

# Self-Explanation Prompts are Less Beneficial if Students Know More

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## *Introduction*

To develop new mathematical problem-solving approaches and understand increasingly difficult concepts, students must integrate new information with relevant prior knowledge (cf. Chi et al., 1989; Lombrozo, 2006). Self-explanation is one learning activity that may support such knowledge integration (Chi et al., 1989). Typically, self-explanation is prompted by showing a student a correct procedure, answer, or text passage and asking that student to explain the rationale underlying it. This instructional technique has been shown to improve learning and transfer across learning domains ranging from four-year-olds completing sequential patterns (Rittle-Johnson, Saylor, & Swygart, 2007), to middle school students learning geometry (Wong, Lawson, & Keeves, 2002), to bank apprentices learning to calculate interest (Renkl et al., 1998; see Atkinson et al., 2000, for a review). In general, there is broad endorsement in psychology and education for encouraging students to generate explanations during learning.

Despite its demonstrated benefits, self-explanation does not improve learning in all situations (e.g., Schworm & Renkl, 2006). For example, self-explanation sometimes has no benefit relative to a no-explain condition in which students instead spend an equivalent amount of time practicing problems (e.g., Matthews & Rittle-Johnson, 2009). And self-explaining sometimes leads to worse performance than not explaining at all (Kuhn & Katz, 2009). Thus, even though self-explanation is a useful instructional tool, there appears to be important constraints on its utility. It is important to elucidate when and how self-explanation will best benefit learning in order for this method to be effectively implemented in educational contexts.

Students commonly possess substantially different levels of knowledge on a given topic, even within the same educational grade or classroom (Hidi & Renninger, 2006). We propose that individual differences in prior knowledge may influence when self-explanation is beneficial as a learning tool. In teaching new mathematical concepts, instructors often begin with formal instruction on critical concepts, followed by problem-solving practice (e.g., Matthews & Rittle-Johnson, 2009). Students who already have some understanding of a topic may find that explaining rationales during problem solving is redundant with conceptual instructions, because conceptual instructions are sufficient to help them consolidate previous and newly-learned information (Wittwer & Renkl, 2006, 2010). Students with higher prior knowledge may benefit more from additional opportunities to practice solving problems (Anderson, 1982). In contrast, students with lower prior knowledge may benefit from self-explanations (above and beyond merely doing additional practice problems), to the extent that these prompts help them integrate the relatively new conceptual information introduced in the instruction with their limited knowledge base.

We examined these ideas within the domain of mathematical equivalence (i.e., that quantities on both sides of the equal sign represent the same amount), because of the importance of this concept to the development of early algebraic thinking (NCTM, 2006). To investigate the impact of prior knowledge on learning, we assessed conceptual and procedural components of mathematical equivalence before and after tutoring elementary school children on math equivalence, incorporating either self-explanation prompts or additional practice in the tutoring session. Because our tutoring session directly targeted conceptual understanding, we expected to

find differences on the conceptual (i.e., explicit understanding of the equal sign as a symbol of equivalence) rather than procedural (i.e., problem solving) measures. We hypothesized that students with lower prior knowledge would demonstrate better conceptual understanding after a tutoring session incorporating self-explanation prompts. In contrast, we predicted that higher-knowledge students would perform better when solving additional practice problems instead of self-explaining, demonstrating an important caveat to implementing this instructional technique.

### *Method*

To assess students' prior knowledge of math equivalence, we asked children in 2<sup>nd</sup> - 4<sup>th</sup> grades to complete a detailed assessment of mathematical equivalence knowledge in their classrooms (Rittle-Johnson et al., 2010). This assessment included explicit conceptual knowledge items (e.g., What does the equal sign mean?) and procedural knowledge items (e.g.,  $3 + 7 + 8 = 3 + \underline{\quad}$ ). Students were selected to participate in our tutoring session if they scored below 75% on the prior-knowledge assessment, to ensure that all students had room for improvement yet varying levels of prior knowledge. These children were randomly assigned to either a self-explain ( $n=40$ ) or additional practice ( $n=39$ ) condition.

