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Learning how to use a computer-based concept-mapping tool: Self-explaining examples helps

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ABSTRACT

In initial skill acquisition in well-structured domains, example-based learning typically leads to better learning outcomes than learning by doing. Cognitive Load Theory explains this result by the worked-example effect: Example-based learning prevents learners from using load-intensive strategies and focuses their attention on the principles to-be-learned. In two experiments, we investigated the use of examples for acquiring a new learning strategy, namely computer-based concept mapping. Experiment 1 compared learners who studied two examples on how to construct a concept map with learners who practiced concept mapping by constructing two concept maps on their own. We did not find significant differences in learning outcomes. Therefore, in Experiment 2, we introduced a third group of learners who studied examples with the additional support of self-explanation prompts. Self-explaining examples led to better learning outcomes than learning with examples without prompts or practicing. With respect to cognitive load, we found that examples without prompts released learners' working memory compared to practicing, whereas self-explaining examples led to a higher cognitive load compared to examples without self-explanation.

1. Concept mapping as a learning method

Concept mapping is a method of graphically representing concepts and their interrelations. Nodes represent concepts and labeled links represent the relations between the concepts. Based on Ausubel's assimilation theory of cognitive learning (Ausubel, Novak, & Hanesian, 1978), concept maps visualize the hierarchy and relationships of concepts. Through the construction of a concept map, meaningful learning can be assisted (Novak, 1990). Novak (1995) describes a variety of applications of concept mapping in learning. For example, concept maps can assist the preparation of lessons and the sequence of topics presented; they can serve as a basis for discussions, and they can be used as a tool for knowledge evaluation. Furthermore, concept maps can assist learning from text. It is this last application of mapping that is the focus of this article.

A variety of studies have demonstrated the effectiveness of concept mapping as a learning method. In a meta-analysis, Horton, McConney, Gallo, and Woods (1993) found a generally positive effect of concept mapping on knowledge acquisition. Compared to other learning techniques, learners who used concept mapping as a learning strategy performed better than, for example, learners who used underlining (Amer, 1994), note-taking (Reader & Hammond, 1994), discussing with co-learners (Chularut & DeBacker, 2004), or outlining (Robinson & Kiewra, 1995). Traditionally, concept maps are generated using paper and pencil. However, using computer software to create concept maps allows learners to re-arrange, color-code, add, or delete concept nodes and links with relative ease. Learners usually prefer the higher flexibility of computer-generated concept mapping (Sturm & Rankin-Erickson, 2002).

Although concept mapping successfully fosters learning and understanding, beginners often lack the skills to productively use concept-mapping tools and thus cannot exploit their full potential. Participants in a study by Reader and Hammond (1994) learned from a hypertext either by note-taking or by concept mapping. Even though learners in the concept mapping condition performed better in a posttest on the learning topic of the hypertext, qualitative analyses showed that they failed to structure and integrate the information provided by the hypertext in an appropriate way. The learners were not able to use the advantages of the method to the expected degree.

Although the employment of worked-out concept maps that are provided by an instructor is a promising method (e.g., Chang, Sung, & Chen, 2001, 2002; Hauser, Nückles, & Renkl, 2006), they are often unavailable and laborious to set up and maintain. Hardy and Stadelhofer (2005) showed that although learning from a

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worked-out concept map can be an effective way of learning contents, creating concept maps on their own helped learners use this technique more effectively. In addition, instructional techniques such as using worked-out concept maps, which are highly effective with inexperienced learners, can lose their effectiveness with more experienced learners (cf. "expertise reversal effect", Kalyuga, Ayres, Chandler, & Sweller, 2003). Thus, in the long-term, learners should be trained to construct their own concept maps for learning.

O'Donnell, Dansereau, and Hall (2002) state that training is a key factor in producing favorable outcomes when concept mapping is employed. In order to cope with beginners' difficulties in using concept maps, a few training studies have been conducted (e.g., Chang et al., 2001; den Elzen-Rump & Leutner, 2007; Leopold, den Elzen-Rump, & Leutner, 2007). However, these training approaches are either not very efficient or quite laborious for trainers and learners to employ. For example, the training approach of den Elzen-Rump and Leutner (2007) was only effective in combination with self-regulation training. An effective and easily employed training method for teaching students how to use concept mapping, which takes the typical needs of beginners into account, is missing at present. This is also due to the fact that there is little empirical evidence indicating which cognitive processes are actually crucial for successful mapping and which needs beginners have in this respect. Most studies merely report some anecdotes of the learners' difficulties during concept mapping (e.g., Jonassen, Beissner, & Yacci, 1993). Knowing beginners' specific deficits is necessary in order to develop effective training approaches.

