Project LEAP: Preparing Students for Success in Algebra

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Talk Overview

- background on the “algebra problem” and a potential solution

- Project LEAP
  - development of an algebra intervention
  - small-scale testing of the intervention
  - large-scale testing of the intervention

- What have we learned?
The Algebra Problem

• (too) many students unsuccessful in algebra
• gatekeeper to future academic and career opportunities
• arithmetic in elementary school does not adequately prepare students for success in algebra in later grades
The Algebra Solution: Early Algebra

- not a matter of moving content of first-year algebra into earlier grades
- algebraic thinking as a K-12 strand
- build on children’s informal intuitions about patterns and relationships
- lays a strong foundation for formal algebra
- long-term and sustained algebra experiences
K-5 Early Algebra Research

- understanding of the equal sign (Carpenter et al)
- generalized arithmetic (Schifter et al)
- representing and symbolizing (Carraher et al)
- functional thinking (Blanton et al)
- reasoning about abstract quantities (Dougherty)
Does Early Algebra Matter?

- not sufficiently comprehensive in the treatment of algebraic content (e.g., equal sign, generalized arithmetic)
- not sufficiently longitudinal (or coordinated) to measure long-term development (i.e., single grade level)
- researcher-led or researcher-intensive early algebra interventions
- some research findings are suggestive of long-term impacts (e.g., Knuth et al, 2006)\footnote{Note: The \textit{et al} stands for \textit{et alium}, which is Latin for \textit{and others}. This usage is common in scientific literature to denote multiple authors who contributed to the work.}
Project LEAP: Learning through an Early Algebra Progression*

Are students who experience early algebra in elementary school better prepared for algebra in secondary school than students who experience a business-as-usual arithmetic curriculum in elementary school?
Project LEAP*

• LEAP 1: Development of a grades 3-7 early algebra learning progression (EALP), associated assessments, classroom lessons, and collection of efficacy data.

• LEAP 2: A small scale, quasi-experimental, longitudinal study of the EALP-based intervention in researcher-led elementary classrooms.

• LEAP 3: A large scale, randomized longitudinal study of the EALP-based intervention in teacher-led elementary classrooms.
Project LEAP Timeline

LEAP 1
2009-13 (NSF)

LEAP 2
2012-16 (NSF)

LEAP 3
2014-18 (IES)
LEAP 1 Project Details

- developed a comprehensive grades 3-7 early algebra learning progression around 5 big ideas*
  - specifies lower and upper anchor points
  - specifies grade level competencies and connections among them
  - informs the design of appropriate instructional strategies and learning tasks, and grade-level assessments
- developed and tested EALP-based assessments
- developed and tested ~20 EALP-based lessons per grade level
- collected “proof of concept” data
Early Algebra Learning Progression

Big Ideas*
- Generalized Arithmetic
- Equality, Expressions, Equations, and Inequality
- Functional Thinking
- Variable
- Proportional Reasoning

Practices*
- generalizing relationships
- expressing relationships
- justifying generalized relationships
- reasoning with relationships
LEAP 1 Efficacy Study Details

- ~300 students in grades 3-5 from one school district; 3 control classrooms per grade, 2 experimental classrooms per grade
- ~20 early algebra lessons (one hour per week) taught by a member of the research team
- Same (grade 3) lessons taught at each grade*
- One-hour assessment given in September as pre-test; same assessment administered in May as post-test
- Interview data collected with sample of students
LEAP 1 Conclusions

• Elementary school students seem capable of understanding a comprehensive approach to early algebra

• A “business as usual” approach to elementary school mathematics does not provide students with an understanding of fundamental algebraic ideas
LEAP 2 Goals

- test the longitudinal effectiveness of the early algebra intervention
- researcher-led implementation of the early algebra intervention in grades 3-5
- follow intervention and control students from grade 3 to grade 6
- refine intervention lesson materials
LEAP 2 Project Details

- ~170 grade 3 students from one school district; 4 control classrooms, 6 intervention classrooms*
- ~20 early algebra lessons (one hour per week) taught by a member of the research team
- Assessment given each year (beginning of grade 3, end of grade 3, end of grade 4, end of grade 5, ...)
- Yearly interviews conducted with a sample of students
- State standardized test data also collected
Sample Lesson Materials

Sample Grade 3 lesson materials
Sample Items (Equivalence)

• Fill in the blank with the value that makes the following number sentence true. How did you get your answer?

\[ 7 + 3 = \underline{} + 4 \]  
Why?

