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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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

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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^{nd}-4^{th} graders
- suburban public school
- Selected if scored < 80%
- *N* = 159

Intervention & Immediate Posttest

Retention Test (≈ 2 weeks)

Math Equivalence Assessment

- Procedural knowledge
  - Solving problems correctly

$3 + 7 + 8 = 3 + \square$

- 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)

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

$$3 + 4 + 8 = \square + 8$$

How did you get your answer?

7 is the right answer.

Tutoring Intervention

Instruct – Solve

Conceptual Instruction

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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

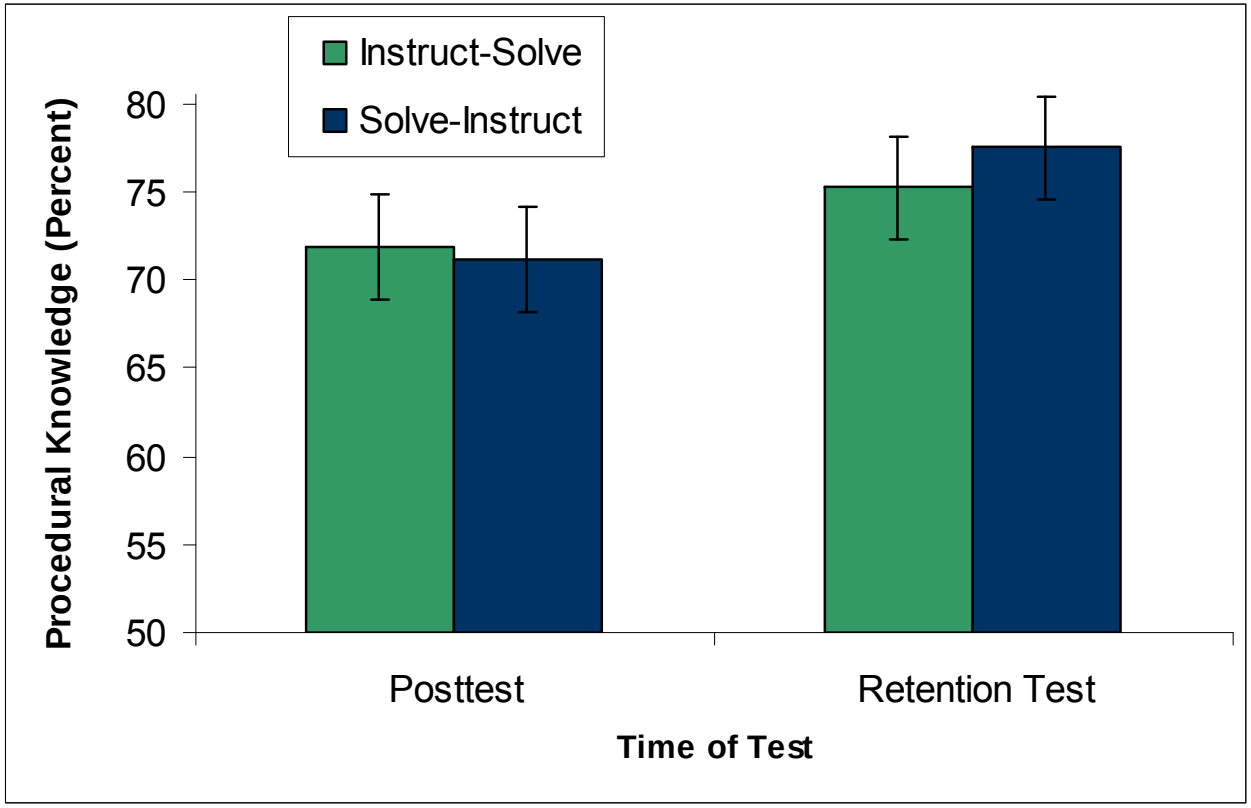
How did you get your answ

7 is the right answer.