2. What characterizes good and poor mappers?

With the aim of developing an effective concept mapping training, Hilbert and Renkl (2008) carried out a think-aloud study to analyze the relations between cognitive processes during concept mapping as well as the characteristics of the concept maps the learners produced and learning outcomes. Unsuccessful learners seldom labeled the links that connected the concept nodes. They were also characterized by employing very little planning and controlling strategies. In contrast, effective learners showed much effort in planning their mapping process and constructing a coherent concept map. Hilbert and Renkl also showed that successful concept mapping is a circular process with three steps: Planning the concept map is the first step. Then, while actually constructing the concept maps, learners have to pay special attention to the relationships between the concept nodes. Finally, the concept map has to be steadily controlled for its correctness and completeness and – if necessary – learners have to engage in a new planning activity to revise their concept map and, thus, begin the circular process of concept mapping over again. In sum, to learn successfully by concept mapping, learners should engage in *planning processes*, should aim to *construct a coherent concept map* and should *control* the progress of their map (Hilbert & Renkl, 2008).

In this study, we investigated whether learning by examples is an effective method of training such heuristic concept mapping activities that are positively related to learning outcomes. In the following, the advantages of worked-out examples and heuristic examples – as a specific variant of worked-out examples – are outlined.

3. Example-based learning

A worked-out example is typically comprised of a solved problem with all solution steps explicitly stated. The problem statement, the solution steps, and the solution itself are presented for students to learn with. According to the worked-example effect postulated by Cognitive Load Theory (e.g., Sweller & Cooper, 1985), learning from such examples prevents learners from using strategies such as means-ends analysis, which are high in extraneous load (i.e., mental effort that is not directly related to learning). Instead, learners can focus their attention on the principles to-be-learned and thus encode, organize, and integrate these principles into their long-term memory (i.e., germane load). The worked-example effect was found predominantly in research on examples from well-structured, usually algorithmic domains. They typically enable learners to study an algorithmic solution of a particular problem. These examples are usually employed in learning materials from domains such as mathematics or physics. Learning from such worked-out examples is very effective in the initial acquisition of cognitive skills in these domains (for an overview see Atkinson, Derry, Renkl, & Wortham, 2000; Paas & van Gog, 2006; Renkl, 2005; Schwonke et al., 2009). Recent research has shown that examples are also beneficial in domains with heuristic solution strategies.

So-called *heuristic examples* combine the idea of modeling with the idea of worked-out examples (Hilbert, Renkl, Kessler, & Reiss, 2008; Reiss & Renkl, 2002; cf. the notion of modeling examples by van Merriënboer & Kester, 2005, and of process-oriented examples by van Gog, Paas, & van Merriënboer, 2006). They have first been – successfully – put on trial in mathematical proof finding, which is a very difficult topic for most learners. Successful proof finding requires the learner to follow a heuristic solution strategy. Thus, presenting learners with traditional worked-out examples that demonstrate a straightforward algorithmic solution process would not reflect the reality of proof finding. It is important to also display the relevant problem-solving heuristics and to demonstrate how they can be applied. In the study by Hilbert et al. (2008), learners' proving skills as well as their conceptual knowledge about proving improved through learning with heuristic examples. Thus, heuristic examples did not only foster the application of the proving skills, learning with heuristic examples also allowed learners to concentrate on the principles of proof-finding, leading to increased conceptual knowledge.

Concept mapping is not a straightforward process and, thus, cannot be presented in a traditional worked-out example. In the case of learning concept mapping by heuristic examples, students are able to "observe" the creation of a concept map based on text sources and the corresponding cognitive processes of an advanced mapper in a written format. At the end, such a heuristic example presents a well-structured concept map based on the contents of the text sources. Accordingly, a heuristic example on learning how to learn by concept mapping will include a well-structured map and the central steps of the previously introduced mapping process: planning the concept mapping process, constructing a coherent concept map, and controlling the map's progress in a circular process.

