SREE 2013

The Timing of Instructional Explanations

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Overview

Capitalizing on Contradiction:
Learning from Mixed Results
SREE 2013

Background

Experiment 1

Experiment 2

Why contrasting results?

What do they tell us?

Optimizing Children's Learning

The sequencing and structure of learning material is at least as important as the learning content

(Chi, 1978; Gelman & Williams, 1998)

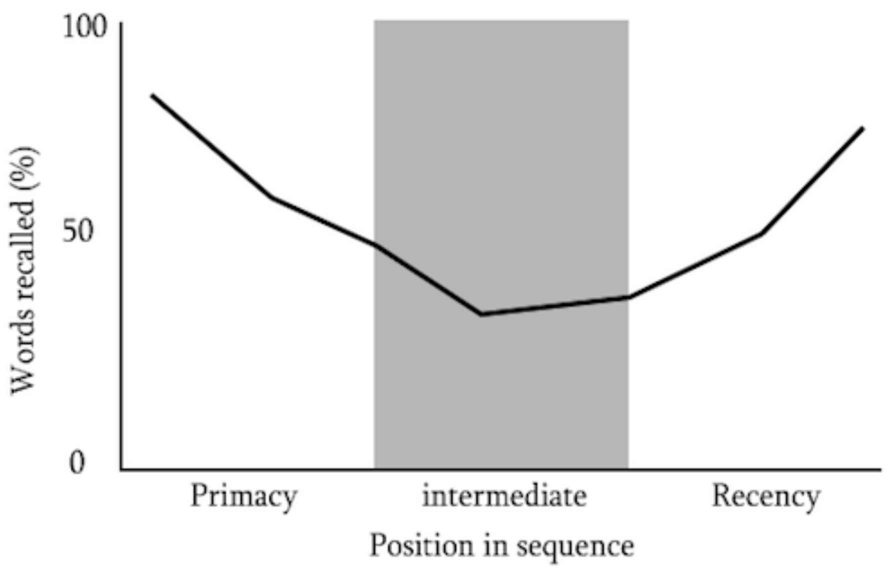


Table
Candle
Maple
Subway
Pencil
Coffee
Towel
Softball
Curtain
Puppy
Concrete

Optimizing Children's Learning

The sequencing and structure of learning material is at least as important as the learning content

(Chi, 1978; Gelman & Williams, 1998)

Learners exposed to the same content can exhibit varying levels of knowledge based solely on the sequencing of the learning material

(e.g., Goldstone & Son, 2005; McNeil & Fyfe, 2012; Taylor & Rohrer, 2012)

Sequencing of Instruction

Learning theorists recent focus is on the sequencing of direct instruction in relation to studying/solving related problems

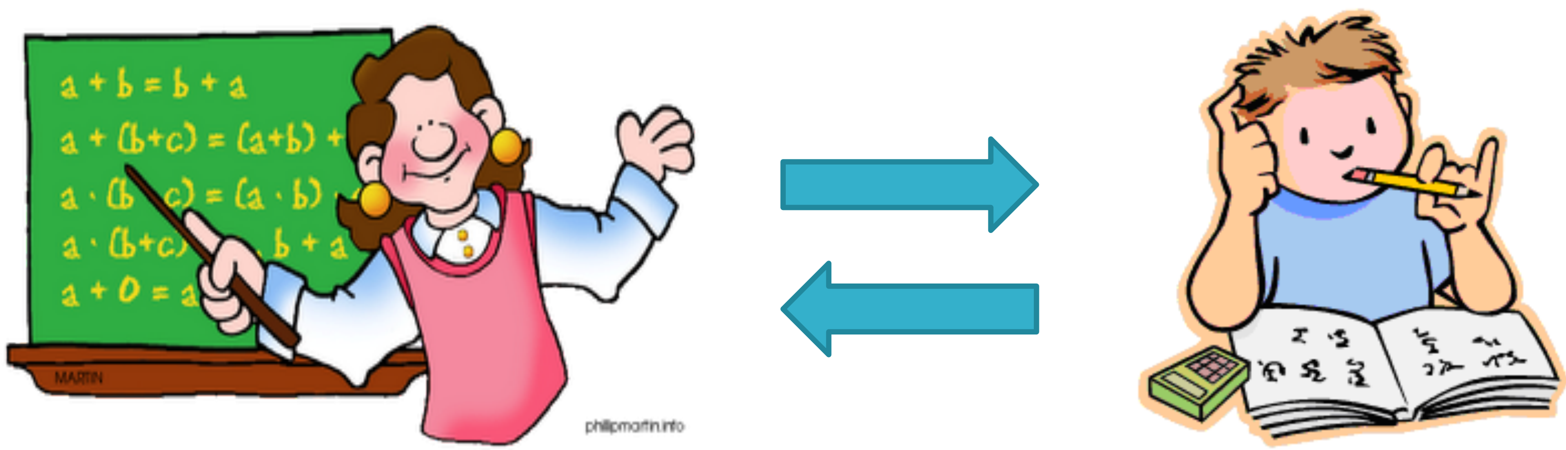
(Kapur, 2012; Schwartz et al., 2011; Wittwer & Renkl, 2008)

