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Comparing the effects of worked examples and modeling examples on learning

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ABSTRACT

Example-based learning is an effective instructional strategy for students with low prior knowledge, and is increasingly being used in online learning environments. However, examples can take many different forms and little is known about whether and how form affects learning outcomes. Therefore, this study investigated whether worked examples and modeling examples with and without a visible model would be equally effective in fostering learning of a problem-solving task. In Experiment 1, secondary education students ($N = 78$) learned how to solve a probability calculation problem by watching two videos that, depending on the assigned condition, provided worked examples (written text, pictures of problem states), modeling examples with a visible model (spoken text, a demonstration of the task), or modeling examples without a visible model (spoken text, pictures of problem states). Results showed that all three conditions were equally effective at fostering learning, near transfer, effort reduction, self-efficacy, and perceived competence. Experiment 2 ($N = 134$) replicated these results with a younger student population that only studied one example. These findings suggest that the format of examples does not affect learning outcomes for this task; future research should investigate whether this would generalize to other problem-solving tasks.

1. Introduction

Example-based learning is an effective and efficient instructional strategy for teaching novice learners new problem-solving skills (Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2014; Sweller, Ayres, & Kalyuga, 2011; Sweller, Van Merriënboer, & Paas, 1998; Van Gog & Rummel, 2010), and for enhancing learners' self-efficacy (Bandura, 1997; Crippen & Earl, 2007). Research has traditionally focused on two forms of example-based learning (for reviews: Renkl, 2014; Van Gog & Rummel, 2010). Studies conducted from a cognitive perspective (e.g., cognitive load theory; Sweller, 1988; Sweller et al., 1998, 2011) have mostly examined text-based *worked examples* that explain how to complete a task. Studies conducted from a social-cognitive perspective (e.g., social learning theory; Bandura, 1977, 1986; cognitive apprenticeship: Collins, Brown, & Newman, 1989) have mostly examined *modeling examples*, in which an expert, teacher, or peer student – the model – demonstrates and (often) explains how to complete a task. Modeling examples can be both live (e.g., Bjerrum, Hilberg, Van Gog, Charles, & Eika, 2013; Krautter et al., 2011) or on video (e.g., Braaksma, Rijlaarsdam, & Van den Bergh, 2002; Groenendijk, Janssen, Rijlaarsdam, & Van den Bergh, 2013; Schunk, Hanson, & Cox, 1987; Schwan & Riempp, 2004; Van Gog, Verveer, & Verveer, 2014). In many video modeling examples, the model is (partly) visible in the video (e.g., Atienza, Balaguer, & Garcia-Merita, 1998; Schunk et al., 1987; Van Gog et al., 2014; Xeroulis et al., 2007). These are henceforth referred to as 'modeling examples with a visible model'.

With technological advances, new forms of video examples are being developed that combine features of worked and modeling examples and are widely used in online learning environments. For instance, one may hear the model explaining the task while seeing the model's computer screen on which he or she is performing the problem-solving steps (e.g., McLaren, Lim, & Koedinger, 2008; Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009; Van Gog, 2011), writing out the steps (e.g., www.khanacademy.org), or illustrating the steps with pictures or slides (e.g., Leahy & Sweller, 2011). Consequently, learners observing such modeling examples can only hear the models but do not see them. These examples are henceforth referred to as 'modeling examples without a visible model'.

Not only do worked examples, modeling examples with a visible model, and modeling examples without a visible model vary in terms of social aspects, but as we will explain below, their

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design may also have potential advantages and disadvantages in terms of cognitive aspects of learning. However, despite the substantial amount of research on example-based instruction, and the fact that worked and modeling examples are increasingly being used in online learning environments or on computers, tablets, or smart boards in the classroom, little is known about how the social and cognitive consequences of the various example types would affect the learning process and learning outcomes. The present study therefore compares the effects of worked examples and modeling examples with and without a visible model on cognitive factors such as learning (i.e., applying what has been learned to new tasks of the same type that differ in surface features but have the same structural features), near transfer (i.e., applying what has been learned to new tasks of the same type that are slightly more complex; i.e., differ in surface features and partly in structural features) and far transfer (i.e., applying what has been learned to new tasks of a different type; i.e., different structural features/solution procedures), and motivational factors of learning such as self-efficacy when learning a problem-solving task.

1.1. Effects of example design on cognitive and motivational factors

Worked examples and modeling examples with and without a visible model have different design characteristics that may be more or less conducive to learning when seen from a cognitive load perspective. Cognitive load theory (Sweller, 1988; Sweller et al., 1998, 2011) argues that it is important to design instruction in such a way that ineffective working memory load (i.e., extraneous load) is reduced so that more working memory resources are available for processes that are effective for learning (i.e., germane load).