4. Experiment 1

Example-based learning is a powerful learning method in well-structured (i.e., algorithmic) domains (Renkl, 2005). First studies showed that so-called heuristic examples can also be used to address the difficult educational problem of teaching heuristic strategies such as proving in mathematics (e.g., Hilbert et al., 2008). We assumed that heuristic examples can also be successfully employed in learning how to use a learning strategy, a heuristic process for which – in contrast to mathematical proof finding – multiple good solutions exist (i.e., no specific map structure is expected). Heuristic examples on concept mapping should help learners to effectively employ this learning technique on their own. Furthermore, since examples enable learners to focus their attention on the principles of a presented solution procedure better, they should also foster learners' conceptual knowledge about concept mapping. This knowledge about the concept mapping process should help learners to further use concept mapping for learning in different contexts. It is important to note that the more training learners have in using concept mapping for learning, the more successful they are in applying this learning technique (Hilbert & Renkl, 2008; O'Donnell et al., 2002). Therefore, in Experiment 1, we compared learners who studied heuristic examples on concept mapping with learners who practiced concept mapping.

We addressed the following hypotheses:

1. Students who were trained in concept mapping with heuristic examples show better learning outcomes when using concept mapping for learning on their own than students who learned concept mapping by practicing.
2. Students who were trained in concept mapping with heuristic examples show better conceptual knowledge about concept mapping than students who practiced.

4.1. Method

4.1.1. Sample and design

Experiment 1 was conducted at a German Police Academy. Participants were 30 students (20 males, 10 females). The participants were between 18 and 30 years old (mean age: 22.53 years, $SD = 3.43$). They were randomly assigned to either a group training "concept mapping by practicing" ($n = 15$), or a group training "concept mapping with heuristic examples" ($n = 15$).

4.1.2. Materials

4.1.2.1. Mapping software. The participants worked with the Easy Mapping Tool; software especially developed for concept mapping (see http://www.cognitive-tools.com). It provided different forms and colors for nodes. Links to connect the nodes could be labeled.

4.1.3. Learning materials

4.1.3.1. Heuristic examples. The learning materials in the example group consisted of two paper-based heuristic examples. These examples included a fictitious student who constructed a concept map according to the circular process of concept mapping. The fictitious students in both heuristic examples had a short text as the basis for their concept maps. The first heuristic example was about martial arts, the second dealt with posttraumatic stress disorder. These two topics were easy to understand for students. They were also specifically chosen to be of particular interest for future police officers.

4.1.3.2. Concept mapping practice. Learners in the practice group were provided with the same short texts on martial arts and posttraumatic stress disorder as in the heuristic examples group. Learners were given blank sheets and were asked to construct a concept map based on these texts on their own, using paper and pencil.

4.1.3.3. Newspaper articles on stem cells. In the posttest on concept mapping, the learning contents were provided in six relatively short printed newspaper articles on stem cells. The newspaper articles had a total of 2116 words, the length of the shortest text was 80 words, and the longest text 1029 words. The stem cell topic was chosen because most students were expected to be relatively unfamiliar with the specifics related to this issue. Furthermore, it is a topic that is rather complex (i.e., requires integration of knowledge of biology and ethics) and is widely discussed in Germany. Providing more than one information source should increase the motivation (necessity) to engage in a follow-up activity after reading.

4.1.4. Learning assessment

Two types of learning outcomes were tested. On the one hand, we wanted to know how effectively students were able to apply the concept mapping technique for learning. A pretest consisting of eight open questions tested the students' prior knowledge about stem cells (maximum score: 8 points; e.g., "What are embryonic stem cells?"). After completing the concept mapping task, students filled out a posttest consisting of 15 items that consisted of the eight questions the students had already answered in the pretest, and seven additional items with a higher complexity. These items especially required the students to integrate knowledge of the different articles on stem cells (e.g., "What is allowed and forbidden by the German stem cell law?" Two articles provided the information for the complete answer to this question). Each correct answer was awarded with one point; half points were awarded for partially correct answers. The maximum score was 15 points.