General consensus that explicit instruction should be provided at some point during learning

(Alfieri et al., 2011; Kirschner, Sweller & Clark, 2006; Mayer, 2004)

However, when to provide this instruction remains unclear

Optimal Sequencing?



WHEN to provide instruction?

WHAT should the instruction be about?

Solving Problems First

Facilitates knowledge of domain structure and thus *prepares* learners for future instruction

(e.g., Schwartz, Lindgren, & Lewis, 2009)

Enhances productive struggle

(e.g., Hiebert & Grouws, 2007; Kapur, 2011)

Creates a desirable difficulty that prevents "illusions of understanding"

(e.g., Bjork, 1994)

Caveat – Instruction Type

Most give instruction on concept AND procedure

- May undermine problem exploration

What about instruction on concepts only?

- Previous research suggests instruction on BOTH concepts and procedures leads to different outcomes than instruction on just concepts

  (Perry, 1991)

- Conceptual instruction does not transmit ready-made solutions, but can guide problem-solving

Conceptual Instruction First

Provides opportunity to *integrate* provided instruction with ongoing problem-solving task

(e.g., Berthold & Renkl, 2010; Wittwer & Renkl, 2008)

Narrows search and reduces cognitive demands

(e.g., Bonawitz et al., 2011)

Facilitates generation of correct procedures

(e.g., Chen & Klahr, 1999; Perry, 1991)

Research Question

Should conceptual instruction precede or follow mathematics problem solving?

- Solving problems first may prepare students to learn from instruction.
- Providing conceptual instruction first may support knowledge integration.

SPOILER ALERT

Experiment 1: Delaying instruction until after problem solving is more beneficial

Experiment 2: Providing instruction before problem solving is more beneficial

Symbolic Mathematical Equality

Concept that two sides of an equation represent the same amount and are interchangeable

- Commonly represented by equal sign (=)

$$3 + 7 + 8 = 3 + \_$$

$$6 + 4 = \_ + 8$$

Experiment 1

Journal of Experimental Child Psychology 113 (2012) 552–568

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

ELSEVIER

Exploring mathematics problems prepares children to learn from instruction

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Exp 1: Design

Session 1: Pretest (~25 minutes)

- Included if score <75% on pretest measures

Session 2: Intervention & Posttest (~50 minutes)

Session 3: Two-week Retention Test (~25 minutes)

Exp 1: Design

Worked with 159 children (2^{nd} – 4^{th} grade)

Manipulated order of instruction and problem solving

- Instruct-Solve
- Solve-Instruct

Instruction on the meaning of the equal sign

Solve 12 novel math equality problems

Some kids also asked to self-explain answers

Conceptual Instruction

Let's take a look at this problem.

3 + 4 = 3 + 4

There are two sides to this problem, one on the left side of the equal sign and one on the right side of the equal sign…

The equal sign means that the left side of the equal side has the SAME AMOUNT AS the right side of the equal sign. If we get the same amount on both sides, we say that they are equal.

Problem Solving

Figure out the number that goes in the box to make the number sentence true.

$$5 + 3 + 9 = 5 + \square$$

How did you get your answer?

