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Example-based learning: The benefits of prompting organization before providing examples

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ABSTRACT

Example-based learning often follows a design in which learners first receive instructional explanations that communicate new principles and concepts and second examples thereof. In this setting, using the knowledge components of the instructional explanations to explain the examples (i.e., generating principle-based self-explanations) is considered to be a highly important learning process. However, a potential suboptimality of this learning process is that it scarcely requires learners to organize the content of the instructional explanations into coherent mental representations. Thus, in two experiments we investigated whether prompting learners to organize the content of the instructional explanations before providing them with the examples (and self-explanation prompts) enhances the effectiveness of example-based learning. We consistently found that organization prompts fostered learning regardless of whether the learners also received self-explanation prompts. Hence, in example-based learning, learners should be prompted to not only generate principle-based self-explanations but also to organize the content of the instructional explanations.

1. Introduction

Example-based learning is a widely-used instructional approach (see Renkl, 2014). In the field of learning from worked examples, it is typically designed so that learners first receive an instructional explanation that communicates basic declarative knowledge regarding new principles and concepts that are to be learned. In the second step, learners are provided with multiple examples that illustrate these principles and concepts (e.g., Atkinson, 2002; Hefter et al., 2015; Kölbach & Sumfleth, 2013; Renkl, 1997; Schworm & Renkl, 2007; Van Gog, Paas, & Van Merriënboer, 2008; see also Wittwer & Renkl, 2010). Both the instructional explanations and the examples can take various forms in this sequence; that is, depending on the respective learning content, the instructional explanations and examples can include verbal, numerical, and (concrete or abstract; static or dynamic) pictorial information (for research regarding the role of the representation type, see e.g., Moreno, Ozogul, & Reisslein, 2011; Scheiter, Gerjets, & Schuh, 2010; Schwonke, Berthold, & Renkl, 2009; see also De Jong, 2014; Scheiter, Gerjets, Huk, Imhof, & Kammerer, 2009).

Overall, research clearly indicates that this example-based learning sequence is a highly effective means to introduce learners to new content (for a recent overview, see Renkl, 2014). Nevertheless, it is not always equally effective; rather, its effectiveness depends on various factors. One of these factors is the extent to which learners generate *principle-based self-explanations*. This learning process entails that learners use the knowledge components that are communicated by the instructional explanations (e.g., a specific principle or concept) to explain or justify (features of) the examples (e.g., Hausmann & VanLehn, 2010; Renkl, 1997) and is widely regarded as highly important in learning from the outlined example-based learning sequence (see Renkl, 2002, 2014). However, learners often fail to sufficiently engage in this learning process on their own accord (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Renkl, 1997). Consequently, an important design principle is to incorporate elements that elicit principle-based self-explanations into the aforementioned learning sequence (e.g., Renkl, 2014). This design principle is frequently implemented by providing the examples in conjunction with self-explanation prompts (e.g., Atkinson, Renkl, & Merrill, 2003; Conati & VanLehn, 2000; Hefter et al., 2015; Schworm & Renkl, 2007).

In this article, we make the case that in example-based learning that follows the outlined sequence, not only the generation of

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principle-based self-explanations but also organization of the new principles and concepts before learners receive the examples should be prompted. More specifically, we argue that incorporating organization prompts could foster the effectiveness of the outlined example-based learning sequence by (a) enhancing the coherence of learners' mental representations of the respective principles and concepts and (b) facilitating the generation of principle-based self-explanations.

1.1. The benefits and a potential suboptimality of principle-based self-explanations

The process of self-explaining involves that learners generate new information in order to make sense of the information presented to them (Chi, 2000; Chi, de Leeuw, Chiu, & LaVancher, 1994; Fiorella & Mayer, 2016; Renkl, 1997; Roy & Chi, 2005; see also; Ainsworth & Burcham, 2007; Richey & Nokes-Malach, 2013). In example-based learning that is designed according to the worked examples sequence, two types of self-explanations are deemed essential: (a) goal-operator elaborations and (b) principle-based self-explanations (see Renkl, 2014).

Goal-operator elaborations entail that learners identify the goals that are achieved by different operators or solution steps that are included in the examples. Accordingly, this type of self-explanation solely refers to cases in which the provided examples have discrete solution steps (e.g., Conati & VanLehn, 2000; Renkl, Stark, Gruber, & Mandl, 1998). As the examples used in the present studies did not include discrete solution steps, we do not refer to this type of self-explanation hereafter.

