Concept Mapping for Learning from Text: Evidence for a Worked-Out-Map-Effect

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Abstract: A concept map consists of nodes representing concepts and links representing the relationships between the concepts. To examine the influence of concept mapping on learning from texts, we varied the support strategies. Eighty students either learned by constructing concept maps on their own, by correcting an incorrect worked-out map, or by studying a correct worked-out map. A control group did not engage in any follow-up activity for learning from text. As expected, learners profited most from studying the correct worked-out map. Students who corrected an incorrect worked-out map did not have a better learning result than students who generated concept maps on their own or the control group. On the contrary, they produced many false conclusions in the comprehension test.

Introduction

Concept maps are two-dimensional, graphical representations consisting of concepts illustrated by hierarchically arranged nodes and labeled links that connect the nodes (Jonassen, Beissner, & Yacci, 1993). The hierarchical organization of the concepts and the explicit representation of the logical and semantic relations between the concepts distinguish concept maps from other maps, such as mind maps (Buzan & Buzan, 1995). Based on Ausubel's (Ausubel, Novak, & Hanesian, 1978) assimilation theory of meaningful learning, Novak and Gowin (1984) developed the method of concept mapping in order to promote meaningful learning by integrating new ideas into the learner's prior knowledge. A variety of studies have demonstrated the effectiveness of concept mapping as a learning method, including a meta-analysis of 19 quantitative studies by Horton et al. (1993). The authors found a generally positive effect on knowledge acquisition. As several studies have shown, meaningful learning can be assisted through the construction of a concept map (Novak, 1990).

What Makes Concept Mapping Beneficial?

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; they can be used as a tool for knowledge evaluation. Furthermore, concept maps can assist learning from texts (Hilbert & Renkl, 2008). It is this latter application of mapping that is the focus of this article.

Concept mapping as a follow-up strategy in text learning can have several important functions. In theory, four functions can be differentiated:

(a) *Reduction function*: Weaver and Kintsch (1991) found that macropropositions which contain the top-level information of a text are recalled in more detail. Maps can enhance the acquisition and retention of macrolevel ideas (O'Donnell, Dansereau, & Hall, 2002). Learners have to appraise the importance of concepts in order to decide whether they should integrate them in their concept map. Thus, learners concentrate on the most relevant macrostructure information of their learning topic.

(b) *Coherence function:* Concept mapping requires the externalization of knowledge and its structure. Thereby working memory is offloaded and the construction of coherence is facilitated (Kintsch, 1998). Labeling the links connecting nodes emphasizes the kind of relationship between concepts. Additionally, spatial arrangements or the use of similar colors can emphasize that concepts belong together. Thus concept mapping fosters the building of a coherent structure of knowledge.

(c) *Elaboration function*: Due to the affordance of expressing notions in nodes and relations in links, concept maps foster elaboration processes (Weinstein & Mayer, 1986). This means that learners have to relate new information to their prior knowledge in order to determine what concepts are important and whether and how they interrelate.

(d) *Metacognitive function*: Metacognitive processes are supported through concept mapping. Knowledge and comprehension gaps can become obvious when constructing and explicating relations between concepts, (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989). At best, learners can overcome these gaps when they become aware of them.

Supporting Concept Mapping

Despite the positive effects of concept mapping, this learning strategy also poses high processing demands on learners. For example, in a study by Reader and Hammond (1994), participants learned from hypertext by either note-taking or concept mapping. Even though learners in the concept mapping condition performed better in a post-test on the learning topic presented in the hypertext, qualitative analyses showed that they failed to structure and integrate the information provided by the hypertext in a favorable way. The learners were not able to use the advantages of the method to the expected degree.