You're right! / Good try. 12 is the right answer.

$$5 + 3 + 9 = 5 + \boxed{12}$$

Ashley got 12, which is the right answer. How do you think Ashley got 12, which is the right answer? Why do you think 12 is the right answer?

$$5 + 3 + 9 = 5 + \boxed{17}$$

Madison got 17, which is the wrong answer. How do you think Madison got 17, which is the wrong answer? Why do you think 17 is the wrong answer?

Assessment of Math Equality

Used at Pretest, Posttest & Retention Test

Procedural Knowledge

- Use correct strategy to solve problems

7 + 6 + 4 = 7 + _	6 - 4 + 3 = _ + 3

Conceptual Knowledge

- Understand concept of equality

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

(Matthews, Rittle-Johnson, McEldoon, & Taylor, 2012; Rittle-Johnson, Matthews, Taylor, & McEldoon, 2011)

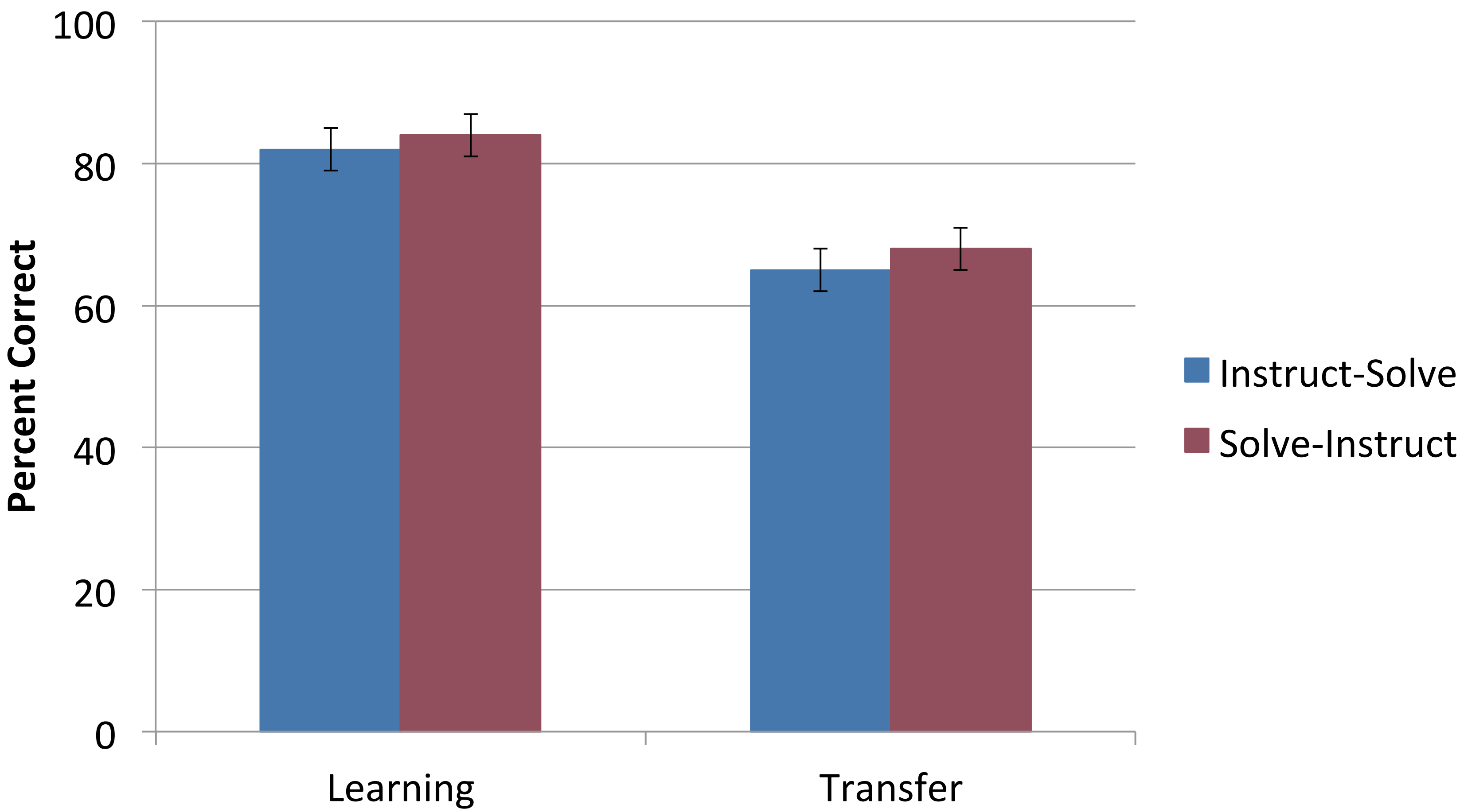
Exp 1: Results

Procedural Knowledge

Conceptual Knowledge

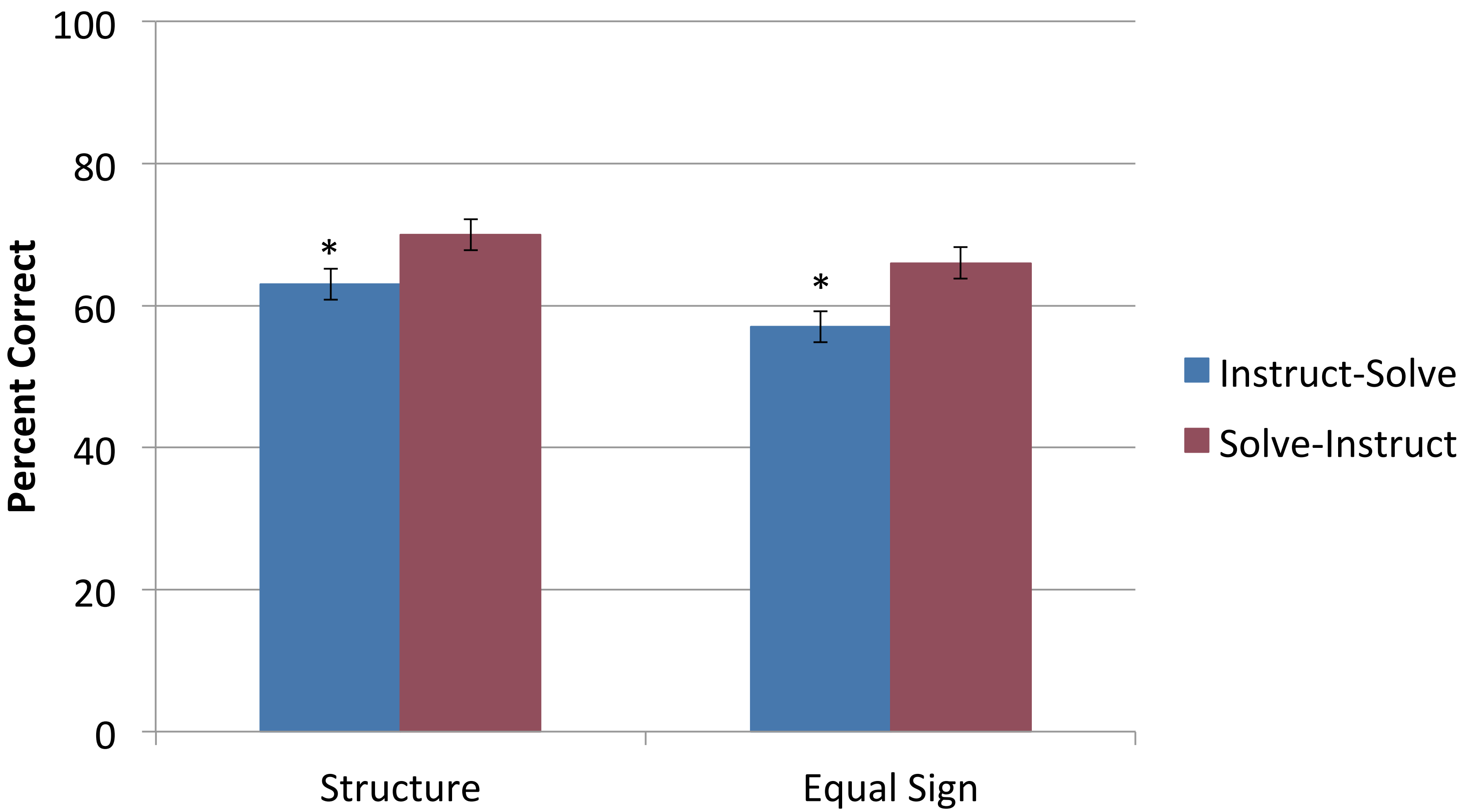
Self-Explanation Content

Procedural Knowledge



Repeated measures ANCOVA including posttest and retention test scores.

