Supporting the Development of Early Mathematical Knowledge Among Dual-Language-Learners with Varying English-Proficiency from Preschool through Kindergarten

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The Research
Socioeconomic Status and Math Achievement

- Mathematical knowledge is less extensive among low-income pre-kindergarten (pre-k) children than in their middle-income peers.
- The socioeconomic gap is broad, and it emerges before 3 years of age.
- Thus, children from different socioeconomic backgrounds enter elementary school at different levels of readiness for school mathematics.
- These early differences lay the foundation for the SES-related achievement gaps in mathematics found later in K-12 and beyond.
Math Knowledge in American 4-Year-Olds

<table>
<thead>
<tr>
<th>Category</th>
<th>Low-income</th>
<th>Middle-income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Geometry</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Measurement</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Patterns</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Composite</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
CMA Scores of American Children

Mean Proportion Correct on the CMA

Lower SES  Higher SES
Language-Related Gap in Math Achievement

Figure 11. Mathematics achievement score gaps between Hispanic and White public school students at grade 4, by English language learner status: Various years, 1996–2009

* Significantly different (p<.05) from 2009.

NOTE: Score gaps are calculated based on differences between unrounded average scores. White includes ELL and non-ELL White students.
Language-Related Gap in Math Achievement

Figure 12. Mathematics achievement score gaps between Hispanic and White public school students at grade 8, by English language learner status: Various years, 1996–2009

* Significantly different (p<.05) from 2009.

NOTE: Score gaps are calculated based on differences between unrounded average scores. White includes ELL and non-ELL White students.

The language-related achievement gap in math also seems to appear early, and has implications for later learning.

Dual language learners with limited English proficiency (DLL-LEP) finish kindergarten with significantly lower math skills compared to both Spanish-speaking children who are also English proficient (DLL-EP), and/or monolingual English speakers (MLLs) (Halle, et al., 2012)

- DLLs who are English proficient by kindergarten entry perform as well on measures of math knowledge throughout elementary and middle school as their monolingual English speaking peers (Halle, et al., 2012)
- For DLLS not English proficient by first grade, the gap widens over time (Halle, et al., 2012).
Our Research

- We will present findings from two studies, each designed to target the SES-related gap in early math knowledge.

- High percentage of dual language learners (DLLs) in each sample allows for secondary analyses focused on relations between developing English proficiency and developing math knowledge.
Study 1: The effects of a one-year, pre-k math intervention on developing math knowledge

- Data drawn from two IES-funded efficacy studies
- In each, Head Start and State Pre-K classrooms were randomly assigned to conditions
  - Treatment: One-year pre-k math intervention
  - Control: Business-as-usual (BAU)
- Teachers in treatment classrooms received professional development via workshops and biweekly coaching to implement tier 1 math curriculum
- Children’s math knowledge was assessed in the fall and spring of pre-k
### Study 1: Participants

<table>
<thead>
<tr>
<th>TOT Sample (N)</th>
<th>Age @ Pretest</th>
<th>Gender (% female)</th>
<th>Latino</th>
<th>MLL</th>
<th>DLL-EP</th>
<th>DLL-LEP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong>: One-Year PK Intervention</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>286</td>
<td>4.41 years</td>
<td>49%</td>
<td>70%</td>
<td>32%</td>
<td>52%</td>
<td>16%</td>
</tr>
<tr>
<td><strong>BAU Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>289</td>
<td>4.43 years</td>
<td>52%</td>
<td>76%</td>
<td>25%</td>
<td>40%</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>575</td>
<td>4.42 years</td>
<td>51%</td>
<td>73%</td>
<td>29%</td>
<td>46%</td>
<td>26%</td>
</tr>
</tbody>
</table>

MLL = Monolingual (English-Only) Language Learner; DLL-EP = Dual Language Learner-English Proficient by End of Pre-K; DLL-LEP = Dual Language Learner-Limited English Proficiency at End of Pre-K
Study 1: Measures and Procedures

Math Measure
- Test of Early Mathematical Ability, 3rd edition (TEMA-3)

Implementation Procedures
- Math intervention: *Pre-K Mathematics* (tier 1 math curriculum)
- All components of the math intervention were available and implemented with children in Spanish and/or English

Data Collection Procedures
- Children were individually assessed in English and/or Spanish by a research project staff at the beginning and end of the school year
Study 1: Research Questions

1. Under BAU conditions, to what extent does informal math knowledge differ between MLLs and DLLs who are English proficient (DLL-EP) and not English proficient (DLL-LEP) at the beginning and end of the pre-k year?