In order to cope with beginners' difficulties in using concept maps for learning from texts, a few studies have been conducted that tested the effectiveness of different support measures. One support measure is to present learners with worked-out expert maps. In general, learning from worked-out examples has proven to be very effective in initial skill acquisition in well-structured domains such as mathematics, physics or programming (e.g., Atkinson, Derry, Renkl, & Wortham, 2000) as well as in more complex domains such as computer-supported cooperation (Rummel & Spada, 2005). According to the worked-example effect postulated by the Cognitive Load Theory (e.g., Sweller & Cooper, 1985), learning from examples prevents learners from using load-intensive strategies and focuses their attention on learning. In the domain of concept maps, studies examining a worked-out effect in the context of mapping as a follow-up study strategy are rare. Nevertheless, the results of O´Donnell et al. (2002) point out that learning with teacher prepared maps (i.e. expert maps) as teaching materials, can be more effective than learning from text. For instance, learners with low verbal ability profited particularly from studying worked-out expert maps.

Chang, Sung, and Chen (2001) compared students who either learned by constructing a concept map or by completing a worked-out concept map. Two different completion tasks were realized: One group had to fill in gaps in a worked-out concept map; another group had to construct a concept map from given concept nodes and given labeled links. The students who accomplished the completion task achieved better results in a comprehension test than the students in the map construction group. In a follow-up study, Chang, Sung, and Chen (2002) showed that text comprehension was most strongly enhanced by correcting a partly incorrect expert map which contained some incorrect links and nodes. The correcting map condition outperformed two map generation conditions and a no mapping control condition, even when map generation was supported by scaffolds. It is noteworthy that in both studies by Chang et al., those students who generated maps were presented a list of concepts and relations to choose from. Thus, they did not have to develop their own concepts and relations. Instead, the provided lists of concepts and relations functioned as scaffolds for the mapping process.

Hauser, Nückles, and Renkl (2006) similarly compared different degrees of scaffolding concept mapping for learning from text: In their experimental study, students were either supported by a list of concepts which they had to spatially arrange and link, or by spatially arranged concepts which they only had to link. A third group of learners studied a worked-out expert map. A fourth group constructed a concept map from scratch, that is, no list of concepts or relations was provided. In this study, students in the two "semi-structured" conditions (concepts provided and concepts arranged conditions) performed no better than students in a fifth group, that is, the control condition which did not engage in any follow-up activity. At the same time, providing students with a worked-out map supported learning most effectively compared with the other conditions. However, constructing a map from scratch was almost equally helpful.

Thus, Hauser et al. (2006) reported an advantage of learning with completely worked-out maps as a follow-up activity for learning from text – a result which is in line with the worked-example effect. Nevertheless, a possible restriction of presenting learners a completely teacher-prepared concept map may be that the learners merely process the map superficially. For example, Renkl (1997) found that most students learning with worked-out examples in mathematics could be classified as superficial or passive learners. To avoid such superficial processing, Chang and colleagues successfully implemented an incomplete map which had to be completed by the students (Chang et al. 2001). Hauser et al. (2006), however, found that substantial scaffolding of the mapping process, for example by providing students with a list of concepts or with the relevant concepts already spatially arranged may narrow attention to specific aspects of the learning process in a dysfunctional way. Also, Hilbert, Renkl, Kessler, and Reiss (in press) showed that a completion task can pose high processing demands on learners and thus hinder them in learning from worked-out examples.

Metacognitive reflection that contributes to deep comprehension can also be fostered by errors (VanLehn, 1999). There is evidence that learning from worked-out examples can be supported by presenting solutions with errors (Große & Renkl, 2007). Similarly, Chang et al. (2002) successfully implemented a correction task in learning with worked-out concept maps. To stimulate metacognitive reflection (cf. the metacognitive function of concept mapping), learners had to find and correct errors in a presented worked-out concept map. However, the authors did not compare this map-correction condition with a condition in which students studied worked-out maps without errors. Thus, strictly speaking, no definite conclusion can be drawn from this work on whether a correction task actually has a surplus value to learning with worked-out expert maps. The study of Große and Renkl (in press) suggests that incorrect examples can also hinder learning especially if the learners do not possess the relevant prior knowledge that would enable them to detect the errors.

