Abstract Title Page
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Title: **Changing the Developmental Trajectory in Early Math Through a Two-Year Preschool Math Intervention**

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Abstract Body
Limit 4 pages single-spaced.

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. Findings from a cross-national study of early math development revealed that a socioeconomic-related gap in mathematical knowledge is present in both American and Chinese children at 3 years of age (Starkey & Klein, 2008). This gap closes over the preschool years for Chinese children, who receive systematic support for math as part of their preschool curriculum beginning at age 3. In 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, 2010) 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. Several recent intervention studies have shown that providing a systematic mathematics curriculum to low-income children during the pre-kindergarten year can significantly enhance their mathematical knowledge when compared to a control group of children (e.g., Clements & Sarama, 2004; Klein, et al, 2008). However, providing a one-year math intervention does not entirely close the socioeconomic gap in early mathematical knowledge at the end of preschool. Furthermore, the positive effects of a pre-kindergarten math intervention begin to diminish in kindergarten and are generally not sustained into early elementary school. Thus, the present study sought to examine the impact of a two-year preschool math intervention on low SES children's early mathematical development.

Purpose / Objective / Research Question / Focus of Study:
The purpose of this study was to implement and evaluate a 2-year preschool math intervention that began at preschool entry when children were 3 years of age and continued through the end of the pre-kindergarten (pre-K) year. Three principal objectives will be addressed in this presentation: (1) to evaluate the efficacy of a math curriculum for 3-year-olds implemented in the pre-pre-kindergarten (pre-pre-K) year of preschool; (2) to compare the impact of a 2-year math intervention (implemented during pre-pre-K and pre-K years) with a 1-year math intervention (PK) or a business-as-usual control condition on children's mathematical knowledge at the end of preschool; and (3) to examine the longitudinal effects of the 2-year and 1-year math interventions on young children's mathematical development in kindergarten.

Setting:
The study was conducted in 63 classrooms in three Head Start programs in Northern California. Approximately half were full-day classrooms and half were part-day classrooms. All of the Head Start programs served an urban, ethnically diverse, low-income population.

Population / Participants / Subjects:
The study sample included 526 preschool children (274 females and 252 males). The ethnic composition was 58% Latino, 18% African-American, 14% Caucasian, 5% Asian-American/Pacific Islander, and 5% multi-ethnic/other. Mean age of the sample was 3.38 years at

the fall assessment of the PPK year. There were 444 children assessed in the spring of the PK year, and attrition over the two years of the preschool math intervention was 15.4%.

Intervention / Program / Practice:
Description of the intervention, program, or practice, including details of administration and duration.

The math interventions evaluated in this study included a mathematics curriculum for 3-year-olds, *Pre-Pre-K Mathematics,* and a curriculum for 4-year-olds, *Pre-K Mathematics. Pre-Pre-K Mathematics* had not been previously evaluated for effectiveness. *Pre-K Mathematics* had been evaluated in a randomized controlled trial (Klein et al., 2008) and received the highest rating of effectiveness by the What Works Clearinghouse. Both curricula provided conceptually broad support for the development of children's informal mathematical knowledge. The pre-pre-K curriculum for 3-year-olds consisted of 13 classroom math activities; the pre-K mathematics curriculum for 4-year-olds included 24 classroom math activities. Thus, there were half as many activities for 3-year-olds as for 4-year-olds, and each activity for 3-year-olds was presented for twice as long as activities for 4-year-olds. Activities in both curricula were implemented with concrete manipulatives and employed rich mathematical language. Children engaged in these activities in small groups, with teachers providing scaffolding or extension activities as needed. The curricula also included home math activities (in English or Spanish) which teachers sent home to parents to support their children's mathematical development.

Children remained in the same classrooms with the same teachers throughout their two years of preschool. Teachers in the I-2 condition received professional development in both *Pre-Pre-K Mathematics* and *Pre-K Mathematics,* and they implemented with their children in the pre-pre-K and pre-K years. Teachers in the I-1 condition engaged in their usual practices during the pre-pre-K year. Then, they received professional development in *Pre-K Mathematics* and implemented the math intervention with their children in the pre-K year. Control teachers engaged in their usual practices with their children over both years.

The professional development model included intensive workshops, distributed across the year of implementation, and on-site facilitation by project professional development staff. Facilitators conducted formative evaluation visits while teachers were implementing the intervention. Facilitators provided corrective feedback when teachers implementation departed from fidelity and provided technical assistance (e.g., with classroom management) as needed.

Observers made fidelity observations of each teacher 6 times during the year. Analysis of these data indicated that fidelity scores of I-2 and I-1 teachers were acceptably high (>.9 of 1.0).

Each teacher received a math curriculum book and manipulative materials to accompany small-group classroom activities in the math curriculum. A designated classroom activity was implemented by teachers and a related home activity was implemented by parents during the same week(s) of the year. Time was built into the curriculum plan for make-ups for children who were absent and for reviewing activities as indicated by a progress-monitoring instrument.

