Don't Just Do It, Explain It: A 5th Grade Worked Examples Curriculum Supports Transfer to Algebra Content

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Abstract: 5th graders (*n*=527) were randomly assigned to self-explain worked examples (WE) or solve problems during a yearlong study. WE students learned more algebra skills when given algebra worked examples on an end-of-year transfer measure. Comparing attempts, conceptual, and mechanical correctness by condition, results demonstrated that the condition difference in accuracy was attributable to better understanding of conceptual ideas in the WE condition, not to greater willingness to try or fewer mechanical errors.

A mathematics curriculum using worked examples

Previous research has shown that using worked examples in an algebra curriculum supports student learning (Booth et al., 2015). This curriculum translates learning sciences principles into practice, drawing on ideas from the worked example principle (Sweller, 1999), the importance of using *incorrect* worked examples (e.g. Siegler, 2002), and the role of self-explanation prompts (e.g., Chi, Leeuw, Chiu, & LaVancher, 1994).

In the current investigation, we explore the effectiveness of using a worked example curriculum for teaching 5th grade mathematics. We extend previous research by measuring whether learning 5th grade mathematics with worked examples supports transfer to a new content area (algebra) using items designed to measure students' Preparation for Future Learning (PFL; Bransford & Schwartz, 1999).

Method

Fifth grade students (*n*=527) in 32 classrooms (19 teachers) across the Midwestern US participated in a yearlong randomized control trial. Students completed 69 assignments covering multi-digit numbers, place value, decimals, basic operations with fractions, multiplying and dividing fractions, geometry and volume, and ordered pairs. To maintain ecological validity, teachers chose when and how to incorporate the problems into the curriculum; the main stipulation was that the problems be used during class time instead of as homework.

Students were assigned to either a Worked Examples (WE) or Control condition. Students in the business-as usual Control condition solved problems for each arithmetic content area. In contrast, the WE condition received correct and incorrect worked examples and targeted prompts to self-explain features of the examples. After each example, WE students solved an isomorphic problem. Both conditions worked with the same problems; WE students self-explained worked examples of half and solved half whereas students in the Control condition solved all of the problems.

At the start of the year, students completed a pretest consisting of standardized test items measuring knowledge of 4th grade math concepts and skills plus research-based measures of student explanation, error anticipation, and flexibility. At the end of the year, students completed several measures, the results of which are reported elsewhere. Here, we analyze a PFL transfer measure. In this measure, students received learning resources (worked examples involving solving algebraic equations) and were asked to solve isomorphic problems. The algebra content was not addressed in the 5th grade curriculum; problems were designed to measure whether students could interpret worked examples and solve problems about new content.

Results

Average scores on the algebra transfer measure were 27.2% correct (SD = 3.53) for the WE condition and 19.7% correct (SD = 3.16) for the Control condition. Even controlling for pretest, students in the WE condition performed significantly better than Control ($F(1, 524) = 7.16$, $p = .008$, $\eta^2 = .013$). Though performance was relatively low, likely because this was a more challenging math topic for this age group, the significant condition difference suggests that learning from worked examples helped students learn in a new content area.

To further understand this condition difference, we investigated whether students' errors resulted from leaving the problem blank or making a conceptual error, a mechanical error, or both. Conceptual errors included mistakes that indicated misconceptions about the mathematical concepts tested, such as order of operations and performing equivalent operations on both sides of the equals sign, whereas mechanical errors included miscopying numbers (e.g. *13* vs. *31*) or simple arithmetic errors (e.g. *2+3=6*). This analysis, visualized in Figure 1, allowed us to address three possible mechanisms for the condition difference in accuracy.

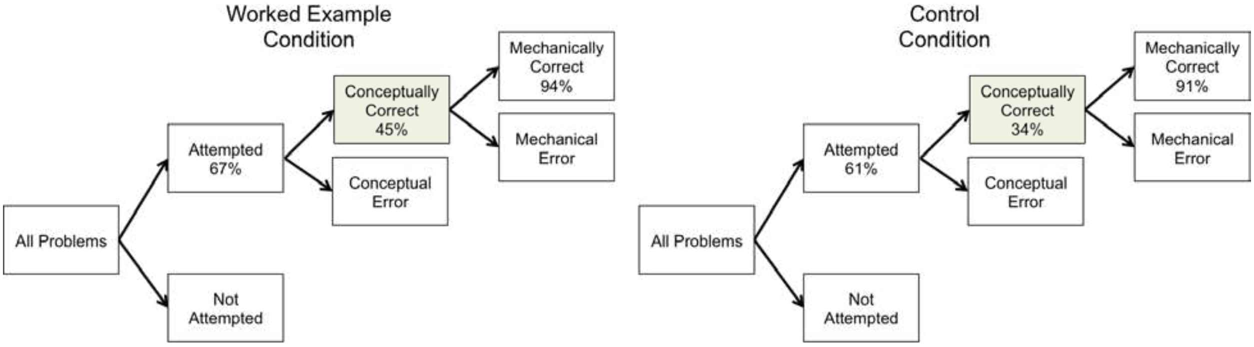

Figure 1. Likelihood of students attempting and correctly solving the algebra problems on the PFL transfer measure by condition. The highlighted level indicates a difference in conceptual understanding.

Attempts

One potential hypothesis is that students in the WE condition were more likely to attempt the problems because of their yearlong experience with worked examples. To answer this, we compared the percent of problems that students attempted: 67% in the WE condition vs. 64% in the Control condition. There was not a significant condition difference in the likelihood to attempt the problem (χ^2=1.67, p=.20); the condition difference in accuracy does not stem from a difference in the conditions' willingness to try.

Conceptual correctness

Alternatively, the condition difference in accuracy may result from a difference in students' ability to transfer their conceptual understanding, recognize the deep structure in the worked example, and apply it to the new problems. We compared the amount of conceptually correct problems as a percent of the attempted problems by group. In the WE condition, students were conceptually correct on 45% of their attempts as compared to 34% in Control. This was significantly different by condition (χ^2=10.76, p<.01); students in the WE condition were better able to understand concepts presented in the transfer resources and less likely to make conceptual errors.

Mechanical correctness

A final mechanism for the difference in accuracy could lie in students' attention to surface features. Of the problems that students got conceptually correct, did one condition make more mechanical errors? Mechanical correctness was high: 94% in the WE condition and 91% in Control. There was no significant condition difference (χ^2=1.33, p=.25); learning from worked examples did not lead to fewer mechanical errors.

Implications

This study extends previous translational research on worked examples to an elementary classroom setting and includes new error analyses to understand the mechanism though which worked examples can promote learning. Our results demonstrate that learning 5th grade mathematics from worked examples leads to greater learning in a new algebra content area. Importantly, this difference can be attributed to a deeper understanding of conceptual ideas among the WE students rather than an increased willingness to try solving the problems or a greater attention to surface feature mechanical details. These findings offer insight into the importance of carefully designing instructional materials that support learning and enable students to learn in future tasks.

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