Cognitive Science Society

The Effects of Feedback During Exploration Depend on Prior Knowledge

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Feedback

Touted as one form of guidance that may be particularly effective during problem solving

Any external information about performance or understanding the learner can use to confirm, reject, or modify prior knowledge

- "Providing timely feedback" identified as an optimal approach in exploratory contexts
  (Alfieri et al 2011)
- Feedback's primary function is to identify errors
  (e.g., Kulhavy, 1977)
- Meta-analyses generally reveal positive effects of feedback relative to no feedback controls
  (Hattie & Timperley, 2007; Kluger & DeNisi, 1996)

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But effects of feedback vary

"Feedback interventions can be double-edged swords" (Kluger & DeNisi, 1998)

"Feedback effects are among the most variable in their influences" (Hattie & Gan, 2011)

Effects of feedback are "contradictory and seldom straight-forward" (Ilgen, Fisher, & Taylor, 1979)

The goal is not to determine IF feedback is beneficial, but to determine UNDER WHAT CONDITIONS feedback aids learning

The role of prior knowledge

Feedback literature points to prior domain knowledge as key characteristic to consider

- Learners with low domain knowledge benefit from feedback; learners with higher knowledge may not

- College students in statistics (Krause, Stark, & Mandl, 2009)
- Children in arithmetic (Alibali, 1999)
- High schoolers in algebra (Hofer, Nussbaumer & Schneider, 2011)

But, few studies and only Krause include both low and high knowledge students in the same study

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Aptitude by Treatment Interactions

Consistent with ATI framework

- Instruction has positive effects for one type of learner, but neutral/negative effects for another (Cronbach & Snow, 1977)

Often occur in the context of differing levels of instructional guidance and learner prior knowledge (Kalyuga, 2007)

Supports notion that guidance (i.e., feedback) may help low knowledge learners, but learners with higher prior knowledge may not need it

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Goals of this study

Examine the effects of feedback during exploratory math practice for children with varying levels of prior domain knowledge

Feedback > No Feedback

Stronger effect for children with low prior knowledge

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Goals of this study

Explore whether the type of feedback matters

Outcome Feedback	Strategy Feedback
Provides information about learner's answer	Provides information about how answer was obtained
Examined extensively	Examined in few studies
Related to positive effects compared to no feedback	Better than outcome feedback in terms of strategy selection

Strategy Feedback > Outcome Feedback

(Ahmad, 1988; Kluger & DeNisi, 1996; Luwel et al., 2011)

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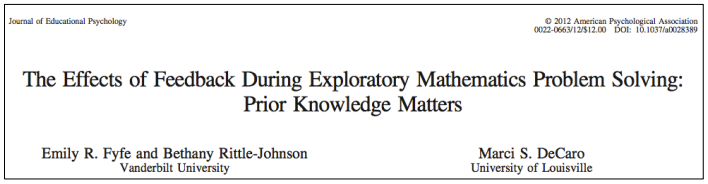
Current Study



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The Effects of Feedback During Exploratory Mathematics Problem Solving: Prior Knowledge Matters

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Evaluate impact of feedback for children with lower and higher prior knowledge in the same study

In the context of exploring novel problems prior to direct instruction

- Facilitates transfer
- Prepares students to learn from future instruction

(DeCaro & Rittle-Johnson, in press; Schwartz & Bransford, 1998; Schwartz et al., 2011)

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Math equivalence problems

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

- Problems contain operations on both sides of the equal sign

3 + 7 + 8 = 3 + _

6 + 4 = _ + 8

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Why math equivalence problems?

Novel and difficult for children in U.S.