On the other hand, we wanted to assess how much students learned about the concept mapping process, that is, we tested their conceptual knowledge about concept mapping. Therefore, in the posttest, students had to answer three questions, which asked for the types of activities that were proposed in the circular process of successful concept mapping. One question asked for two phases, the second question asked for one phase and the circularity. The third question asked for the whole circular process. ("A friend of yours has to create a concept map for homework. As this is the first time he has ever had to use the concept mapping technique, he asks you for help. What procedure would you advise?"). We awarded one point for mentioning each of the phases of the concept mapping process (planning, coherence, controlling) as well as for mentioning the circularity of the process. Therefore, a maximum of eight points could be achieved.

4.1.5. Procedure

The experiment began with a short introduction to concept mapping, the terms 'node' and 'link' were explained and an example of a concept map (topic: cows) was provided. Furthermore, the phases of the circular process of successful concept mapping were introduced. In the following training phase, students in the example group were given a first heuristic example on martial arts. Students in the practice group received a short text on the same topic and were asked to produce a paper-and-pencil concept map on their own. Both groups had 15 min to work with their training materials. Afterwards, the students received the heuristic example on posttraumatic stress disorder or the corresponding text, respectively (again for 15 min). In the following application phase, students first answered a pretest on stem cells and were then provided with newspaper articles concerning stem cells on which they produced a concept map. Participants were provided enough time to read each article once (15 min). The concept maps had to be produced with the mapping software Easy Mapping Tool and the participants received a brief instruction on how to use the software before constructing their concept maps. After this introduction, the participants were given 30 min to construct the concept map, and were encouraged to use the newspaper articles as a basis for constructing their maps. Finally, students were asked to fill out a posttest on stem cells and on conceptual knowledge about concept mapping.

4.2. Results

An α-level of .05 was used for all statistical analyses. Table 1 shows the pretest scores of the experimental groups. The differences in prior knowledge about stem cells were not significant, $t(28) = 1.61$, $p > .10$. Knowledge about stem cell research in the pretest did not significantly correlate with knowledge about stem cell research in the posttest ($r = .20$, $p > .10$) or with conceptual knowledge about concept mapping ($r = .21$, $p > .10$).

Table 1
Mean (standard deviation in parentheses) of the pretest and posttest scores in the experimental groups (Experiment 1).

	Practice group	Example group
Pretest	2.10 (.93)	1.63 (.67)
Posttest: stem cells	7.30 (2.23)	6.20 (2.21)
Posttest: conceptual knowledge	4.80 (3.20)	4.00 (1.93)

We expected learners in the example group to achieve better learning outcomes when using concept mapping for learning on their own. Table 1 shows the results of the posttest. The differences with respect to stem cells between the two experimental groups were not significant, $t(28) = 1.36$, $p > .10$. In addition, learners in the example group did not gain more conceptual knowledge about concept mapping (see Table 1), $t(28) = .83$, $p > .10$.

4.3. Discussion

Although learning from worked-out examples is generally effective, we did not find a beneficial effect of example-based learning. Learners who were trained in concept mapping with examples were neither able to use concept mapping more effectively on their own nor did they have a better conceptual knowledge about concept mapping. Learners in the example group seemingly did not make use of the advantages examples usually offer.

As worked-out examples do not require the learner to find the solution on their own, the amount of extraneous cognitive load is reduced (e.g., Sweller & Cooper, 1985; Sweller, van Merriënboer, & Paas, 1998; van Merriënboer & Sweller, 2005). Therefore, they have more cognitive capacities left for schema-acquisition (Sweller & Chandler, 1994; Sweller & Cooper, 1985). However, in order to fully profit from learning with worked-out examples, learners have to use their free working-memory capacity for germane load activities (i.e., schema–acquisition), that is, they have to actively explain the examples to themselves (Atkinson & Renkl, 2007). Chi, Bassok, Lewis, Reimann, and Glaser (1989) call this phenomenon the *self-explanation effect*. Chi et al. (1989) found that successful learners devoted more time to the study of worked-out examples, elaborated on the application conditions and goals of operators more frequently, and related operators to domain principles more regularly. However, Renkl (1997) showed that most learners do not employ successful self-explanation strategies on their own. We assume that this was also the case in Experiment 1: presumably, students did not use their working-memory capacity in order to learn how to effectively construct a concept map, but used the presented heuristic examples rather superficially. Thus, in Experiment 2, we tested the hypotheses that learners need to be prompted to use their working-memory capacity to actively process the heuristic examples.