2. To what extent does participation in an early math intervention influence any potential differences in math knowledge by language status?
Treatment Condition, TEMA-3

TEMA-3

Fall  | Spring
---|---
Treatment MLL  | Treatment DLL-EP  | Treatment DLL-LEP
Treatment vs. Control by Level of English Proficiency, TEMA-3

![Graph showing the comparison of TEMA-3 scores between Treatment and Control groups, differentiated by level of English proficiency (MLL, DLL-EP, DLL-LEP) and by season (Fall, Spring). The graph illustrates the improvement in raw scores over time for each group.]
## Study 1: Condition X Language (TEMA-3)

<table>
<thead>
<tr>
<th></th>
<th>MLL M (SD)</th>
<th>DLL-EP M (SD)</th>
<th>DLL-LEP M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall PK</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>7.84 (6.11)</td>
<td>5.77 (4.78)</td>
<td>4.92 (3.68)</td>
</tr>
<tr>
<td>Control</td>
<td>7.39 (5.23)</td>
<td>5.77 (4.72)</td>
<td>5.86 (5.16)</td>
</tr>
<tr>
<td><strong>Spring PK</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>15.90 (6.78)</td>
<td>14.51 (13.68)</td>
<td>13.68 (5.89)</td>
</tr>
<tr>
<td>Control</td>
<td>13.28 (7.39)</td>
<td>12.25 (6.81)</td>
<td>10.90 (6.60)</td>
</tr>
</tbody>
</table>
Study 1: Conclusions

- A language-related gap in math knowledge is already present at the beginning of pre-k
- Both DLL-EP and DLL-LEP children benefitted from the math intervention
- DLLs who were English proficient by the end of pre-k performed similarly on math to MLLs at the end of pre-k
- DLL-LEP treatment children performed similarly to MLL control children at the end of pre-k
Study 2: The effects of a two-year, preschool math intervention on developing math knowledge

Since the language gap already exists at the start of pre-k, examination of even younger children is warranted.

- Many children attend preschool for two years.
- Math intervention in Study 1 was implemented during the pre-k year only.
- Purpose of Study 2 was to examine relations between language and math over two years of preschool—the pre-pre-k year (3-year-olds) and the pre-kindergarten year (4-year-olds).
Study 2: Design

- 42 classrooms were randomly assigned to one of two conditions
  - Treatment: Two-year pre-k math intervention
  - Control: Business-as-usual
- Children remained in the same classroom over both years of preschool
- Teachers in treatment classrooms received professional development via workshops and biweekly coaching to implement tier 1 math curriculum over both years
  - Year 1: Pre-Pre-K Mathematics
  - Year 2: Pre-K Mathematics
- Children’s math knowledge was assessed in the fall and spring of each preschool year (measures and procedures the same as Study 1)
Study 2: Participants

<table>
<thead>
<tr>
<th>TOT Sample (N)</th>
<th>Age @ Pretest</th>
<th>Gender (% female)</th>
<th>Latino</th>
<th>DLL</th>
<th>DLL-EP</th>
<th>DLL-LEP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Two-Year Intervention</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>3.35</td>
<td>56%</td>
<td>60%</td>
<td>65%</td>
<td>35%</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>117</td>
<td>3.41</td>
<td>51%</td>
<td>73%</td>
<td>72%</td>
<td>26%</td>
<td>46%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>261</td>
<td>3.38</td>
<td>54%</td>
<td>66%</td>
<td>68%</td>
<td>31%</td>
<td>37%</td>
</tr>
</tbody>
</table>
Study 2: Research Questions

1. Under current (BAU) conditions, does informal math knowledge differ among (1) MLLs, (2) DLL-EPs, and (3) DLL-LEPs in the pre-pre-k year?

