Scaling Up An Effective Pre-K Mathematics Intervention: Mediators and Child Outcomes

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Socioeconomic Differences in Early Mathematical Knowledge

A growing body of research has revealed a socioeconomic gap in young children’s mathematical knowledge

- This gap is broad
- It appears before children enter preschool
- It widens during the preschool years in the United States
Math Knowledge in American 4-Year-Olds

Low-income vs. Middle-income
CMA Scores of American Children

Age

Lower SES

Higher SES

0

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

3, 0 3, 9 4, 0 4, 9
CMA Scores of Chinese Children

Age

Lower SES

Higher SES
Why does the math gap widen in the United States?

Home Learning Environment of Young, Economically Disadvantaged American Children

• American preschool children from low-income families, in comparison with their middle-class peers, receive less support for mathematical development in their home environment
Preschool Classroom Learning Environment of Economically Disadvantaged Children

• The IES Preschool Curriculum Evaluation Research Initiative (2008) found that several general curricula (e.g., Creative Curriculum) in widespread use in public preschool programs are not effective in the area of mathematics relative to control curricula. Math-focused curricula, however, can be effective.

• The Head Start Impact Study (2005, 2008) found no difference in mathematical knowledge between intervention (Head Start) and control children at the end of the pre-kindergarten year. Creative Curriculum is the most widely used curriculum in Head Start.
Why does the math gap narrow in China?

Possible explanations:

• Universal preschool (in urban areas)
• National mathematics curriculum for preschools
• High parental and teacher expectations for mathematical development
Evidence for the Efficacy of the *Pre-K Mathematics Intervention*

PCER Project (Starkey, Klein, Clements, & Sarama)
Supported by IES/ U.S. Department of Education Grant R305J020026

Objectives

- Implement a pre-kindergarten mathematics curriculum in preschools serving low-income children in California and New York
- Evaluate the effects of the intervention on children’s early mathematical development and their learning environments (home and classroom)
Design

• 40 classrooms: 10 Head Start, 10 public preschool classrooms per state (California and New York)

• Random assignment of classrooms to intervention (Pre-K Mathematics) or control (business-as-usual general curricula) conditions, using block randomization at the program level

• Random selection of 8 low-income children per classroom

• Child sample:
  Cohort 1 (Year 1): 316 pre-K children
  Cohort 2 (Year 2): 312 pre-K children
Pre-K Mathematics Curriculum

Units of the Curriculum:
- Unit 1 - Number Sense and Enumeration
- Unit 2 - Arithmetic Reasoning (Fall)
- Unit 3 - Spatial Sense and Geometric Reasoning
- Unit 4 - Pattern Sense and Pattern Construction
- Unit 5 - Arithmetic Reasoning (Spring)
- Unit 6 - Measurement and Data Representation

- Each unit contains multiple small-group activities with concrete materials for teachers to use in their classrooms.

- Each unit also includes home activities for parents to use with their children. Home activities are explicitly linked to small-group activities in the classroom.
Professional Development for Intervention Teachers

Year 1:
- Workshops (4 days Fall and 4 days Winter)
- On-site facilitation (fidelity with feedback during classroom visits every 2 weeks)
- Fidelity of implementation: .89 (of 1.00) = moderate/high

Year 2:
- Refresher workshops (2 days Fall and 2 days Winter)
- On-site facilitation (fidelity with feedback during classroom visits every month)
- Fidelity of implementation: .96 = high
CMA Scores of Intervention and Control Children in Fall and Spring

- Intervention Cohort 1
- Control Cohort 1
- Intervention Cohort 2
- Control Cohort 2
• Cohort 1 effect size (Cohen’s $d$)=.58 (What Works Clearinghouse), a 62% increase in math knowledge for intervention children relative to control children

• Cohort 2 effect size=.70 (What Works Clearinghouse), a 79% increase for intervention children relative to control children

• Kindergarten: Math knowledge at end of kindergarten was significantly greater in intervention children than in control children