5. Experiment 2

Prompting learners to self-explain enhances germane-load related learning activities and learning outcomes (Atkinson, Renkl, & Merrill, 2003; Renkl & Atkinson, 2007). In particular, so-called principle-based prompts that direct the learners' attention to the domain principles applied in the presented solution are of particular importance (Renkl, 2005). Thus, it is reasonable to also prompt learners to self-explain the phases of our circular mapping process, which are regarded as the principles of concept mapping.

In accordance to the worked-example effect, we expected that students' learning outcomes when using concept mapping for learning and their conceptual knowledge about concept mapping were better after being trained by heuristic examples compared to students who were trained by doing concept mapping practices. On the other hand, students' cognitive load while learning concept mapping with heuristic examples should be reduced compared to students' cognitive load while learning by doing concept mapping practices (i.e., reduced extraneous load). However, we also expect that self-explanation prompts would assist learners in focusing on the phases of our circular process of successful concept mapping. Therefore, students' learning outcomes when using concept mapping for learning and their conceptual knowledge about concept mapping should improve. These self-explanation prompts should also induce a higher cognitive load (i.e., increased germane load).

We addressed the following hypotheses:

1. Students who were trained in the use of concept mapping with heuristic examples, with and without self-explanation prompts, show better learning outcomes when using concept mapping on their own than students who learned concept mapping by practicing.
2. Students who were trained in the use of concept mapping with heuristic examples, with and without self-explanation prompts, show better conceptual knowledge about concept mapping than students who learned concept mapping by practicing.
3. Students who learned concept mapping by heuristic examples with self-explanation prompts show better learning outcomes when using concept mapping on their own than students who learned concept mapping by heuristic examples without such prompts.
4. Students who learned concept mapping by heuristic examples with self-explanation prompts show better conceptual knowledge about concept mapping than students who learned concept mapping with heuristic examples without such prompts.
5. Compared to practicing, the cognitive load is reduced by heuristic examples without self-explanation prompts.
6. Compared to heuristic examples without self-explanation prompts, the cognitive load is increased by prompts to self-explain heuristic examples.

5.1. Method

5.1.1. Sample and design

In Experiment 2, all participants were 11th-grade students from a German commercial high school ($N = 76$, 20 males, 56 females, mean age: 16.9 years, $SD = .78$). The students were randomly assigned to the practice group and the two example groups. The practice group ($n = 24$) was trained in concept mapping by constructing two concept maps on their own. The example group ($n = 24$) had the opportunity to study two heuristic examples on concept mapping. The example + prompts group ($n = 28$) was additionally supported by self-explanation prompts.

5.1.2. Materials

5.1.2.1. Task load questionnaire. To measure how much cognitive load learners perceived while practicing concept mapping or while learning with heuristic examples, we used the NASA Task Load Index (NASA-TLX, Hart & Staveland, 1988) in a paper and pencil-version. The NASA-TLX questionnaire is a multi-dimensional rating procedure that assesses an overall workload score (maximum score: 100) based on a weighted average of ratings on six subscales (mental demand, physical demand, temporal demand, performance, effort, and frustration). Learners filled in the NASA-TLX directly after practicing concept mapping and learning with heuristic examples, respectively.

5.1.2.2. Heuristic examples. The learning materials in the two example groups consisted of two paper-based heuristic examples, which were identical in their structure to the heuristic examples in Experiment 1. However, in Experiment 2, the first heuristic example was about two short texts on sales contracts, the second dealt with two short texts on amortizations – topics that had been part of the curriculum of the participating students prior to this experiment. Besides the experimental variation of instructional support by prompts, the heuristic examples in both example groups were identical.

Learners in the example + prompts group were additionally supported by principle-based self-explanation prompts. The nine self-explanation prompts in each of the heuristic examples asked learners, "To which phase of the concept mapping process can you assign what Carolin/Karsten just did? Why?" (Carolin and Karsten were fictitious students in the examples). There was no feedback on the self-explanations of the students for two reasons. Firstly, self-explanation prompting without feedback has been found to be effective in previous studies (e.g., Schworm & Renkl, 2006, 2007). Secondly, a non-feedback condition is more ecologically valid, as it is seldom feasible to provide immediate feedback to students in the classroom when working on their own (e.g., during seatwork).

5.1.2.3. Concept mapping practices. Learners in the practice group were provided with the same short texts on sales contracts and amortization that served as a basis for the concept maps the fictitious students in the heuristic examples had constructed. Learners were asked to use these texts to construct a concept map on their own using paper and pencil and were given three sheets of blank paper for this purpose.