Research Questions

The empirical studies discussed above provide rather mixed evidence regarding the question of how concept mapping as a learning strategy can be effectively scaffolded. Partly, prior research suggests that providing students with worked-out concept maps may facilitate learning (Hauser et al., 2006; O'Donnell et al., 2002). Studying a worked-out concept map may be regarded as a less load-intensive learning activity (cf. Sweller & Cooper, 1985) as compared with the affordance of generating a concept map from scratch that can easily overwhelm learners (Reader & Hammond, 1994). On the other hand, presenting learners with a worked-out solution may also lead to superficial processing (Renkl, 1997). Against this background, the aim of this study was to investigate the potential benefits of worked-out concept maps on the acquisition of factual knowledge and deep comprehension in further detail. Following Hauser et al. (2006), providing students with a worked-out concept map for learning from text, should facilitate comprehension substantially. Chang et al. (2002) additionally showed that the dangers of superficial processing can be averted by encouraging students to detect errors in a partly incorrect worked-out map. However, in Hauser's study, students who constructed a map on their own performed almost equally well as students who studied a worked-out map for learning from text.

Given the results of Hauser et al. and Chang et al., it would be interesting to directly contrast a worked-out map condition, a map-correction condition, and a map construction condition within the same experimental design. Following Hauser et al., students studying a worked-out map for learning from text should outperform students in a control condition who engage in no such follow-up activity. Following Chang et al., encouraging students to detect errors in a worked-out map containing errors might even lead to better learning success. Finally, if constructing a concept map from scratch helps students to focus on relevant aspects of the learning material, provision of worked-out maps may be even dispensable. However, it cannot be ruled out that constructing a map from scratch may be a too demanding task for students inexperienced with concept mapping and may therefore hinder learning success.

The following specific research questions were addressed:

1. Do learners who studied expert maps have better learning outcomes than learners who generated a concept map from scratch and learners who did not engage in a follow-up activity?
2. Do learners who corrected errors in an incorrect worked-out map have better learning outcomes than learners who generated a concept map from scratch and learners who did not engage in a follow-up activity?
3. Is there a difference in the learning outcomes between learners who studied expert maps and learners who corrected errors in an incorrect worked-out map?
4. Does generating a concept map from scratch lead to better learning outcomes than doing no follow-up activity?

Methods

Sample and Design

Eighty university students (21 male, 59 female, mean age: 25.7 years) from different academic fields took part in this study. On average, they had studied for 6.7 semesters (3.4 years). The participants were randomly assigned to the four experimental conditions of a one-factorial design: Participants in the *mapping group* (n = 20) constructed a concept map from scratch as follow-up activity for learning from text. The participants in the *correction group* (n = 20) had to find and correct errors in an incorrect map as follow-up activity. Participants in the *expert map group* (n = 20) were asked to study a correct expert map. The control group (n = 20) did not engage in any follow-up activity for learning from text. Dependent variables were the learners' factual knowledge and comprehension in a posttest.

Materials

Mapping Software

The participants in the three mapping conditions worked with the easy mapping tool, software especially developed for concept mapping (see http://www.cognitive-tools.de for more information). We chose the Easy Mapping Tool for this study because it is very easy to learn how to handle it. Learners in the mapping group constructed a concept map from scratch. Therefore, they were able to use all necessary functions of the Easy Mapping Tool: constructing and moving concept nodes, and drawing and labeling the links. For the correction group and the expert map group the range of functions was varied. Learners in the correction group only were able to manipulate the inscription of the concept nodes and the links, or to change the direction of the links. In the expert map group, participants were only able to look at the presented expert map, but could not manipulate it.

Learning materials

Text about ethical and biological issues in human embryo research. The learning topic on human embryo research was presented in a complex learning text (2257 words). The text discussed whether and when human embryos should be protected against research endeavors. The interdisciplinary and complex characteristic of this text assured that it was challenging enough for advanced students from different fields. In fact, earlier studies revealed that students on average had comparatively low prior knowledge about the content domain (Nückles & Salhab, 2005). In addition, human embryo research is a domain that recently attracted much attention in German media. Therefore learning about these contents should be motivating and interesting.

Expert map. Participants in the expert map group were presented an expert map after reading the learning text. This concept map consisted of 46 concept nodes and 60 links. The participants were instructed to examine the expert map carefully.

Incorrect map. Participants in the correction group had to correct an incorrect map as a follow-up activity after reading the text. The map was essentially identical to the expert map. However, nine errors were built in: Three links pointed in the wrong direction, three concept nodes were wrongly inscribed, and three links were wrongly labeled. The participants were informed about the number of errors in the incorrect map and about the types of errors that could occur.