Scaling Up the Pre-K Mathematics Intervention: A Randomized Controlled Trial

Objectives

1. To determine whether the intervention is effective when implemented under routine conditions:
   • At a customary level of scale: a Head Start program or a school district’s pre-K program
   • With mandatory participation by all teachers
   • When teachers are trained through the program’s PD system (e.g., program trainers provide on-site PD)
Objectives

2. To examine the effectiveness of the intervention in varied contexts (e.g., Head Start vs. state pre-K programs)
3. To study sustainability of the intervention beyond the initial year in which they learned to implement
The Main Study

Design

- A cluster randomized trial with preschool site as the unit of randomization
- Classrooms were randomly selected within sites
- Pre-kindergarten children were randomly selected within classrooms (8-10 per classroom)

States: California and Kentucky/Indiana
Program Type: Head Start and public pre-K
Treatment Condition: Intervention (Pre-K Mathematics curriculum) vs. Control (Business-as-usual general curricula)

California and Kentucky/Indiana

Preschool Sites: CA = 36 (18 I and 18 C)

KY = 26 (13 I and 13 C)

Classrooms: CA = 48 (24 I and 24 C)

KY = 46 (24 I and 22 C)
Child Sample

California

Total Sample (N = 367)
- Males = 168; Females = 199
- Mean Age = 4.4

Language:
- English = 298
- Bilingual (English/Spanish)=69

Intervention (N = 181)
- Mean Age = 4.4

Control (N = 186)
- Mean Age = 4.4

Kentucky/Indiana

Total Sample (N = 377)
- Males = 175; Females = 202
- Mean Age = 4.5

Language:
- English = 377
- Bilingual =0

Intervention (N = 206)
- Mean Age = 4.5

Control (N = 171)
- Mean Age = 4.5
Components of Pre-K Mathematics Intervention

Classroom component:
• *Pre-K Mathematics* small group activities
• Supplementary mathematics software (*DLM Express*)
• Math learning center

Home component:
• *Pre-K Mathematics* home activities

Professional development component: Trainer-of-trainers model
• Facilitators Institute for training of program trainers
• Teacher workshops and on-site facilitation by program trainers
• Instructional videos of math activities (on CDs)
• Bi-weekly fidelity monitoring by program trainers: Fidelity = .95 (high)
Main Research Measures

Child Math Outcomes
• Child Math Assessment (CMA)
• Test of Early Mathematics Ability (TEMA-3)

Teachers’ Mathematics Practices
• Fidelity of Implementation
• Math Mastery (progress monitoring)
• Early Mathematics Classroom Observation (EMCO) of teachers’ mathematics practices

Children’s Home Learning Environment
• Parent Survey of home mathematics activities
Controlling for pretest scores, regression analyses revealed that mastery of the math curriculum activities significantly predicted posttest scores on both the CMA, \( F(2, 342) = 161.24, p < .001 \), and the TEMA-3, \( F(2, 342) = 294.04, p < .001 \).
Effects of the Intervention on Children’s Mathematical Knowledge

An ANOVA (3-level) revealed a significant Condition X Time Interaction, $F(1,666)=171.28$, $p < .0001$; Effect Size = .83.
Effects of the Intervention on Children’s Mathematical Knowledge

An ANOVA (3-level) revealed a significant Condition X Time Interaction, $F(1,663)=47.66$, $p < .0001$; Effect Size = .42.
What Was NOT Significant:

- State ($p = .15$) and State X Time ($p = .54$)
- Program Type ($p = .16$) or Program Type X Time ($p = .74$)

Thus, the effectiveness of the intervention is robust across varied contexts: California Head Start and state preschool programs serving ethnically diverse urban families, and Kentucky/Indiana Head Start and state preschool programs serving predominantly white rural families.
Mediation Model

- Group
- Mediator (Math Practices)
- Pretest
- Outcomes

Arrows indicate paths: a, b, and c.
Differences in Math Practices by Intervention and Control Teachers