5.1.2.4. Schoolbook texts on marketing. To measure how well the learners could use concept mapping as a follow-up strategy to learn from texts (after the training phase), they were asked to use concept mapping for learning on their own. The learning contents for the application phase in Experiment 2 were provided in three relatively short schoolbook texts on marketing. The texts had a total of 1113 words (text 1, 501 words; text 2, 224 words; text 3, 388 words). The topic was chosen because it is part of the participants' curriculum and because the students' teachers stated that they had not dealt with this topic prior to this study.

5.1.3. Learning assessment

As in Experiment 1, two types of learning outcomes were tested. First, we tested how effectively students were able to apply concept mapping for text learning. A pretest consisting of five items tested the students' prior knowledge of marketing (maximum score: 10 points; e.g., "What is the difference between a buyer's market and a seller's market?"). After learning by concept mapping, students filled out a posttest consisting of six items (maximum score: 12 points), which consisted of four items that were identical to the pretest; two items of greater complexity were added (e.g., "Which phases of the life cycle of a product comply with the categories of the market portfolio?"). The questions in the pretest and in the posttest were extracted from the schoolbook from which we took the text sources used in this study. Whereas the questions in the pretest asked for well-defined concepts, the more complex questions in the posttest required combining different marketing concepts. Each correct answer in the pretest and in the posttest was awarded with two points; one point was awarded for partially correct answers. We also tested students' conceptual knowledge about concept mapping using the same test consisting of three items as in Experiment 1 (maximum score: 8 points).

5.1.4. Procedure

Experiment 2 consisted of two sessions over two consecutive days. It was conducted during the students' regular lessons. On the first day, students received a short introduction to concept mapping (see Experiment 1). The terms 'node' and 'link' were explained and an example for a concept map (topic: cows) was provided. In addition, the circular process of successful concept mapping was introduced. The following training phase was structured as in Experiment 1: the example groups were first given the heuristic example on the topic of sales contracts while the students in the practice group constructed a concept map based on two short texts on the same topic (15 min). Afterwards, the students received the heuristic example on amortization or the corresponding texts, respectively (15 min). At the end of the training phase, the students rated their load by filling out the NASA-TLX questionnaire.

On the following day, students first worked on a pretest on marketing. They were then given three schoolbook texts on marketing with enough time to read each text once (10 min). Next, the students received a brief instruction on how to use the concept mapping software (Easy Mapping Tool) and then produced a concept map on the topic of marketing. For concept mapping, 30 min were assigned. The participants were encouraged to use the schoolbook texts as a basis for their maps. Finally, the students worked on a posttest on marketing and conceptual knowledge about concept mapping.

5.2. Results

An α-level of .05 was used for all statistical analyses. As an effect size measure, we used partial eta squared (η_p^2) – qualifying values of about .01 as weak effect, values of about .06 as medium effect, and values of about .14 or bigger as large effect (Cohen, 1988).

Table 2 shows the pretest scores. The differences in prior knowledge about marketing were not significant, $F(2,76) = 2.94$, *ns*. Thus, the groups were comparable with respect to prior knowledge. There were significant correlations between prior knowledge about marketing and marketing knowledge in the posttest ($r = .52$, $p < .001$). In the following analyses on learners' marketing knowledge in the posttest, prior marketing knowledge was included as covariate in order to heighten test power. No correlation was found for learners' conceptual knowledge and prior marketing knowledge, $r = -.10$, $p > .10$.

Table 2 shows the posttest scores. An ANCOVA with the learners' marketing knowledge in the posttest as dependent variable and their marketing knowledge in the pretest as covariate revealed significant group differences, $F(2,72) = 4.31$, $MSE = 4.77$, $p = .017$, $\eta_p^2 = .11$ (medium effect). An ANOVA with the learners' conceptual knowledge about concept mapping as dependent variable showed no significant overall group differences, $F(2,73) = 1.05$, *ns*.

To test our hypothesis, we computed a series of a priori contrasts (cf. Rosenthal & Rosnow, 1985; Rosenthal, Rosnow, & Rubin, 2000). We assumed that learning with heuristic examples is superior. Therefore, we contrasted the practice group and the two example groups using ANCOVAs with the learners' marketing knowledge in the posttest as dependent variable and prior knowledge as covariate. Against our expectations, learning how to use

Table 2
Mean (standard deviation in parentheses) of the pretest and posttest scores in the experimental groups (Experiment 2).