Learning Assessment

Factual knowledge test. Two types of learning outcome were tested. On the one hand we wanted to know how much *factual knowledge* participants acquired. Therefore, we employed a multiple-choice test consisting of ten items on ethical and biological issues on human embryo research (e.g., “Which statement about the German stem cell law is true?”; maximum score: 10 points). This factual knowledge test was answered as a pretest prior to reading the learning text and as a posttest after the learning task.

Comprehension test. In order to assess learners’ deep understanding and comprehension of the learning contents, the posttest also included six open questions (e.g., “What are the advantages and disadvantages of using embryonic stem cells and of using adult stem cells, respectively?”). The *level of comprehension* was assessed using the SOLO-taxonomy (“Structure of Observed Learning Outcome”) proposed by Biggs and Collis (1982). According to the SOLO-taxonomy, each answer was differentiated into six levels of knowledge ranging from 1 (= no central points, low level of understanding, incoherent) to 6 (= all central points, high level of understanding, very coherent). Additionally, we rated the answers more differentiated on a Likert scale ranging from 1 (“dimension not present”) to 6 (“dimension clearly present”) regarding three dimensions:

a. *Main points:* The extent to which important arguments were taken up.
b. *Coherence:* The extent to which learners produced a coherent answer.
c. *Elaboration:* The extent to which the answer was explicit and exact.

Procedure

The study was conducted in group sessions of 10-20 participants in the faculty’s computer lab. Learners in the three mapping groups were tested together; the control group was tested in separate sessions.

After answering some demographic questions, participants filled in the pretest on human embryo research. Then they were given the learning text about ethical and biological issues in human embryo research. Participants were instructed not to underline or take notes on the text. Learners in the control group subsequently filled in the posttest.

In the three mapping groups, reading the learning text was followed by a short introduction in concept mapping as a learning strategy. Concept mapping was shortly described and the advantages of the method for learning were specified. A short instruction informed the participants of their specific tasks (mapping, correcting a map, or self-explaining an expert map, respectively) and gave a short tutorial on how to use the mapping software Easy Mapping Tool. During the next 30 minutes, participants either constructed a concept map on their own (mapping group), corrected an incorrect map (correction group), or studied the given expert map (expert map group). Finally, the participants in the three mapping groups filled in the posttest.

Results

An alpha-level of .05 was used for all statistical analyzes. As an effect size measure, we used partial η^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; pp. 285-287).

Figure 1 shows the pretest scores in the factual knowledge test for the experimental groups. The differences in prior factual knowledge about ethical and biological issues on human embryo research were not significant, $F < 1$. On average, students’ prior knowledge about human embryo research was rather small (M = 1.71, SD = 1.42).

Factual knowledge

The factual knowledge in the posttest for the experimental groups is displayed in Figure 1. An ANOVA with the learners' factual knowledge in the posttest as dependent variable showed that the differences between the groups were not significant, $F < 1$. Descriptively the correction group scored best followed by the control group. Surprisingly, the mapping group and the expert map group performed worse than the control group. However, the differences between the groups were marginal.

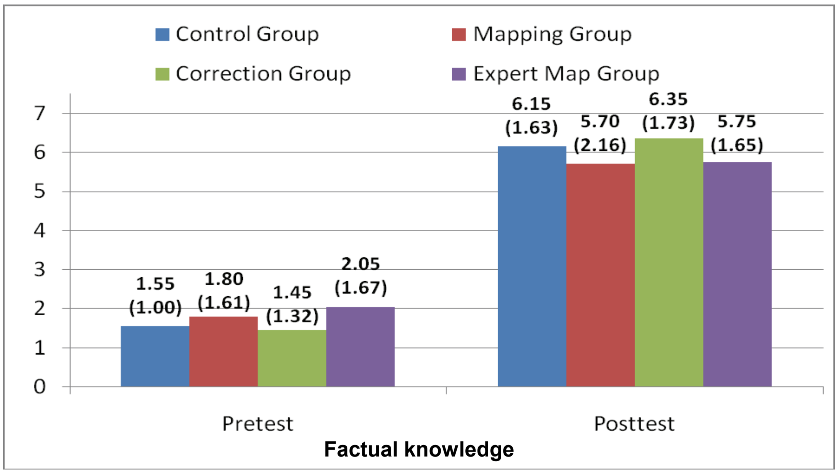

Figure 1. Means (standard deviations in parentheses) of learners' factual knowledge in the pretest and in the posttest for the experimental groups