Conceptual Knowledge



Repeated measures ANCOVA including posttest and retention test scores.

Self-Explanation Content

Explanation Type	Sample Explanation (“Why is X the correct/incorrect answer?”)	% Trials		
		Instruct-Solve	Solve-Instruct	Total
Equal	They both have to equal the same.	36	25	31
Answer	Because that’s the answer.	15	12	14
Procedure	Because you add this and this.	37	39	38
Don’t Know	I don’t know.	4^	15	10
Other	That’s how you do it.	7	10	8

Exp 1: Summary

Solving problems prior to conceptual instruction resulted in better conceptual knowledge than receiving instruction first

CONCLUSION:

Optimal sequence is to delay conceptual instruction until AFTER problem solving in the domain of math equality

Experiment 2

Explore the generalizability of our findings

Modifications

- Altered self-explanation prompts to enhance integration across activities
- Altered format of problem-solving task to include "typical" arithmetic problems and to group into sets of related problems

Exp 2: Participants

Worked with 122 children (2nd & 3rd grade)

- *M* age = 8 yrs, 2 mo
- Range age = 7 yrs, 1 mo – 9 yrs, 10 mo
- 70 females, 52 males

Randomly assigned to one of two conditions:

- *Instruct - Solve*
- *Solve - Instruct*

(Instruction nearly identical to Experiment 1)

Problem Solving

Figure out the number that goes in the box to make the number sentence true.

$$5 + 3 + 9 = \boxed{17}$$

You’re right! / Good try. Your answer was X, and the correct answer was 17.

$$5 + 3 + 9 = 5 + \boxed{12}$$

You’re right! / Good try. Your answer was X, and the correct answer was 12.

Why does 12 make this a true number sentence?

$$5 + 3 + 9 = \boxed{10} + 7$$

How did you solve that problem?

You’re right! / Good try. Your answer was X, and the correct answer was 10.

Why does it make sense to put 10 in the box and not some other number?