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), Intervention-1 (I-1), or Control (C). Thus, 21 classrooms were assigned to each condition. All participating classrooms at a preschool site were assigned to the same experimental condition to protect

against treatment diffusion. Furthermore, by recruiting the study 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 all experimental conditions.

The three conditions differed in terms of the number of years of math intervention that the children received. The I-2 condition involved a 2-year intervention in which children received *Pre-Pre-K Mathematics* during their first year of preschool and then *Pre-K Mathematics* during the final year (pre-K) of preschool. The I-1 condition was a 1-year intervention in which the children received no treatment during their first year of preschool and then received *Pre-K Mathematics* during their final year of preschool. Lastly, the C condition did not involve any treatment and children received the usual math practices in their classrooms for both years of preschool.

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 (CMA) and the Test of Early Mathematics Ability (TEMA-3). Furthermore, data on classroom 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:
Research Question 1. What is the effect of the *Pre-Pre-K Mathematics* intervention on the growth of early mathematical knowledge in 3-year-olds? It was found that greater gains in math knowledge were experienced by 3-year-old treatment children (I-2 condition) in the pre-pre-K year than by 3-year-olds who did not receive this intervention (I-1and C conditions). This was found both on the CMA (ES=1.11) and the TEMA-3 (ES=.89) (see Figure 1).

Research Question 2. What is the effect of the *Pre-K Mathematics* intervention on the growth of early mathematical knowledge in 4-year-olds? It was found that greater gains in math knowledge were experienced by 4-year-old treatment children (I-2 and I-1 conditions) in the pre-K year than by 4-year-olds who did not receive this intervention (C condition). This was found both on the CMA (ES=1.08) and the TEMA-3 (ES=.59) (see Figure 2).

Research Question 3. What is the relative effect of 1 vs. 2 years of early math intervention? CMA and TEMA scores were higher for I-2 children than for I-1in fall of pre-K and in K but were not significantly different in spring of pre-K (see Figure 3).

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. Treatment teachers, relative to controls, provided significantly more MOM through focal, scaffolded, small-group activities during both the pre-pre-K and pre-K years ($ps < .01$).

Conclusions:

The *Pre-Pre-K Mathematics* intervention had a large impact on 3-year-olds' mathematical knowledge. Likewise, the *Pre-K Mathematics* intervention had a significant impact on 4 -year-olds' mathematical knowledge. The cumulative impact of receiving 1 vs. 2 years of math intervention appeared to be surprisingly similar at the end of pre-K. Gains children made during the 1-year intervention began to fade in K, but gains children made during the 2-year intervention were sustained in K. Possible explanations are better retention after 2 years of intervention or greater consolidation of previously learned informal math knowledge.

Relevance of these findings for education policy and practice will also be discussed. One policy issue concerns the potential advantage to school readiness of expanding public preschool enrollment for 3-year-olds. An issue for educational practice concerns the need to differentiate school readiness interventions by age, since 3-year-olds are often not developmentally ready for the same interventions as 4-year-olds.

Appendices

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Appendix A. References

Administration for Children and Families (2010). *Head Start Impact Study: final report*. www.acf.hhs.gov/programs/opre/hs/impact_study/
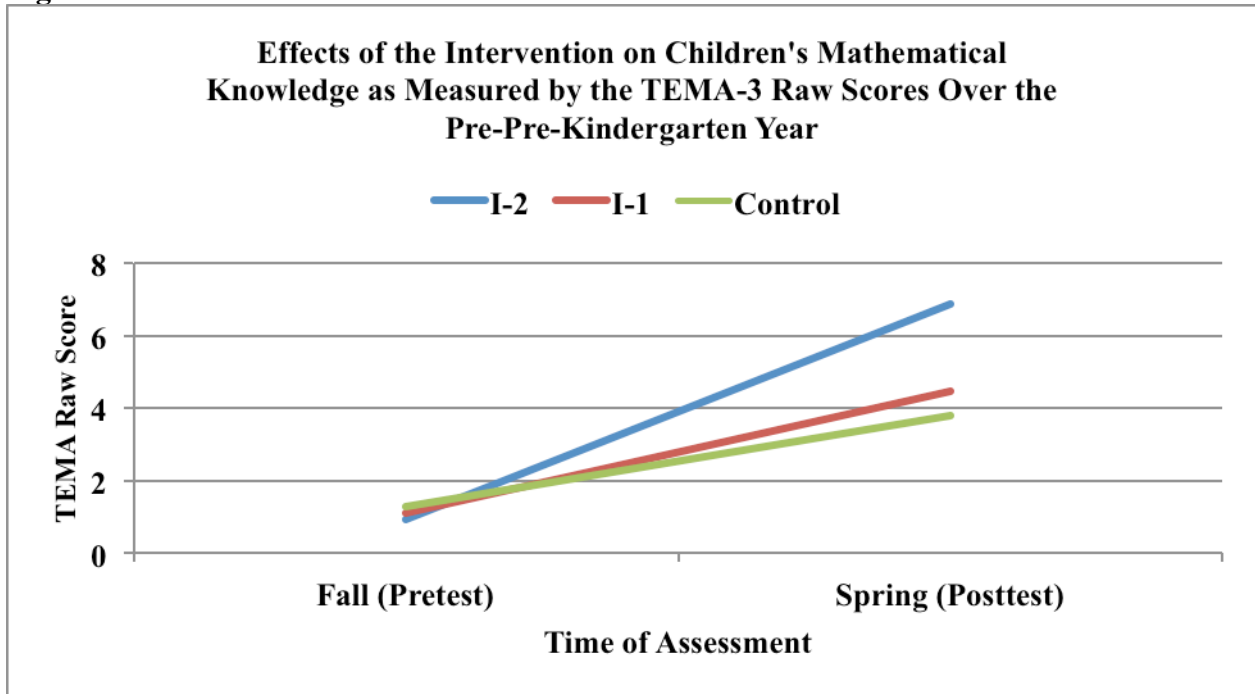
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Klein, A., Starkey, P., Clements, D., Sarama, J. & Iyer, R. (2008). Effects of a pre-kindergarten mathematics intervention: A randomized experiment. *Journal of Research on Educational Effectiveness, 1,* 155-178.