Planned contrasts according to our specific research questions showed that against our expectations, the expert map group did not outperform the mapping group and the control group, $F < 1$. Also, the correction group did not score better than the mapping group and the control group, $F < 1$. The difference between the expert map group and the correction group also failed significance, $F(1, 76) = 1.11$, $p > .05$, as did the difference between the mapping group and the control group, $F < 1$. Thus, according to the factual knowledge test there were no differences between the experimental groups and our assumptions were not confirmed.

Comprehension test

In the posttest, we also tested the learners' deep understanding and comprehension of the topic human embryo research. Figure 2 presents the learners' overall score in the comprehension test and the ratings of their answers in the comprehension test according to the identification of main points, coherence, and elaboration. In an ANOVA with the learners' overall score as dependent variable, the group differences were significant, $F(3, 76) = 3.61$, $p = .017$, $\eta^2 = .13$ (medium to large effect). A MANOVA with the learners' rating for main points, coherence and elaboration revealed that learners' answers differed with respect to the identification of main points, $F(3, 76) = 4.19$, $p = .008$, $\eta^2 = .14$ (large effect). The groups did not differ with respect to the elaboration of their answers in the comprehension test ($F < 1$) and with respect to the coherence, $F(3, 76) = 1.72$, $p > .05$.

We assumed that the expert map group should outperform the mapping group and the control group. To test our hypothesis we contrasted the expert map group against the correction group and the mapping group using ANOVAs with the comprehension test scores (overall score, main points, coherence, and elaboration) as dependent variables. In accordance to our assumption, learners who studied an expert map showed a better overall score of their answers in the comprehension test, $F(1, 76) = 10.08$, $p = .002$, $\eta^2 = .12$ (medium to large effect). Also, our assumptions were asserted for the identification of main points, $F(1, 76) = 10.68$, $p = .002$, $\eta^2 = .12$ (medium to large effect), and for the coherence of learners' answers to the comprehension test answers, $F(1, 76) = 4.15$, $p = .045$, $\eta^2 = .052$ (medium effect). Though descriptively the expert map group also performed better according to elaboration of their comprehension test answers, the planned contrasts for these ratings were not significant, $F < 1$. Overall, we found a worked-out map effect for the comprehension test.

Our second hypothesis was that correcting errors in incorrect maps should lead to better learning outcomes than generating maps or engaging in no follow-up activity after reading the learning text. As Figure 2 shows, learners in the correction group and in the mapping group performed very similar in the comprehension test. We contrasted the correction group with the mapping group and the control using ANOVAs with the comprehension test scores as dependent variables. We did not find a benefit of the correction task compared to the mapping group and the control group for the overall score, $F < 1$. Also, the correction task did not significantly differ from the mapping group and the control group with respect to the identification of main points ($F < 1$), elaboration ($F < 1$), or coherence, $F(1, 76) = 2.58$, $p > .05$. Thus, a correction task was not superior to generating a concept map from scratch and doing no follow-up activity for learning from text.

Figure 2 shows that while learners' factual knowledge was descriptively higher in the correction group than in the expert map group (see Figure 1), their score in the comprehension test was lower. The difference in the comprehension test in favor of the mapping group was significant, $F(1, 76) = 8.13$, $p = .006$, $\eta^2 = .10$ (medium effect). Also, the identification of main points in the comprehension test was better in learners studying worked-out expert maps than in learners correcting incorrect maps, $F(1, 76) = 9.05$, $p = .004$, $\eta^2 = .11$ (medium effect). We found no significant differences between the expert map group and the correction group with respect to coherence ($F < 1$) and elaboration ($F < 1$). Therefore, correcting errors in an incorrect map did not have the effect of improving learning compared to studying correct expert maps. On the contrary, learning was better supported by studying worked-out expert maps without errors.