	Practice group	Pure example group	Example + prompts group
Pretest on marketing	2.17 (1.43)	2.23 (1.91)	1.29 (1.38)
Posttest: marketing	3.60 (2.65)	3.77 (2.79)	4.38 (2.58)
Posttest: conceptual knowledge	2.29 (2.42)	4.46 (3.11)	5.50 (3.90)
Cognitive load	29.58 (6.47)	16.91 (7.11)	25.33 (6.47)

concept mapping by heuristic examples did not lead to a better learning result when using this learning technique, $F(1,72) = 2.56$, *ns*. However, in accordance to our hypothesis, in an ANOVA with the learners' conceptual knowledge about concept mapping as dependent variable, we found that the provision of examples was more effective than practicing concept mapping, $F(1,72) = 11.25$, $MSE = 10.52$, $p = .001$, $\eta_p^2 = .13$ (strong effect).

With respect to the two example groups, we expected that self-explanation prompts would help learners profit more from learning with heuristic examples. The pure example group and the example + prompts group were contrasted using ANCOVAs with learners' posttest results on marketing as dependent variable and their prior knowledge on marketing as covariate. We found that learners who were supported by self-explanation prompts in the training phase learned more effectively when concept mapping on their own, $F(1,72) = 5.96$, $MSE = 4.77$, $p = .017$, $\eta_p^2 = .076$ (medium effect). However, both example groups did not differ when contrasting them by an ANOVA with conceptual knowledge on concept mapping as dependent variable, $F(1,73) = 1.33$, *ns*. In sum, providing examples of successful mapping instead of practice is sufficient for fostering conceptual knowledge. However, to also attain the benefits of mapping with respect to the acquisition of domain knowledge, the processing of the examples provided has to be supported by self-explanation prompts.

Furthermore, we asked whether the learners in the different conditions reported different cognitive load during the training phase. Table 2 shows the cognitive load as measured by the NASA-TLX. An ANOVA revealed a significant difference between the groups, $F(2,73) = 22{,}48$, $MSE = 44.58$, $p < .001$, $\eta_p^2 = .381$ (large effect). We assumed that the cognitive load should be higher for learners in the practice group than in the pure example group. A planned contrast showed that the assumed difference was significant, $F(1,73) = 43.23$, $MSE = 44.58$, $p < .001$, $\eta_p^2 = .372$ (large effect). On the other hand, we assumed that learning with heuristic examples with self-explanation prompts should lead to a higher cognitive load compared to learning with heuristic examples without prompts. A planned contrast revealed that the assumed difference in cognitive load between the example groups with and without self-explanation prompts was also significant, $F(1,73) = 20.54$, $MSE = 44.58$, $p < .001$, $\eta_p^2 = .220$ (large effect).

5.3. Discussion

In summary, the findings of Experiment 2 showed that: (a) learning with heuristic examples leads to better conceptual knowledge about concept mapping and (b) prompting to identify the phases of the circular process of successful concept mapping assists the simultaneous acquisition of concept mapping skills and conceptual knowledge about concept mapping. Cognitive load was higher in the practice group than in the pure example group – a finding consistent with Cognitive Load Theory's predictions (decrease of extraneous load). The difference of load between the pure example group and the example + prompts group confirmed the assumption that the self-explanation prompts increased cognitive load.

6. General discussion

The findings of Experiment 2 show that for learners in the pure example group cognitive load is reduced compared to practicing concept mapping. Also, prompting learners to self-explain increases their cognitive load compared to learners in the pure example group. This pattern of results corroborates our assumptions for the lack of significant results in Experiment 1: learners who had the opportunity to study heuristic examples instead of practicing concept mapping on their own probably had more cognitive capacities left to focus on the effective heuristic strategies of concept mapping. However, as the results of the NASA-TLX questionnaire and the posttest results in Experiment 2 showed, only those learners whose study of examples was supported by self-explanation prompts presumably made real use of their free cognitive capacities for productive learning. Further studies will have to take a closer look on the actual cognitive processes when learning complex cognitive skills with heuristic examples. Nevertheless, the finding of the two presented experiments point to the usefulness of learning from worked-out examples (Sweller & Cooper, 1985), but point to the necessity of employing self-explanation prompts to fully exploit the potential of this learning method (e.g., Renkl, 2005). Many studies have found that in order to fully profit from learning with worked-out examples, learners have to use their working-memory capacity for schema-acquisition, that is, they have to actively self-explain the examples (e.g., Renkl, 2005). However, an instructional problem arises from the fact that most learners spontaneously self-explain either in a very superficial or passive way (Renkl, 1997), which presumably in both experiments lead to the result that learners who were provided with heuristic examples without further instructional support were not able to profit from these examples to the expected degree. According to the results of Experiment 2, principle-based prompts should be employed when learning with heuristic examples.

