** Coefficient significantly different from zero, $p < 0.01$.

The figure shows regression coefficients for the relationship between participating in the intervention and math achievement as mediated by minutes of math instruction. The regression coefficient between participating in the intervention and math achievement, controlling for minutes of math instruction, is in parentheses.