During the tutoring session, students were first taught the concept of math equivalence in the context of number sentences, such as  $3 + 5 = 5 + 3$ . Then they solved problems that required operations on both sides of the equal sign. After each problem, students in the *self-explain condition* obtained accuracy feedback and were then shown the problem solutions of two other (hypothetical) children: one correct answer and one typical incorrect answer. These students were asked to explain how each child might have gotten his or her answer and then why the answer was correct or incorrect. Students in the *practice condition* simply solved additional problems with accuracy feedback, but received twice the number of problems to equate the amount of time self-explain students spent performing the task. To measure learning and retention, we re-assessed math equivalence knowledge immediately after the tutoring intervention (posttest), and again after a two-week delay (retention test), using separate versions of the same math equivalence assessment.

### *Results*

We report retention test results here, because we were ultimately interested in whether students retained math equivalence knowledge over time (i.e., retention) and because posttest and retention test findings were similar. We first discuss the results for procedural knowledge; then we discuss the results for conceptual knowledge.

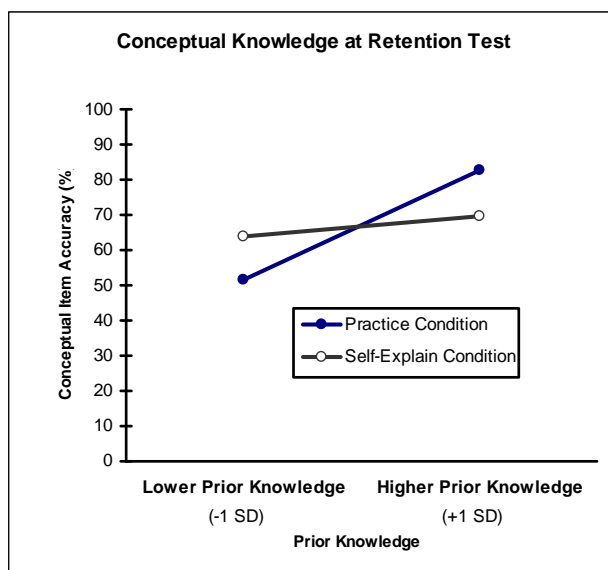
*Procedural Knowledge.* As expected, procedural knowledge at retention test was not impacted by tutoring condition, and there was no significant condition  $\times$  prior procedural knowledge interaction. However, prior knowledge of procedures did impact performance,  $B=.468$ ,  $t=3.31$ ,  $p=.001$ . Students higher in prior knowledge solved the problems better overall, and this better performance was not due to tutoring condition.

*Conceptual Knowledge.* For conceptual knowledge at retention test, there was a main effect of prior conceptual knowledge,  $B=.74$ ,  $t=4.05$ ,  $p<.001$ . There was no main effect of tutoring condition. And as predicted there was a significant condition  $\times$  prior conceptual knowledge interaction,  $B=-.60$ ,  $t=-2.41$ ,  $p=.019$ . The effect of tutoring condition depended on students' prior conceptual knowledge.

To better understand this interaction, we examined the relationship between prior conceptual knowledge and conceptual knowledge at retention test separately for each tutoring

condition. As shown in Figure 1, higher prior conceptual knowledge was associated with better conceptual performance at retention in the additional practice condition,  $B=.74$ ,  $t=4.04$ ,  $p<.001$ . but not in the self-explain condition,  $B=.11$ ,  $t=.64$ ,  $p=.53$ . Simple-effects tests (Cohen et al., 2003), further revealed that lower-prior knowledge students (1 SD below the mean) demonstrated better conceptual understanding in the self-explain condition than in the practice condition,  $B=13.01$ ,  $t=1.71$ ,  $p=.046$ , one-tailed. In contrast, their higher-prior knowledge counterparts (1 SD above the mean) showed better conceptual knowledge in the practice condition than in the self-explain condition,  $B=-12.41$ ,  $t=-1.72$ ,  $p=.045$ , one-tailed.

*Figure 1.* Conceptual knowledge (explicit understanding of the equal sign as a symbol of equivalence) at retention test as a function of prior conceptual knowledge and tutoring condition. Lower and higher knowledge are plotted at  $\pm 1$  standard deviation from the mean.



### Discussion

As predicted, after first receiving formal conceptual instructions on a to-be-learned topic, prior conceptual knowledge of the topic influenced whether self-explanation benefited conceptual learning above and beyond additional practice. Even though higher-knowledge students had significant room for improvement on our math assessment and potentially could have benefited from self-explanation, they did not. For higher-knowledge students, self-explanation after receiving formal instruction was less beneficial than simply completing additional practice problems. In contrast, students with lower prior conceptual knowledge benefited from self-explanation after receiving formal instruction—they performed best with self-explanation tutoring following instruction and worst when simply doing additional practice problems.