2. If so, to what extent does participation in an early math intervention impact these differences?
BAU Control Condition, TEMA-3

![Graph showing TEMA-3 scores over time for different control conditions.](image)

- Fall
- Spring

- Control MLL
- Control DLL-EP
- Control DLL-LEP
Treatment Condition, TEMA-3

TEMA-3

- Treatment MLL
- Treatment DLL-EP
- Treatment DLL-LEP
Treatment vs. Control by Level of English Proficiency, TEMA-3

![Graph showing TEMA-3 scores by treatment and control groups throughout Fall and Spring. The graph includes lines for Treatment MLL, Treatment DLL-EP, Treatment DLL-LEP, Control MLL, Control DLL-EP, and Control DLL-LEP.]
## TEMA Scores from Preschool Entry through End of Pre-K

<table>
<thead>
<tr>
<th></th>
<th>MLL</th>
<th>DLL-EP</th>
<th>DLL-LEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>Fall PPK (Year 1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1.36 (2.24)</td>
<td>1.13 (1.69)</td>
<td>.45 (.96)</td>
</tr>
<tr>
<td>Control</td>
<td>1.33 (1.61)</td>
<td>1.63 (2.41)</td>
<td>1.07 (1.64)</td>
</tr>
<tr>
<td><strong>Spring PK (Year 2)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>15.90 (6.78)</td>
<td>14.51 (6.45)</td>
<td>13.68 (5.89)</td>
</tr>
<tr>
<td>Control</td>
<td>13.28 (7.39)</td>
<td>12.25 (6.81)</td>
<td>10.90 (6.60)</td>
</tr>
</tbody>
</table>
Treatment Condition, TEMA-3 Experimental Scoring

TEMA-3

Fall | Spring
---|---
Treatment MLL | Treatment DLL-EP | Treatment DLL-LEP
Treatment vs. Control by Level of English Proficiency, TEMA-3 Experimental Scoring
3. To what extent does informal mathematical knowledge differ by condition and language status over two years of preschool?
TEMA Raw Scores by Condition and Language Over Two Years of Preschool

- Fall, Year 1 (age 3)
- Spring, Year 1 (age 3)
- Spring, Year 2 (end of pre-k)

- Treatment MLL
- Treatment DLL-EP
- Treatment DLL-LEP
- Control MLL
- Control DLL-EP
- Control DLL LEP
The SES gap in early math knowledge is more nuanced than previously thought: Children who differ in their dual language proficiency also differ in early math knowledge.

Even in preschool, MLLs and DLLs who will be English proficient by kindergarten appear to develop math knowledge at similar rates;

DLLs benefit from effective math curriculum; however, children who are slower to develop English proficiency (DLL-LEP) may be in need of more intensive intervention (e.g. dual math and language intervention);

Research is needed to better understand the relationship between English proficiency and the development of mathematical knowledge.
The Pre-K Mathematics Intervention
The *Pre-K Mathematics* curriculum provides support for children’s mathematical development in their preschool classrooms and at home.

It is designed to foster a broad foundation of informal mathematical knowledge.

We have developed and evaluated this math curriculum in different types of preschools serving children from diverse socioeconomic backgrounds.
Components of the *Pre-K Mathematics* Intervention

- **Classroom component**
  - *Pre-K Mathematics* curriculum
  - Math learning center

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

- **Professional development component**
  - Workshops and on-site coaching for teachers
The *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
The Pre-K Mathematics Curriculum

- Each unit contains multiple small-group activities with concrete materials for teachers to use in their classrooms.
- Activities are introduced at a rate of approximately one per week, in accordance with a prescribed curriculum plan.
- Each unit includes home activities for parents to use with their children. Home activities are explicitly linked to small-group activities in the classroom. Instructions for home activities are provided as illustrations with minimal text (in English and Spanish) to reduce literacy demands on parents.
- Teachers are encouraged to keep records of individual children’s progress in mastering the small-group activities; review weeks are built in to the curriculum plan for teachers to revisit activities not mastered by individual children.
Activities are designed to be sensitive to the developmental needs of individual children.

Classroom activities include downward extensions for children who have difficulty with the main activity, and upward extension for those who complete the main activity easily.

Scaffolding, or extra support, is suggested for children who experience difficulty with a part of the activity.
Pre-Pre-K Mathematics

- Similar to Pre-K Mathematics, but developed for three-year-olds (e.g., focus on simpler foundational concepts, fewer activities with increased dosage)

- Includes classroom, home, and professional development components
  - Classroom component
    - Pre-Pre-K Mathematics curriculum
    - Math learning center
  - Home component
    - Pre-Pre-K Mathematics home activities
  - Professional development component
    - Workshops and on-site coaching for teachers
Q & A
Our Questions to You

- Which features of the curricular interventions promoted math gains among DLLs?
- What are the implications for classrooms/teachers not participating in a targeted math intervention?
- Why might DLL-LEP children have less math knowledge than DLL-EP children?
- Should DLL children be dichotomized into two categories (EP vs. LEP), or is there an argument for placing them on a continuum?