

## PAPER #2 SUMMARY

### **When and how do worked examples work? Middle school students' use of worked examples in textbook homework assignments**

Eliane Stampfer Wiese, *Carnegie Mellon* [stampfer@cs.cmu.edu](mailto:stampfer@cs.cmu.edu)

Elizabeth A. McLaughlin, *Carnegie Mellon* [mimim@cs.cmu.edu](mailto:mimim@cs.cmu.edu)

Julie Booth, *Temple University* [jlynn80@temple.edu](mailto:jlynn80@temple.edu)

Kenneth R. Koedinger, *Carnegie Mellon* [koedinger@cmu.edu](mailto:koedinger@cmu.edu)

Worked examples provide students with powerful learning opportunities, but these opportunities are not always realized. Previous work has shown benefits for worked examples when students are directed in how to study them (Mwangi & Sweller, 1998; Sweller & Cooper, 1985). What happens when students are on their own? This study examined how students approach worked examples when they are not given guidance from an experimenter. Using the revised CMP2-R materials (6<sup>th</sup> and 8<sup>th</sup> grade content) in a think aloud study, we examined how middle school students learn from worked examples. Additionally, we developed a theoretical model of desired learning with worked examples (see Figure 1), which includes reading the example and generating self-explanations of unclear steps. We found that participants deviated from the theoretical model in many ways, illustrating several behaviors that may pose obstacles to learning from worked examples.

To assess immediate learning from worked examples, we developed test forms for each unit with sequences of a pre-item, worked example, and post-item. The four pre-item forms consisted of two problems taken directly from the revised materials. The post-item forms repeated both pre-items, and included two additional items that were analogous to the pre-items (i.e., they shared the same deep problem features and were solvable with the same general strategy). One problem on each post-item form included a worked example. Of the sequences that students completed, three consisted of a pre-item, a worked example of that pre-item, and an analogous post-item. In six sequences the worked example problem was analogous to the pre item, and the pre- and post-items were identical. One problem included three parts, and we count each part as a separate sequence.

This study included three types of worked examples: full, faded, and incorrect. Of the sequences of pre-item, worked example, and post-item that students completed, four sequences included full examples, which provided the correct solution with at least one intermediate step, and prompted students to explain some aspect of the solution or problem solving strategy. Four sequences included faded examples, which provided some but not all of the solution steps, and did not prompt students for explanations. One sequence included an incorrect example, which provided a mostly correct solution, indicated which part of the solution was incorrect, and prompted students to explain why that part was incorrect.

Ten middle school students came in to the lab for a one-hour session and were instructed to think out loud as they worked through the forms. Students were told to treat the problems as they would a homework assignment. Students took as long as they wanted for each problem. In total, 25 pre-item, worked example, post-item sequences were completed. Though encouraging that six of eight students reported in a post interview that the worked examples helped them learn, a quantitative pre-post comparison was less clear. Of the 25 sequences, eight were conceptually

correct on both pre and post (one sequence included arithmetic errors). Of the 17 sequences where the pre-item was incorrect, three ended with a correct post-item (clear evidence of learning), and five repeated the same incorrect strategy on both the pre- and post-items (evidence of no learning). Seven sequences involved an incorrect strategy on the post-item that was different from the incorrect strategy used on the pre-item, indicating possible learning not revealed in simple correctness. Our main goal of the analysis was to identify limitations in the metacognitive learning strategies students employ with worked examples.

In analyzing students' learning strategies with the worked examples, we compared the students' actions to a theoretical model of desired learning (Figure 1). In the theoretical model, students read the problem statement (step 1), notice the worked example (step 2), and read each step of the worked example (step 3). For each step, if the student only partially understands the step, the student should attempt a self-explanation (steps 4, 5, and 7). If the student does not understand the step at all, the student should seek additional information from another resource (steps 4-6). After reading through all the steps, the student should group steps by sub-goal and infer a general strategy (step 9). We developed this model of desired example study as a theoretical hypothesis, with the importance of self-explanation and sub-goal identification supported by prior work (Renkl, 1997).