In this study, we found a generally rather low learning outcome, at least at first glance. In both experiments, even the groups with the highest learning outcome on average did not achieve more than half the maximum score in the posttests on the learning topics (i.e., stem cell research and marketing, respectively). However, it has to be taken into account that the posttest tasks required substantial transfer. In the application phase of both experiments, learners had to apply their concept mapping skills in order to learn a quite different topic (Experiment 2) or even a different domain (Experiment 1) as in the training phase. Also, the questions on conceptual knowledge were transfer questions as they did not only ask students to reproduce the circular process of successful concept mapping but also embedded the questions in an application context. Thus, we do not think the results were very disappointing, given the usual transfer effects found in experimental studies (cf. Detterman, 1993: "First, most studies fail to find transfer. Second, those studies claiming transfer can only be said to have found transfer by the most generous of criteria and would not meet the classical definition of transfer", p. 15).

Another possible explanation for the relatively low posttest results is that learners were not only overstrained by using a new learning technique, but also by learning with an unfamiliar computer program. Unfortunately, we did not control for learners' cognitive load during the application phase of this study. Such measures would give information on how these demands affected learning when using concept mapping for learning on their own. Thus, further studies will have to measure cognitive load during the application of the to-be-learned complex cognitive skill.

It is also conceivable that motivational problems prevented learners from profiting more from the training phase. Informal communication of some of the students who took part in the experiments showed that they appraised the training phase as rather boring. This assumption is corroborated by the results of the NASA-TLX questionnaire in Experiment 2. Though the maximum score to be obtained with this questionnaire is 100, the mean overall cognitive load in Experiment 2 was only 24.01 ($SD = 8.37$). The range of this measure was between 5.33 and 40.17. Possibly, learners in all groups would have had more capacity left for germane load activities and, therefore, could have profited from the concept mapping training more. A possible solution for the motivation problems could be to employ an informed training. Such an approach has, for example, already been successfully applied in training on writing learning protocols (Hübner, Nückles, & Renkl, in press).

Nevertheless, the present findings are promising for instructors. As shown in Experiment 2, learning from heuristic examples with self-explanation prompts helped learners to effectively use the concept mapping technique as a follow-up strategy for learning from texts that treated a topic that substantially deviated from the topics used during training. Thus, instructors have an effective training method at hand, which allows them to teach their students new learning techniques in a relatively short time (in our experiments, just 30 min). Den Elzen-Rump's and Leutner's (2007) concept mapping training, for example, was effective only in combination with a self-regulation training. Our example-based approach showed beneficial effects without further training of other skills. However, it would also be interesting to test a combination of such self-regulation training with heuristic examples.

There are also some restrictions of the present studies that should be addressed in further studies. (a) We only tested the effects of learning from heuristic examples on concept mapping. It is still an open question whether example-based learning can also be used to train other learning techniques. (b) We analyzed only immediate effects; possible mid-term or long-term effects still have to be investigated. (c) Only example-based learners were prompted during the learning-phase. Possibly, supporting the practice group with prompts would also lead to better learning results. However, we did not form a prompted practice-group for reasons of practicability: Example-based learners received the self-explanation prompts at critical points of the concept mapping process. The correct timing of self-explanation prompts during practicing is rather difficult. However, in a recent study we tested the effects of different prompts during concept mapping (Hilbert et al., 2008). Compared to a control group without prompts, participants who were prompted during concept mapping actually achieved better learning outcomes.

In a nutshell, we can conclude that the worked-example effect can also be found in non-algorithmic domains. However, learners have to be encouraged to use their free working-memory capacities for learning.

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