• Circle True or False and explain your choice.

\[ 57 + 22 = 58 + 21 \]  
True  False

How do you know?
57 + 22 = 58 + 21  True or False?
Representative Student Strategies

57 + 22 = 58 + 21  True or False?

Operational strategy

- *False, because 57 + 22 = 79, not 58*

Computational strategy

- *True, because 57 + 22 = 79 and 58 + 21 = 79.*

Structural strategy

- *True, because you add one to 57 and minus one from 22.*
Why Understanding the Equal Sign Matters

- Solve $3x - 5 = 7 + x$
- The solution to $3x + 4 = 7$ is $x = 1$. Determine the solution to the following equation, $3x + 4 - 15 = 7 - 15$.
- The solution to $3x + 4 = 7$ is $x = 1$. Determine the solution to the following equation, $3(x + 2) + 4 = 7$. 
Brady is having his friends over for a birthday party. He wants to make sure he has a seat for everyone. He has square tables.

- He can seat 4 people at one square table in the following way:

- If he joins another square table to the first one, he can seat 6 people:
Sample Item (Variable)

Tim and Angela each have a piggy bank. They know that their piggy banks each contain the same number of pennies, but they don’t know how many. Angela also has 8 pennies in her hand.

- How would you represent the number of pennies Tim has?
- How would you represent the total number of pennies Angela has?
- Angela and Tim combine all of their pennies. How would you represent the number of pennies they have all together?
Overall Assessment Correctness*

- Intervention
- Comparison

- Grade 3 Pre
- Grade 3 Post
- Grade 4
- Grade 5

Overall assessment correctness for different grades and groups, showing a comparison between intervention and comparison groups.
LEAP 2 Preliminary Results

- At pre-test, no significant differences between grade 3 intervention and control students.

- At end-of-year grade 3 assessment, intervention students significantly outperformed control students on 21 of 26 items (outperformed on other 5 items, but not significant).

- At end-of-year grade 4 assessment, intervention students significantly outperformed control students on 21 of 29 items (outperformed on other 8 items, but not significant).

- At end-of-year grade 5 assessment, intervention students significantly outperformed control students on 24 of 35 items (outperformed on other 11 items, but not significant).
LEAP 3 Goals

- test the effectiveness of the early algebra intervention on a larger scale
- *teacher*-led implementation of the early algebra intervention in grades 3-5
- follow intervention and control students from grade 3 to grade 7
- refine intervention lesson materials
- develop professional development materials
LEAP 3 Project Details

- randomized experimental design
- ~4,500 grade 3 students from ~50 schools
- ~20 early algebra lessons (one hour per week) taught by regular classroom teachers
- assessment given each year (beginning of grade 3, end of grade 3, end of grade 4, end of grade 5, ...)
- standardized assessment data collected each year
- yearly interviews conducted with a sample of students
- fidelity of implementation data collected*
- monthly professional development
LEAP 3 Preliminary Results

- At pre-test, no significant differences between Grade 3 intervention and control students.
- Grade 3 intervention students outperformed control students on assessment (not as significant).
- Grade 4 intervention students outperformed control students on assessment (not as significant).
- Intervention student performance is mediated by the fidelity of implementation:
  - higher fidelity $\rightarrow$ greater student performance
Concluding Thoughts

- Early algebra on a small-scale (~20 lessons per year) can be implemented with success on a large scale (~2,500 students).
- How do we help more teachers implement the intervention with greater fidelity at scale?
- Will the early algebra experience “pay-off” down the road?
Acknowledgements

- Maria Blanton, TERC
- Angela Gardiner, TERC
- Ana Stephens, Wisconsin Center for Education Research
- National Science Foundation
- Institute for Education Sciences
Thank You!

For more information about Project LEAP, visit:

www.algebra.wceruw.org