- Rarely introduced in early math curriculum
  (Rittle-Johnson et al., 2011; Seo & Ginsburg, 2003)
- In one study, only 24% of U.S. children in 3rd and 4th grade solved math equivalence problems correctly
  (McNeil & Alibali, 2000)

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Outline

Experiment 1

- Method
- Results
- Summary

Experiment 2

- Method
- Results
- Summary

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Exp. 1: Design and Procedure

Participants: 87 children
(*M* age = 8 yrs, 6 mo; Range = 7 yrs, 7 mo – 10 yrs, 6 mo)

Session 1: Pretest (~25 minutes)

- Excluded if score >80% on pretest measures

Session 2: Intervention & Posttest (~50 minutes)

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

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Tutoring Intervention

Exploratory Practice

- Attempt to solve 12 math equivalence problems
- Randomly assigned to 1 of 3 conditions
  - No Feedback (n = 31)
  - Outcome Feedback (n = 31)
  - Strategy Feedback (n = 25)

Midtest

Brief conceptual instruction

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Exploratory Practice

Find the number that goes in the blank.
3 + 4 + 8 = 3 + □

How did you solve that problem?

No Feedback: "OK, let's move on to the next problem."

Outcome Feedback: "Good try, but that's not the correct answer. The correct answer is 12."

Strategy Feedback: "Good try, but that's not a correct way to solve that problem."

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Assessment of Math Equivalence

Procedural Knowledge

Used at Pretest, Midtest, Posttest, & Retention Test

- Use correct strategy to solve problems

7 + 6 + 4 = 7 + _

6 - 4 + 3 = _ + 3

Conceptual Knowledge

- Understand concept of equivalence

What does the equal sign mean?

4 + 8 = 8 + 4
True or False?

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

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Analysis & Results

Feedback (no feedback vs. two feedback conditions combined)

Feedback Type (outcome feedback vs. strategy feedback)

Included prior knowledge interactions

- Prior procedural knowledge
  - Lower knowledge = no correct strategies
  - Higher knowledge = know at least one correct strategy but don't always use it

Included several covariates

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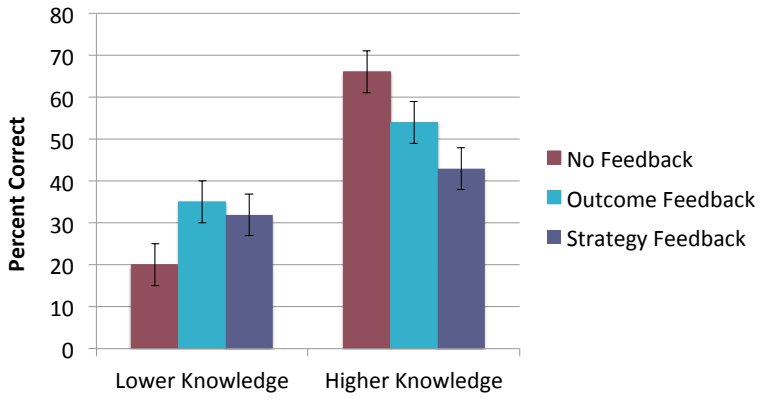
Procedural Knowledge

Repeated Measures ANCOVA: Midtest, Posttest, and Retention Test.



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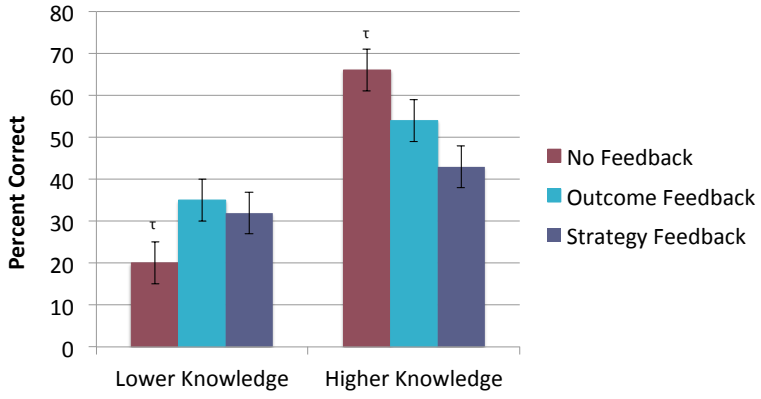
Procedural Knowledge

Repeated Measures ANCOVA: Midtest, Posttest, and Retention Test.