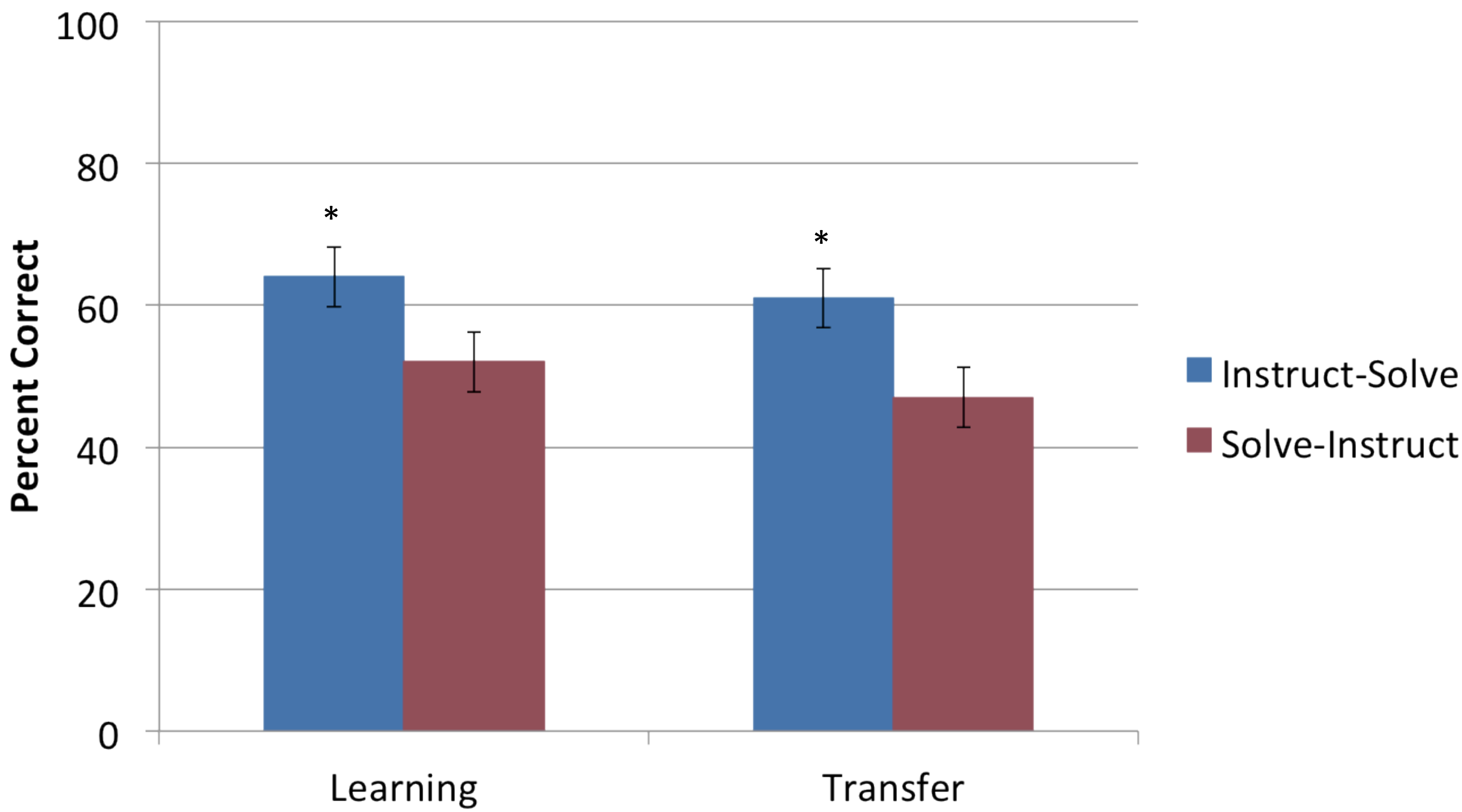
Exp 2: Results

Procedural Knowledge

Conceptual Knowledge

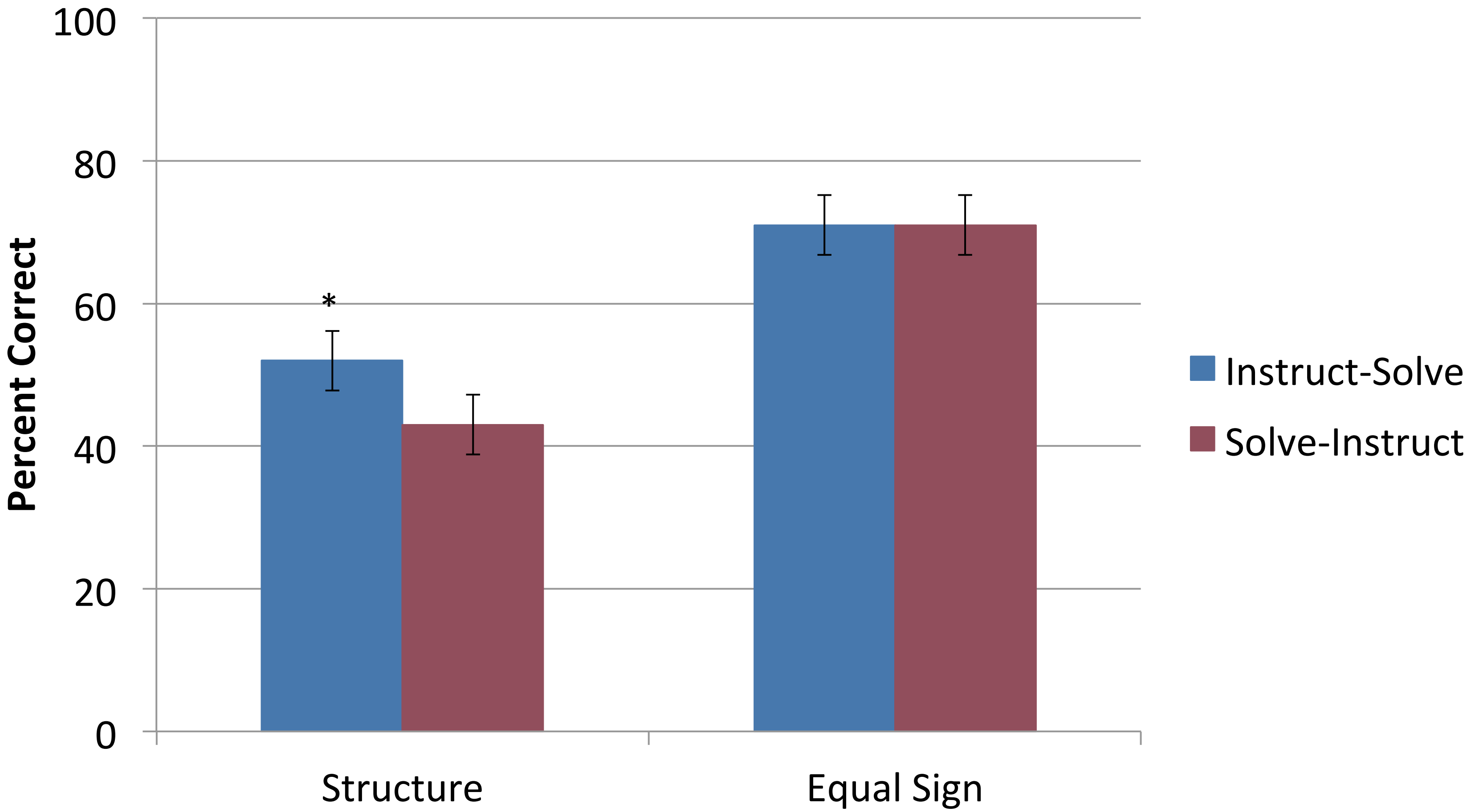
Self-Explanation Content

Procedural Knowledge



Repeated measures ANCOVA including posttest and retention test scores.

Conceptual Knowledge



Repeated measures ANCOVA including posttest and retention test scores.

Self-Explanation Content

Explanation Type	Sample Explanation (“Why does X make this a true number sentence?”)	% Trials		
		Instruct-Solve	Solve-Instruct	Total
Equal	They both have to equal the same.	46*	26	36
Answer	Because that’s the answer.	8^	14	11
Procedure	Because you add this and this.	26	30	28
Don’t Know	I don’t know.	8^	12	10
Other	That’s how you do it.	13	18	16

Exp 2: Summary

Providing conceptual instruction before problem solving resulted in better procedural and conceptual knowledge than the reverse

CONCLUSION:

Optimal sequence is to provide conceptual instruction BEFORE problem solving in math equality

Future Direction

Results contrast those from previous study

- Our goal is to hypothesize WHY the results differ
- Under what conditions does instruct-solve work better than solve-instruct for learning math equality? (and vice versa)

Clues from 2 key differences between experiments

Key Difference #1

Format of problem-solving

$$5 + 3 + 9 = 5 + \square$$

$$5 + 3 + 9 = \square$$

$$5 + 3 + 9 = 5 + \square$$

$$5 + 3 + 9 = \square + 7$$

Activating Misconceptions

Inclusion of “typical” arithmetic problems can create cognitive conflict by activating an operational view of the equal sign