In contrast to goal-operator elaborations, principle-based self-explanations can be generated regardless of the specific design of the examples. In this learning process, learners use the knowledge components of the instructional explanations that are provided in the first step to explain or justify (features of) the provided examples. Hence, generating principle-based self-explanations entails that learners generate interrelations between the instructional explanations and the examples (e.g., Hausmann & VanLehn, 2010; Hefter et al., 2015; Nokes, Hausmann, VanLehn, & Gershman, 2011; Renkl, 1997).

Based on example-based learning theory (Renkl, 2014), it can be argued that the process of generating principle-based self-explanations serves two beneficial functions. First, it fosters the learners' understanding of the principles and concepts that are included in the instructional explanations. This is because the generation of principle-based self-explanations entails that learners relate the respective principles and concepts to concrete examples, a process that enhances the degree of elaboration of their mental representations thereof. Second, the process of generating principle-based self-explanations fosters the learners' understanding of the examples. Specifically, it fosters the extent to which examples are stored according to their structural and relevant features (i.e., the reflected principles and concepts) instead of their superficial ones (e.g., Reimann, 1997). These theoretical notions are underpinned by a rich empirical basis; a wealth of research clearly shows that self-explaining is actually crucial for the benefit of the outlined example-based learning sequence to occur (e.g., Berthold & Renkl, 2009; Chi et al., 1989; Hefter et al., 2015; Hilbert, Renkl, Kessler, & Reiss, 2008; Nokes et al., 2011; Renkl, 1997, 2002; Schworm & Renkl, 2006, 2007; see also Hausmann & VanLehn, 2010).

Against this background, it is understandable that the generation of principle-based self-explanations is considered to be a highly important learning process in example-based learning (see Renkl, 2014). However, in spite of this benefit, by itself, this process might be insufficient to exploit the full potential of the outlined example-based learning sequence. As stated above, the generation of principle-based self-explanations requires learners to use the knowledge components of the instructional explanations to explain or justify the features of the examples (e.g., Hausmann & VanLehn, 2010; Renkl, 2014). Hence, if prompted to generate principle-based self-explanations, learners might search the instructional explanations for knowledge components that are suitable for explaining the respective example features. Arguably, the process of searching for (and finding) the respective knowledge components does not necessitate that learners attend to all of the knowledge components and, if possible, relate them to each other. Any knowledge components that are not directly relevant for generating the respective self-explanations might be disregarded or merely shallowly processed. Thus, although it elicits elaborations regarding specific knowledge components, a potential suboptimality of self-explaining is that it does not require learners to process all of the provided knowledge components in an integrated manner and thus *organize* (all of) them into coherent mental representations.

From the perspective of knowledge-construction oriented learning theories (e.g., Chi, 2009; Kintsch, 2004; Mayer, 2009; Wittrock, 2010; see also; Fiorella & Mayer, 2016), such organization processes would be highly beneficial. The learners' understanding of the learning content (e.g., new principles and concepts) is theorized to increase together with the degree to which learners engage in the generative learning process of organizing the content into coherent mental representations.

On this basis, it is reasonable to assume that the effectiveness of example-based learning will increase if learners not only generate principle-based self-explanations but also organize the content of the instructional explanations that are provided in the first step of the sequence. Learners could do so, for instance, by explaining the respective provided principles and concepts in their own words before they proceed to the examples. Explaining provided content requires learners to engage in identifying, restating, and relating the main knowledge components to each other, which are necessary sub-processes in the course of organizing provided content (e.g., Chi, 2009; Fiorella & Mayer, 2013, 2016; Leopold, Sumfleth, & Leutner, 2013; for recent research on the use of explaining content [to others], see also; Fiorella & Mayer, 2014; Hoogerheide, Loyens, & Van Gog, 2014).

Unfortunately, similar to self-explaining, learners rarely engage in such organization processes independently. Research on the processing of instructional explanations that communicate basic declarative knowledge regarding new principles and concepts clearly indicates that learners hardly engage in deep processing of the provided content on their own accord (e.g., Berthold & Renkl, 2010; Roelle, Lehmkuhl, Beyer, & Berthold, 2015; Sánchez & García-Rodicio, 2013; Wittwer & Renkl, 2008). This research also suggests that a viable means to elicit the targeted processing is to provide prompts. Thus, it can be hypothesized that the effectiveness of the outlined sequence of example-based learning will increase if learners are prompted to not only generate principle-based self-explanations but also explain the content of the instructional explanations and thus organize the new principles and concepts before receiving the examples.

1.2. Prompting organization: two potential mechanisms of action

There appear to be two mechanisms of action that enhance example-based learning when organization is prompted before learners receive the examples. First, in light of the notion that organizing learning content fosters learning outcomes, one apparent mechanism via which *organization prompts* could foster the effectiveness of example-based learning is that they enhance learners' organizational processing of the content of the instructional explanations.