Overall feedback x prior knowledge interaction, $F(1, 79) = 5.70$, $p = .02$
Low Knowledge: Feedback vs. No Feedback, $F(1, 79) = 3.28$, $p = .07$
High Knowledge: Feedback vs. No Feedback, $F(1, 79) = 3.66$, $p = .06$

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Experiment 1 Summary

Aptitude by Treatment Interaction

Feedback during exploration led to higher procedural knowledge than no feedback, but only for children with low knowledge

For children with higher prior knowledge, reverse was true; benefited more from no feedback

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Experiment 1 : Issues to address

1. Predicted that feedback would be more effective for low knowledge learners, BUT did not expect complete reversal with feedback harming higher knowledge learners
2. Several limitations in the design
3. Clarify influences of strategy feedback vs. outcome feedback

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Experiment 2

Strengthen condition manipulation in Experiment 1 and replicate results with independent sample

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Exp. 2: Design and Procedure

Participants: 95 children

(*M* age = 7 yrs, 11 mo; Range = 6 yrs, 10 mo – 9 yrs, 10 mo)

Session 1: Pretest

Session 2: Intervention & Posttest

Session 3: Two-week Retention Test

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Tutoring Intervention

Exploratory Practice

- Attempt to solve 12 math equivalence problems
- Randomly assigned to 1 of 3 conditions
  - No Feedback (n = 31)
  - Outcome Feedback (n = 33)
  - Strategy Feedback (n = 31)

Midtest

Brief conceptual instruction

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Exploratory Practice

Find the number that goes in the blank.

3 + 4 + 8 = 3 + □

No Feedback: Report when finished with problem.

"OK, let's move on to the next problem."

Outcome Feedback: Report numerical answer.

"Good try, but you did not get the right answer. [Child's answer] is not the correct answer."

Strategy Feedback: Report problem solving strategy.

"Good try, but that is not a correct way to solve that problem. [Child's strategy] is not a correct way to solve it."

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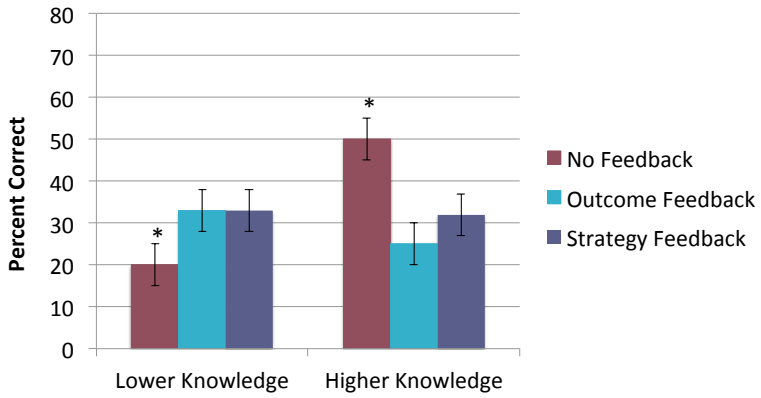
Procedural Knowledge

Repeated Measures ANCOVA: Midtest, Posttest, and Retention Test.



Overall feedback x prior knowledge interaction, $F(1, 87) = 4.67$, $p = .03$
Low Knowledge: Feedback vs. No Feedback, $F(1, 87) = 4.00$, $p = .05$
High Knowledge: Feedback vs. No Feedback, $F(1, 87) = 7.54$, $p = .007$

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Experiment 2 Summary

Replicated results of Experiment 1

Feedback led to higher procedural knowledge of math equivalence than no feedback, but only for children with low prior knowledge

For children with higher prior knowledge, no feedback was better

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Potential explanations

Why does feedback help low knowledge learners but hurt higher knowledge learners?

1. Changes in children's strategy knowledge
   - Feedback may help low knowledge learners figure out a correct strategy, but it's not necessary for higher knowledge learners
2. Experience of cognitive load
   - Feedback may reduce cognitive load for low knowledge learners but increase it for higher knowledge learners

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Implications

Theoretical

- Extends aptitude by treatment interaction work
  - Need not be "experts" to differ from low-knowledge
- Variable effects of feedback may be due to differences in prior knowledge

Practical

- Pay more attention to when you give feedback during tutoring and teaching

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Thank You

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For more information about our work
http://peabody.vanderbilt.edu/earlyalgebra.xml

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