Preparing to Learn from Math Instruction by Solving Problems First

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Should children be taught new concepts directly…

or discover these ideas for themselves?
Direct Instruction
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Discovery Learning
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Direct Instruction

Discovery Learning
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Lessens burden on cognitive resources

(Kirschner et al., 1996)

Discovery Learning

Increases motivation and depth of understanding

(Wise & O’Neill, 2009)
Direct Instruction

Lessens burden on cognitive resources

(Kirschner et al., 1996)

How can aspects of both approaches be combined to improve learning?

Discovery Learning

Increases motivation and depth of understanding

(Wise & O’Neill, 2009)
Exploratory Activities May Help Children Learn from Instruction

Evidence

– College students who explored examples learned more deeply from a psychology lecture than those who summarized a text
  
  (Schwartz & Bransford, 1998)

– 9th graders who explored datasets before instruction on descriptive statistics learned more from new instructional resources than those who received extended instruction
  
  (Schwartz & Martin, 2004)
Exploratory Activities May Help Children Learn from Instruction

**Current Study**

- Extended to elementary-school children’s math learning using an easily-implemented exploratory activity
- Examined learning mechanisms
Exploratory Activities May Help Children Learn from Instruction

Current Study

- 2 conditions
  - Instruct – Solve
  - Solve – Instruct
- Self-explanation (no effects)
Exploratory Activities May Help Children Learn from Instruction

Current Study

Exploring problems should...

- Help children better gauge their understanding of the underlying concept (or lack thereof)
- Challenge them to try to new ways to solve problems, helping them notice important problem features

... prepare children to learn from instruction at a deeper level

(Bjork, 1994; Carpenter et al., 2003; Duffy, 2009; Mayer, 2004; Schwartz & Martin, 2004; Schwartz, Sears, & Chang, 2007)
Math Equivalence

Operations on both sides of the equal sign represent the same quantity

\[ 3 + 4 = 3 + 4 \]

Children often treat the equal sign operationally

\[ 3 + 4 = \square + 4 \]

– “It means add the numbers” or “get the answer”

Need to get to a relational view

– Look at relations across both sides of the equal sign

Important prerequisite for understanding algebra, even in early grades (NCTM, 2006)
Procedure

Pretest

- 2\textsuperscript{nd}-4\textsuperscript{th} graders
- suburban public school
- Selected if scored < 80%
- $N = 159$

Intervention & Immediate Posttest

Retention Test ($\approx 2$ weeks)
Math Equivalence Assessment

• Procedural knowledge
  – Solving problems correctly
    
    $3 + 7 + 8 = 3 + \Box$

• Conceptual knowledge
  – Understand concept of equivalence

  Is $4 + 8 = 8 + 4$ True or False?
  What does the equal sign mean?

(Rittle-Johnson, Matthews, Taylor, & McEldoon, 2011)
### Conceptual Instruction

3 + 4 = 3 + 4

*There are two sides to this problem...*

*What the **equal sign** means is that the things on both sides of the equal sign are **equal** or **the same**...*

### Problem Solving

\[3 + 4 + 8 = \Box + 8\]

*How did you get your answer?*

7 is the right answer.
Tutoring Intervention

Conceptual Instruction

3 + 4 = 3 + 4

There are two sides to this problem...

What the equal sign means is that the things on both sides of the equal sign are equal or the same...

Problem Solving

3 + 4 + 8 = □ + 8

How did you get your answer?

7 is the right answer.
Posttest & Retention Test Results

Procedural Knowledge (Problem Solving)

No effect of order
Posttest & Retention Test Results

Conceptual Knowledge

*Solve-Instruct order led to greater learning
Why Do Exploratory Experiences Help?
Problem Solving Accuracy at Intervention

*Solve-Instruct group had lower accuracy at intervention
Ratings of Understanding

Example: “Do you understand what the equal sign means?”
Yes (2)    Maybe (1)    Probably Not (0)

<table>
<thead>
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*Solve-Instruct group initially rated their understanding as lower*
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*Solve-Instruct group initially rated their understanding as lower, and were more accurate
# Strategy Variability at Intervention

## Number of Different Strategies Used

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## Strategy Variability at Intervention

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<td><strong>Incorrect Strategies</strong> (2 possible)</td>
<td>.47</td>
<td>.74*</td>
<td>.07</td>
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*Solve-Instruct group used a wider variety of strategies*
Encoding of Problem Structure at Intervention

2 problems shown for 5s each (e.g., $5 + 2 = \square + 3$)

- Write down from memory
- Often make systematic errors in line with misconceptions (e.g., $5 + 2 = \square$) (McNeil & Alibali, 2004)

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<td>Instruct-Solve</td>
<td>44% (4%)</td>
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<tr>
<td>Solve-Instruct</td>
<td>54%* (4%)</td>
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*Solve-Instruct group encoded problem features at a higher level*
Summary

Exploring problems prior to instruction boosted subsequent conceptual knowledge

– Solve-Instruct group outperformed Instruct-Solve group
Summary

Microgenetic analyses support the idea that exploratory experiences prepare children to learn from instruction

- Help children better gauge their understanding of the underlying concept (or lack thereof)
  - Solved problems more poorly during intervention
  - More accurate ratings of understanding (less illusion of competence)
Summary

Microgenetic analyses support the idea that exploratory experiences prepare children to learn from instruction

- Challenge them to try new ways to solve problems, helping them notice important problem features
  - Tried a wider variety of problem-solving strategies
  - Better encoding of problem structure
Conclusions

Demonstrates one practical way learning situations can be structured to improve children’s understanding

– Solve novel problems with feedback

Combines elements of discovery learning and direct instruction

– Joins a growing body of literature

(e.g., Schwartz & colleagues)

Examines processes supporting learning

– Better understanding of what factors improve learning – can design learning environments to maximize learning
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