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Appendix B. Tables and Figures
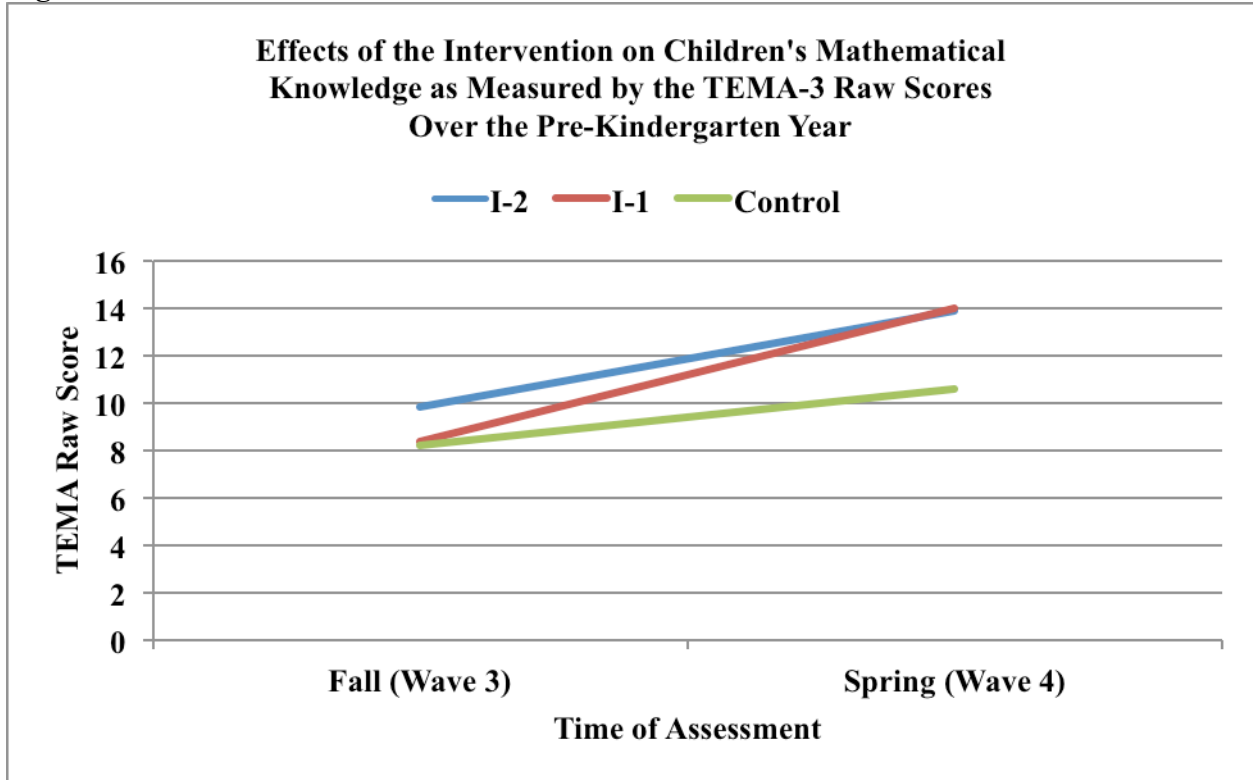
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Figure 1.

Effects of the Intervention on Children's Mathematical Knowledge as Measured by the TEMA-3 Raw Scores Over the Pre-Pre-Kindergarten Year

Effect Sizes
I-2 vs I-1, C at Wave 2 = 1.11

Figure 2.

Effects of the Intervention on Children's Mathematical Knowledge as Measured by the TEMA-3 Raw Scores Over the Pre-Kindergarten Year

Effect Sizes
I-2 vs I-1 at Wave 3 = .35
I-2 and I-1 vs C at Wave 4 = .59

Figure 3.

Effects of the Intervention on TEMA-3 Scores in Kindergarten