![Bar chart showing differences in math practices by intervention and control teachers. The chart compares total, small group, focal, and scaffolded activities, with intervention and control groups.]
Similarities in Math Practices by Intervention and Control Teachers

Minutes of Math Per Day

Type of Math Activity

Whole Group
Embedded
Non-Scaffolded

Intervention
Control

Graph showing the comparison of minutes of math per day for Intervention and Control teachers across different types of math activities: Whole Group, Embedded, and Non-Scaffolded.
Mediation Model

Group \rightarrow Mediator (Math Practices) \rightarrow Outcomes

Pretest \rightarrow Outcomes

arrows labeled: a, b, c
Classroom Mediator Variables That Predict Growth in Children’s Mathematical Knowledge

<table>
<thead>
<tr>
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<th>CMA Outcomes</th>
<th>TEMA-3 Outcomes</th>
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<tbody>
<tr>
<td></td>
<td>$t$</td>
<td>$p$</td>
</tr>
<tr>
<td>Total MOM</td>
<td>4.82</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Small-Group MOM</td>
<td>5.68</td>
<td>&lt; .0001</td>
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<tr>
<td>Focal MOM</td>
<td>5.00</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Scaffolded MOM</td>
<td>4.56</td>
<td>&lt; .0001</td>
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<tr>
<td>Focal, Scaffolded Small-Group MOM</td>
<td>6.12</td>
<td>&lt; .0001</td>
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Which Classroom Variables Do Not Predict Growth in Children’s Mathematical Knowledge?

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<tr>
<td></td>
<td>$t$</td>
<td>$p$</td>
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<tr>
<td>Whole-Group MOM</td>
<td>1.01</td>
<td>ns</td>
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<tr>
<td>Embedded MOM</td>
<td>1.08</td>
<td>ns</td>
</tr>
<tr>
<td>Non-Scaffolded MOM</td>
<td>1.85</td>
<td>ns</td>
</tr>
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Mediation analyses are being done two ways to allow us to examine consistency of results

1. Method using Mplus structural equation modeling software. Models include the grouping variable (intervention), the mediator, and the outcome, controlling for the pretest. Two level models are being used.

2. Method using a bootstrap approach

Thus far, we have found consistent evidence of mediation by total MOM.
The Sustainability Study

**Objective:** To determine whether programs and teachers were able to sustain an effective implementation beyond the initial year in which teachers learned the intervention.

**Design:** 39 of 48 intervention teachers from Main Study (9 teachers were no longer teaching pre-K children in the program).

**Child Sample (N=326)**

**California**
- Total Sample (N = 171)
  - Males = 83; Females = 88
  - Mean Age = 4.3
- Language:
  - English = 126
  - Bilingual (English/Spanish)=45

**Kentucky/Indiana**
- Total Sample (N = 155)
  - Males = 67; Females =88
  - Mean Age = 4.4
- Language:
  - English = 155
  - Bilingual =0
Effects of the Intervention on Children’s Mathematical Knowledge

An ANOVA (3-level) revealed a significant Condition X Time Interaction, $F(1,527)=68.82$ $p < .0001$; Effect Size = .70.
Effects of the Intervention on Children’s Mathematical Knowledge

An ANOVA (3-level) revealed a significant Condition X Time Interaction, $F(1,522)=34.57$, $p<.0001$; Effect Size = .45.

An ANOVA (3-level) revealed a significant Condition X Time Interaction, $F(1,522)=34.57$, $p<.0001$; Effect Size = .45.
Conclusions

• Pre-K children exhibit impressive gains in mathematical knowledge (approximately double that of control children)
• The intervention is robust across varied contexts
• Child math outcomes were mediated by specific math practices: Math-focused, teacher-scaffolded, small group activities were most effective
• Program staff were able to train teachers to utilize these effective math practices
• An effective implementation was sustained by teachers and their programs

Policy Implication

Public preschool programs should be given encouragement and assistance to implement effective mathematics curricula.