There are several known causes of extraneous load. For instance, the split attention effect (for reviews, see Ayres & Sweller, 2005; Sweller et al., 2011) shows that separately presenting mutually referring written text and graphical information requires learners to split their attention between both information sources and to mentally integrate them, which can hinder learning. This split in attention can be (partially) remedied by providing learners with an integrated format (i.e., text mapped onto corresponding parts of the picture; e.g., Chandler & Sweller, 1992), by visually guiding learners' attention to the corresponding elements (i.e., color-coding cues; e.g., Ozcelik, Karakus, Kursun, & Cagiltay, 2009), or by replacing written text with spoken text (i.e., making use of the modality effect; Kühl, Scheiter, Gerjets, & Edelmann, 2011; Mayer & Moreno, 1998; Mousavi, Low, & Sweller, 1995). A potential benefit of using multiple modalities is that information processing is divided over different working memory systems (Baddeley, 1986), which helps reduce working memory load, because learners can devote their visual attention to the pictures while listening to the spoken text (Ginns, 2005; Leahy & Sweller, 2011; Sweller et al., 2011). Note that, with regard to example design, replacing written text with spoken text could result in a modeling example in which the model is not visible, but learners only hear the model's explanation of how to perform the task, supported by pictures of the problem states or slides.

The use of spoken text can, however, also have a potential drawback, because it leads to information transience. The transient information effect shows that, because of the temporal limits of working memory, spoken text can lead to an increase of extraneous load and can therefore hamper learning outcomes compared to written text, which is often permanently available (Singh, Marcus, & Ayres, 2012; Sweller et al., 2011). Yet transient information is not always detrimental to learning. For instance, when learners already have a substantial amount of prior knowledge, or when the instructional text is short in length or low in complexity, then learners should be able to easily process the learning materials regardless of information transience (Leahy & Sweller, 2011). Consequently, the negative effects of transient information on cognitive load and learning can be remedied by dividing lengthy sections into smaller segments (Mayer & Chandler, 2001; Spanjers, Wouters, Van Gog, & Van Merriënboer, 2011; Wong, Leahy, Marcus, & Sweller, 2012).

With regard to modeling examples with a visible model, the *model* might possibly present a source of split attention. Although it is a natural process to observe a demonstration by another person and we learn human-movement tasks (e.g., assembly, origami, knot-tying) more effectively by observing dynamic visualizations compared to static ones (Höffler & Leutner, 2007; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009), it could be argued that in tasks to which human movement is not inherent, seeing the model might draw attention away from the task because we tend to automatically focus our attention on other people's – and even animated pedagogical agents' – faces (see Van Gog et al., 2014). In addition, just like certain features of animated pedagogical agents (i.e., virtual characters that simulate human instructional roles) have been hypothesized to be able to draw attention away from the learning materials (Moreno & Flowerday, 2006; Walker, Sproull, & Subramani, 1994), a model may do the same because he or she provides learners with additional, redundant information compared to written text, such as the model's tone of voice, clothes, and task-irrelevant movements.

The social cues that are more strongly available in modeling examples (regardless of whether or not the model is visible) than in written worked examples may also affect motivational aspects of learning, such as self-efficacy or perceived competence. Because modeling allows for social comparison (Berger, 1977; Johnson & Lammers, 2012), observing another person successfully explain and perform a task increases the likelihood that learners believe that they can perform the task as well (Bandura, 1981; Schunk, 1984). According to the cognitive theory of multimedia learning, social cues such as the model's voice and visibility allow for this social comparison to take place because they stimulate learners to link the presented content to their own personal self (Mayer, 2005). A study with animated pedagogical agents by Rosenberg-Kima, Baylor, Plant, and Doerr (2008) showed that adding an animated pedagogical agent that lip-synchronized the instructional text and occasionally gestured, enhanced self-efficacy compared to a voice-only condition. If this would also apply to video modeling examples, then seeing the model might positively affect self-efficacy.

Research on worked examples has largely ignored motivational effects of example-based learning (Van Gog & Rummel, 2010), presumably because social cues are less prominent in written examples. However, when comparing the effectiveness of worked examples and modeling examples, it is important to not only focus on cognitive effects, but to also take into account effects on self-efficacy and perceived competence. That is, self-efficacy seems to have significant bearing on factors such as academic motivation, study behavior, and learning outcomes (Bandura, 1997; Bong & Skaalvik, 2003; Schunk, 2001). The closely related construct of perceived competence, which refers to more broad perceptions and knowledge that are consequently also more stable and enduring (Bong & Skaalvik, 2003; Hughes, Galbraith, & White, 2011; Klassen & Usher, 2010), has also been shown to have significant influence on academic motivation and learning outcomes (Bong & Skaalvik, 2003; Harter, 1990; Ma & Kishor, 1997).

To conclude, it is an open question whether and how the different design characteristics of worked examples and modeling examples with and without a visible model would affect the learning process (e.g., effort investment) and learning outcomes. Regarding self-efficacy and perceived competence, the literature reviewed above suggests that modeling examples can be expected