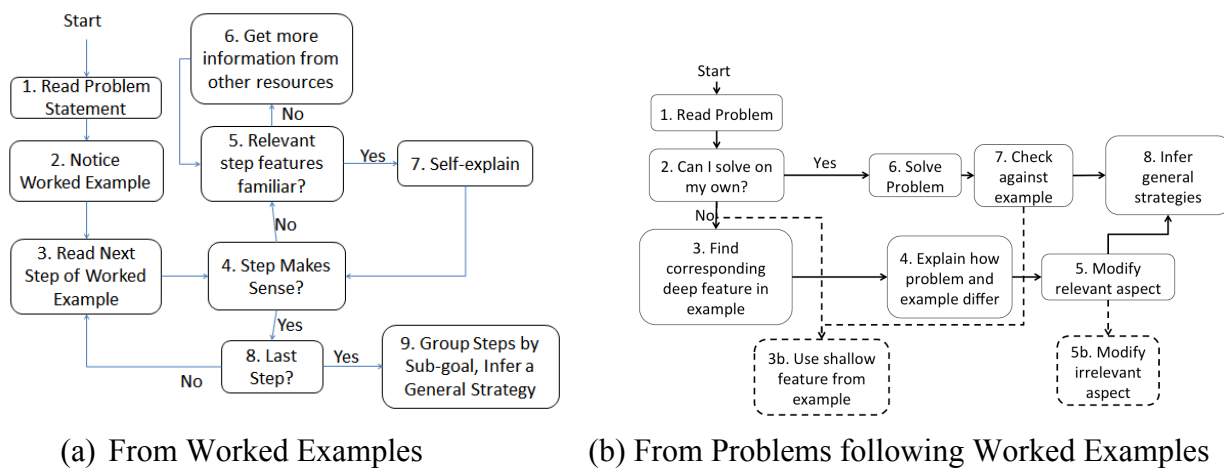
Students deviated from the desired model in several ways, starting with not noticing the worked example. In four sequences, the student only read the worked example after solving the problem independently; in four sequences the student did not read the worked example at all. Of the 17 sequences where the student did notice the worked example and did not solve the problem on their own, in 14 of those sequences the student read the whole example, while in the remaining sequences the student read the example only partially. Further, students generally did not generate spontaneous self-explanations. Of the 25 sequences, most included explicit explanation prompts either in the original problem statement or in the worked example (e.g., Why should you use an inequality instead of an equation to solve this problem?). Students generated explanations for almost all of the sequences with an explicit explanation prompt (15 of 16). In contrast, students generated explanations on fewer than half of the sequences without explanation prompts (4 of 9). We found no evidence of students spontaneously extracting problem-solving strategies while studying the worked examples.

Students may demonstrate learning from a solution example (either a worked example or a self-created solution from a prior problem) when solving a subsequent problem. Figure 1b shows a theoretical model of desired learning from solution examples. In this model, if the student cannot solve the new problem, the student refers back to prior examples to induce relevant patterns or features (step 3). If the student can solve the new problem, according to the model the student should refer to the prior solution example to check their work (step 7). Students rarely made these spontaneous connections between the problems they were solving and the isomorphic worked example or the previously solved pre-item. Of the 25 sequences, students made substantive connections in four of them (e.g., explicitly referencing a previously used strategy). Students made shallow connections in an additional three sequences (e.g., saying that the answer from the worked example could also be used for the isomorphic post-item).

Worked examples are intended to demonstrate general strategies that students can use on later problems. If a student makes a substantive connection between the post-item and the isomorphic worked example, indicating that the strategy illustrated in the worked example can be applied to the post-item, we take such a connection to be one indication of immediate learning

from the worked example. As an example of a substantive connection, one student finding the area of an irregular shape on a post-item verbalized “I’ll divide it like he did,” referring to the worked example strategy (Figure 2). This example illustrates a student extracting a deep feature from a worked example and adapting to the current problem (instead of using a shallow strategy such as copying the answer from the worked example). Additionally, this brief utterance indicates that the student extracted a problem-solving strategy from the worked example, even though it was not verbalized until the student solved a problem independently.

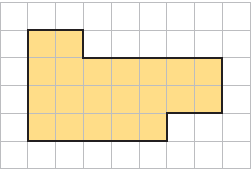
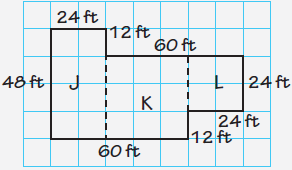
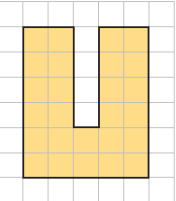
In other cases, students may acquire shallow features from solution examples. For example, one pre-item asked “Draw two different shapes with an area of 16 square units. What is the perimeter of each shape?” One student started with a 4x4 square. After calculating that the area and perimeter were both 16, the student chose a 2x8 rectangle for the second shape, and indicated that it too had a perimeter of 16 (suggesting use of a shallow strategy of copying the perimeter from the first shape). On subsequent problems this student demonstrated an understanding of the difference between area and perimeter, clarifying that the student had not simply mixed up the formulas. However, even after reading through a relevant worked example, the student gave the same answer (and same error) on the post-item as the pre-item.