When students receive conceptual instruction immediately prior to problem solving, self-explanation prompts may help them integrate these new concepts with their prior knowledge if they have more to learn. However, the self-explanation activity may be redundant with conceptual instruction for students who already have some prior knowledge. Thus, for higher-knowledge students, extra problem-solving practice may be more helpful than self-explaining

because the extra practice enables them to solidify the procedural and conceptual knowledge they have integrated during instruction (cf. Anderson, 1982). Alternatively, the self-explanation activity itself might be hindering higher-knowledge students' ability to attain higher-level understanding. Specifically, when prompted to self-explain, higher-knowledge students may have the illusion that they already understand the material, which leads them to disengage interest from the self-explanation activity (Kuhn & Katz, 2009; Pressley et al., 1992; Wittwer & Renkl, 2006).

The exact means by which self-explanation benefits lower-knowledge students, but not higher-knowledge students, will be an important avenue for future research. However, our findings demonstrate an important, practical caveat for instructors to keep in mind when using self-explanation as an instructional tool. How students respond to the self-explanation activity depends on the student. Low-knowledge students learn better with self-explanation, but self-explanation is less beneficial for students who know more.

### References

- Anderson, J. R. (1982). Acquisition of a cognitive skill. *Psychological Review*, 89, 369-406.
- Atkinson, R. K., Derry, S. J., Renkl, A., & Wortham, D. (2000). Learning from examples: Instructional principles from the worked examples research. *Review of Educational Research*, 70(2), 181-214.
- Bjork, R.A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185–205). Cambridge, MA: MIT Press.
- Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.
- Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences* (3rd Edition). Lawrence Erlbaum: New Jersey.
- Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, 41, 111-127.
- Kuhn, D., & Katz, J. (2009). Are self-explanations always beneficial? *Journal of Experimental Child Psychology*, 103, 386-394.
- Lombrozo, T. (2006). The structure and function of self-explanations. *Trends in Cognitive Sciences*, 10, 464-470.
- Matthews, P., & Rittle-Johnson, B. (2009). In pursuit of knowledge: Comparing self-explanations, concepts, and procedures as pedagogical tools. *Journal of Experimental Child Psychology*, 104, 1-21.
- NCTM (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics*. Reston, Va: National Council for Teachers of Mathematics.
- Pressley, M., Wood, E., Woloshyn, V. E., Martin, V., King, A., & Menke, D. (1992). Encouraging mindful use of prior knowledge: Attempting to construct explanatory answers facilitates learning. *Educational Psychologist*, 27, 91-109.
- Renkl, A., Stark, R., Gruber, H., & Mandl, H. (1998). Learning from worked-out examples: The effects of example variability and elicited self-explanations. *Contemporary Educational Psychology*, 23, 90-108.

- Rittle-Johnson, B., Matthews, P., Taylor, R. & McEldoon, K. (2010, October). Assessing Knowledge of Mathematical Equivalence: A Construct Modeling Approach. *Proceedings of the 2010 annual meeting of the North American Chapters of the International Group for the Psychology of Mathematics Education*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education
- Rittle-Johnson, B., Saylor, M., & Swygart, K. (2007). Learning from explaining: Does it matter if mom is listening? *Journal of Experimental Child Psychology*, doi: 10.1016/j.jecp.2007.10.002.
- Roediger, H. L. III, & Karpicke, J. D., (2006). Test-enhanced learning: Taking memory test improves long-term retention. *Psychological Science*, 17, 249-255.
- Schworm, S., & Renkl, A. (2006). Computer-supported example-based learning: When instructional explanations reduce self-explanations. *Computers & Education*, 46, 426-445.
- Wittwer, J., & Renkl, A. (2006). Why instructional explanations often do not work: A framework for understanding the effectiveness of instructional explanations. *Educational Psychologist*, 43, 49-64.
- Wittwer, J., & Renkl, A. (2010). How effective are instructional explanations in example-based learning? A meta-analytic review. *Educational Psychology Review*, doi: 10.1007/s10648-010-9136-5.
- Wong, R. M. F., Lawson, M. J., & Keeves, J. (2002). The effects of self-explanation training on students' problem solving in high-school mathematics. *Learning and Instruction*, 12, 233-262.