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Effects of Worked Examples, Example-Problem Pairs, and Problem-Example Pairs Compared to Problem Solving

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Abstract. Research has demonstrated that instruction that relies more heavily on example study is more effective for learning than instruction consisting of problem solving. However, ‘a heavier reliance on example study’ has been implemented in different ways, using worked examples only, example-problem pairs, or problem-example pairs. Despite a large amount of research on example-based learning, these three strategies have not been compared to each other and to problem solving in a single study. Moreover, effects on cognitive load of these different strategies have not yet been systematically compared. Therefore, this study investigated the effects on cognitive load and learning of example study only, example-problem pairs, problem-example pairs, and problem solving only. Results show that it is not strictly necessary to alternate example study and problem solving: example study only and example-problem pairs were more effective and efficient than problem solving only and problem-example pairs.

Keywords: worked examples; problem solving; cognitive load

Introduction

Whereas conventional problems contain only a description of “givens” (e.g., how fast a car accelerates and its average velocity) along with a goal statement (e.g., ‘calculate how far the car has travelled’), worked examples additionally show learners the worked-out solution steps required to reach the goal. Research has shown that for novices, instruction that relies more heavily on worked example study is more effective for learning and transfer than instruction consisting of problem solving, and is also often more efficient, in that this higher learning is reached with less investment of time or mental effort (for reviews, see Atkinson, Derry, Renkl, & Wortham, 2000; Sweller, Van Merriënboer, & Paas, 1998). This is known as the ‘worked example effect’ (Sweller et al.).

Placing more emphasis on example study during instruction can be done in different ways. A few studies have compared the effects of example study only to problem solving only, and found example study to be more effective for learning and transfer as well as more efficient in terms of mental effort investment (Nivelstein, Van Gog, Van Dijck, & Boshuizen, 2010; Van Gerven, Paas, Van Merriënboer, & Schmidt, 2002; Van Gog, Paas, & Van Merriënboer, 2006). Most studies, however, have alternated example study with problem solving. Several studies have shown that example-problem pairs were more effective for learning and transfer than problem solving only (e.g., Cooper & Sweller, 1987; Sweller & Cooper, 1985). Sweller and Cooper (1985) mention that engaging in solving a similar problem immediately after example study may be more motivating for students, because it is more active than studying another example would be. A few studies have investigated the use of problem-example pairs (e.g., Reisslein, Atkinson, Seeling, and Reisslein, 2006; Stark, Gruber, Renkl,

& Mandel, 2000), arguing that when learners first experience deficiencies in their performance during problem solving, they may be more motivated to study the example and may focus on the steps that they could not solve. Even though many of the above mentioned studies were inspired by cognitive load theory (Sweller et al., 1998) not all of them addressed the effects of cognitive load imposed by the by the different example-based learning strategies.

Despite the substantial amount of research that has been conducted on the effectiveness of each of those different strategies, no comparison has been made between all those strategies in a single study. Therefore, this study compared the effects of examples only, example-problem pairs, problem-example pairs, and to problem solving only on novices' cognitive load and learning.

Method

Participants

Participants were 103 secondary education students from two Dutch schools (48 male; age $M = 16.22$, $SD = 0.84$). Participants were randomly assigned to one of the four conditions: (1) problem solving only ($n = 26$), (2) problem-example pairs ($n = 26$), (3) example-problem pairs ($n = 25$), and (4) example study only ($n = 26$).

Materials and procedure

Participants first completed a prior knowledge test on electrical circuits troubleshooting (cf. Van Gog, Paas, & Van Merriënboer, 2008). Then, they engaged in two pairs of training tasks (i.e., four tasks in total) consisting of a malfunctioning parallel electrical circuit (cf. Van Gog et al., 2006, 2008) presented on paper that participants had to 'troubleshoot' (i.e., diagnose the fault), or the solution to which they had to study (i.e., when it was presented as a worked example). After the training tasks, participants solved a retention test problem and a transfer test problem. Immediately after each example or problem in the learning or test phase, participants rated the amount of mental effort they invested on the 9-point rating scale developed by Paas (1992).

Results

Mental effort invested in the training tasks was significantly lower in the examples only and example-problem pairs conditions than in the problems only and problem-example pairs conditions. Performance on both the retention and transfer test was significantly higher in the examples only and example-problem pairs conditions than in the problems only and problem-example pairs conditions. Mental effort invested in the retention test was significantly higher in the problem-example pairs condition than in the example-problem pairs and examples only conditions, and mental effort invested in the transfer test was significantly higher in the problem-example pairs than in the example-problem pairs condition.

Discussion

Results showed that the problem solving only and problem-example pairs conditions were less effective than the examples only and example-problem pairs conditions. Not only did the examples only and the example-problem pairs conditions significantly outperform the problem solving only and problem-example pairs conditions on the retention and transfer test, this higher performance was also reached with significantly lower investment of mental effort during the training. This is indicative of

higher efficiency in terms of the learning process, that is, in terms of the cognitive 'costs' and benefits of training (see Van Gog & Paas, 2008).

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