Solve – Instruct

Posttest & Retention Test Results

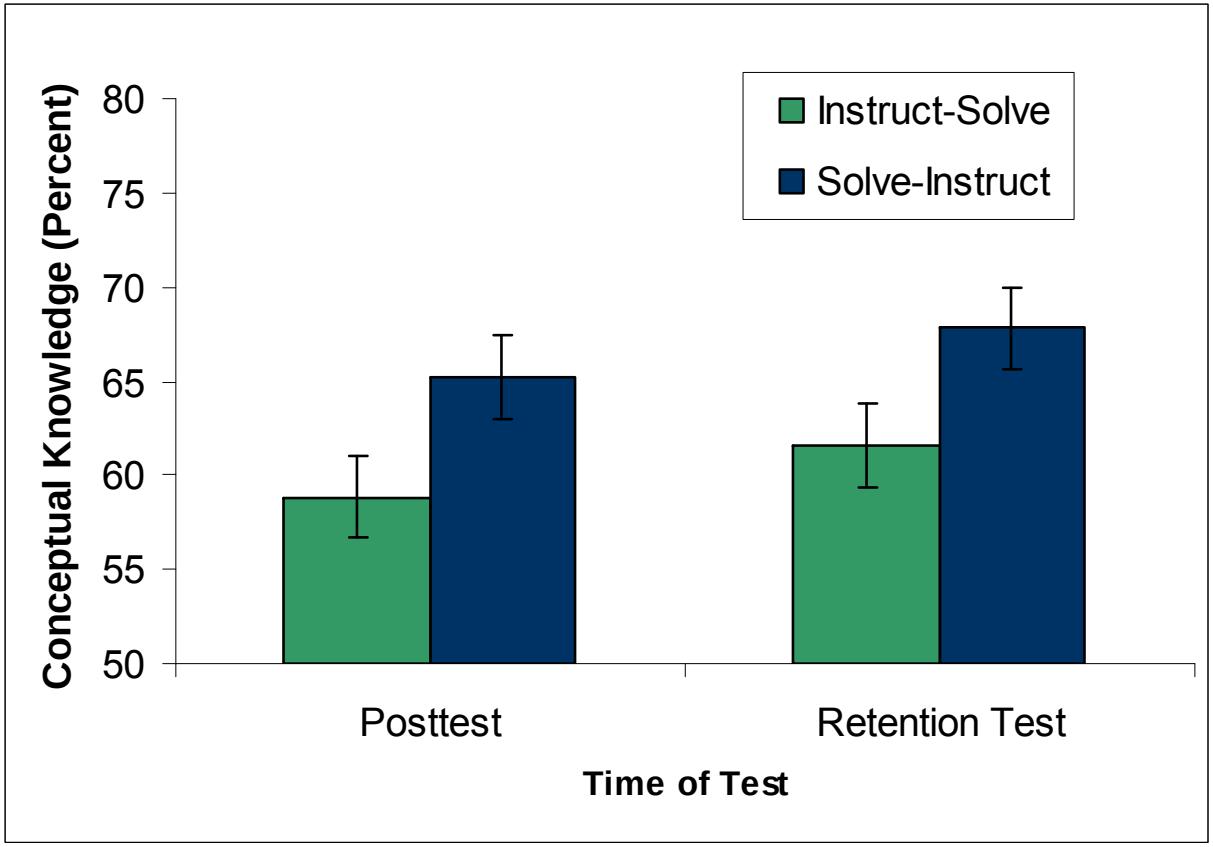
Procedural Knowledge (Problem Solving)