**Figure 1.** Desired models of learning metacognitive learning strategies with (a) from Worked Examples and (b) From Problems following Worked Examples. Dashed lines and boxes show incorrect actions.

These findings indicate challenges that middle school students face in taking full advantage of worked examples as learning opportunities. Some of these behaviors (e.g., not reading or noticing the worked examples) may be addressed with improved problem design or explicit prompts from teachers. Other behaviors, such as not attempting to infer a general strategy from an example may be more difficult to address simply through material redesign. Many middle school students may not have the metacognitive skills necessary to monitor their own understanding, infer the strategy that the worked example is intended to illustrate, identify what type of problem that strategy works for, and then apply that strategy to a later problem. Although middle school students have experience with worked examples from classroom demonstrations and textbooks, they may require more and repeated support to develop the necessary metacognitive skills to make the best use of them. In particular, students may benefit from explicit instruction in how to study worked examples, how to make use of them when

solving subsequent problems, and how to generate self-explanations. While students are practicing these metacognitive skills, it may be appropriate for them to study worked examples for easy problems, so that they can focus solely on learning the metacognitive strategies instead of also learning new content.

<p>For Exercise 3, each unit length represents 12 feet. Find the area and perimeter of each floor plan.</p> <p>3.</p>  <p>Igor started to solve this problem, but he got stuck. He divided the large shape into smaller shapes that he labeled J, K, and L. Fill in the missing side lengths and complete the problem.</p>  <p> <math>P = 24 + 12 + 60 + 24 + \square + \square + 60 + 48</math>  <math>P = \square \text{ ft}</math> </p> <p>           Area of Shape J = <math>48 \text{ ft} \times 24 \text{ ft} = 1152 \text{ ft}^2</math>            Area of Shape K = <math>\square \text{ ft} \times 36 \text{ ft} = \square \text{ ft}^2</math>            Area of Shape L = <math>\square \text{ ft} \times 24 \text{ ft} = \square \text{ ft}^2</math>            Total area = <math>1152 \text{ ft}^2 + \square \text{ ft}^2 + \square \text{ ft}^2</math>  <math>= \square \text{ ft}^2</math> </p>	<p><b>Faded Worked Example</b> (exercise 3)</p> <p> <math>3P = 264 \text{ ft}</math>  <math>A = 3024 \text{ ft}^2</math> </p> <p> <math display="block">\begin{array}{r} 3 \\ 36 \\ + 36 \\ \hline 72 \\ 216 \\ 1080 \\ \hline 1296 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 1 \\ 24 \\ + 24 \\ \hline 48 \\ 240 \\ 1200 \\ \hline 1440 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 2 \\ 4196 \\ 12480 \\ 60576 \\ 2424 \\ 24 \\ 12 \\ 60 \\ 48 \\ \hline 264 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 121 \\ 1296 \\ 576 \\ \hline 1152 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 31024 \end{array}</math> </p>
<p>(a) Faded Worked Example</p>	<p>(c) Student work for faded Worked Example</p>
<p>For Exercise 4, each unit length represents 15 feet. Find the area and perimeter of each floor plan.</p> <p>4.</p> 	<p>4. <math>P = 450 \text{ ft}</math> <math>A = 5850 \text{ ft}^2</math></p> <p> <math display="block">\begin{array}{r} 30 \\ + 60 \\ \hline 1800 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 5600 \\ + 2250 \\ \hline 5850 \end{array}</math> </p> <p> <math display="block">\begin{array}{r} 1 \\ 75 \\ 20 \\ \hline 2250 \end{array}</math> </p>
<p>(b) Post-item</p>	<p>(d) Student work for Post-item</p>

**Figure 2.** A faded worked example (a) and isomorphic post-item (b). The problem at the top of (a), without the worked example, serves as a pre-item for this sequence. In (d), a student's work on the post-item shows the same strategy as used in the faded worked example (c).

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