(e.g., McNeil, 2008; McNeil & Alibali, 2005)

Activating this misconception of equality may hinder learning during subsequent instruction

But, this conflict may be more productive after conceptual instructional on equality

Key Difference #2

Self-explanation prompts

3 + 4 + 8 = □ + 8
Ashley got 7, which is the right answer.
How do you think Ashley got 7, which is the right answer?
Why do you think 7 is the right answer?

3 + 4 + 8 = □ + 8
Madison got 15, which is a wrong answer.
How do you think Madison got 15, which is the wrong answer?
Why do you think 15 is the wrong answer?

3 + 4 + 8 = □
3 + 4 + 8 = 5 + □
3 + 4 + 8 = □ + 8

Why does 7 make this a true number sentence?

Self-Explanation Prompts

Different prompts elicit different processes and this may influence optimal timing of instruction

(Berthold & Renkl, 2009; Nokes, et al. 2011)

"How" prompts promote generation of more varied and generalizable strategies

(Rittle-Johnson, 2006; Siegler, 2002)

May be more useful when exploring problems prior to instruction

"Why" prompts promote application of concepts

(e.g., Berthold & Renkl, 2009)

May be more useful after receiving instruction on concepts

What have we learned?

Sequencing Matters

Supports the notion that the seemingly minor differences in the structure and sequencing of learning materials is just as (if not more) important than the learning content itself

Learners exposed to the same learning material construct different knowledge based on the sequence of presentation

Thank You

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