No effect of order

Posttest & Retention Test Results

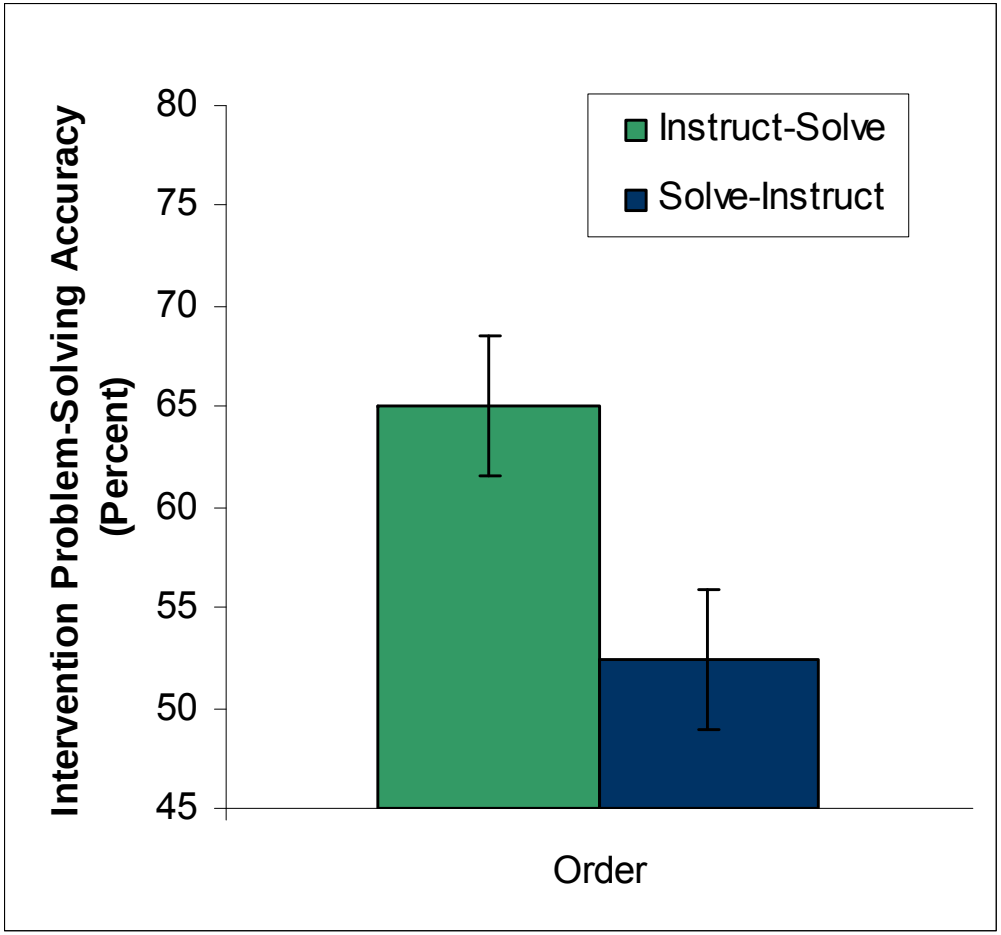
Conceptual Knowledge



***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)

	Block 1	Block 2
Instruct-Solve	**Instruct**	**Solve**
Solve-Instruct	**Solve**	**Instruct**

Ratings of Understanding

Example: “Do you understand what the equal sign means?”

Yes (2) Maybe (1) Probably Not (0)

	Block 1	**Block 2**
Instruct-Solve	**1.67** (.05) **Instruct**	**1.67** (.04) **Solve**
Solve-Instruct	 **Solve**	 **Instruct**

Ratings of Understanding

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Yes (2) Maybe (1) Probably Not (0)

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Solve-Instruct	**1.54** (.05) **Solve**	**1.71** (.04) **Instruct**

***Solve-Instruct group initially rated their understanding as lower**

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Solve-Instruct	**1.54** (.05) **Solve**	**1.71** (.04) **Instruct**	**r=.27***

***Solve-Instruct group initially rated their understanding as lower, and were more accurate**

Strategy Variability at Intervention

Number of Different Strategies Used

	Instruct-Solve	**Solve-Instruct**	Standard Error
Correct Strategies (3 possible)	1.17	1.34	.08

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Correct Strategies (3 possible)	1.17	1.34	.08
Incorrect Strategies (2 possible)	**.47**	**.74***	.07

***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 = ☐ + 3)

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

	Encoding Accuracy
Instruct-Solve	**44%** (4%)
Solve-Instruct	**54%*** (4%)

***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 to 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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