Finally, to test whether there is a need to support learners with worked-out maps, we also compared the learning outcomes of learners generating a concept map from scratch with learners in the control group who did not engage in any follow-up activity. Planned contrasts revealed that the mapping group and the control group did not differ with respect to any of the comprehension measures (all $F < 1$). Thus, support measures are clearly needed by learners.

In order to compare the other conditions, we performed Tukey HSD post hoc tests regarding the overall score in the comprehension test and the dimensions main points, coherence and elaboration. The mapping group outperformed the correction group (overall score: $p = .028$; main points: $p = .025$), the mapping group (main points: $p = .025$), and the control group (overall score: $p = .047$; main points: .035). No other difference reached the level of statistical significance (all $p > .05$).

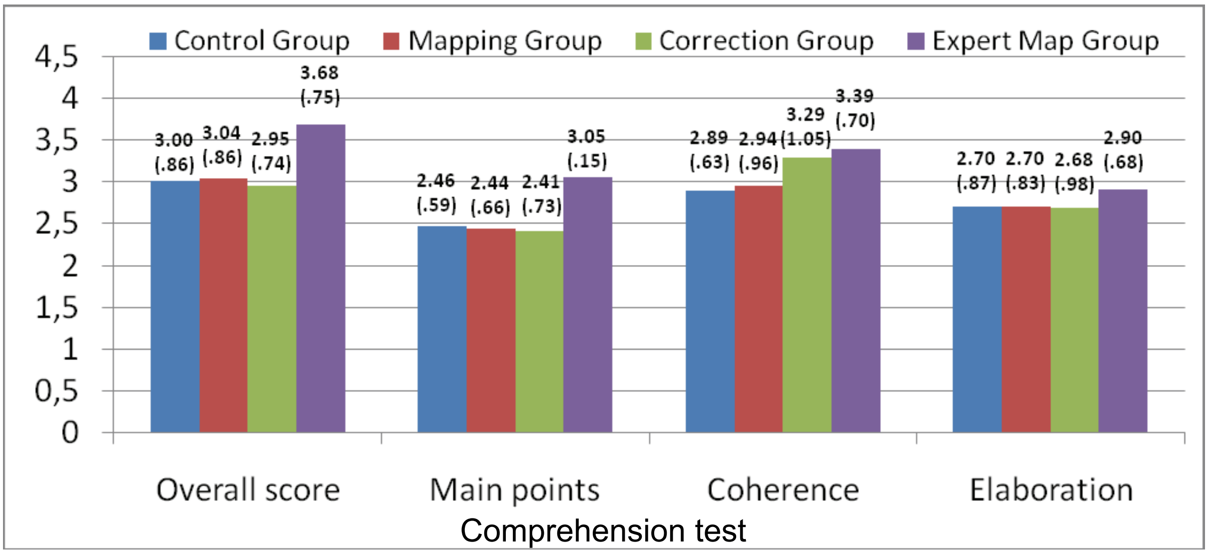

Figure 2. Means (standard deviations in parentheses) of learners' comprehension test scores for the experimental groups

Discussion

Studying worked-out expert maps without errors may be a successful approach to foster learning (Hauser et al, 2006; O'Donnell et al., 2002). According to the worked-example effect (Sweller & Cooper, 1985), studying worked-out examples can be considered as a less load intensive learning activity than constructing concept maps from scratch. Especially beginners using this learning strategy can easily become overwhelmed by the demand to generate a concept map (Reader & Hammond, 1994). However, the mere study of a worked-out solution can also lead to superficial processing of the learning material. Chang et al. (2002) reported that correcting errors in an incorrect concept map fostered text comprehension better than generating concept maps. In this study, we examined whether a correction task can enhance learning with worked-out concept maps compared to studying expert maps. In summary, we found that: (a) studying worked-out expert maps fostered text comprehension best and (b) learners correcting errors in incorrect worked-out concept maps did not perform better than learners generating concept maps on their own or a control group that did not engage in any follow-up activity for learning from text.

Interestingly, we found no effect of the different mapping strategies on the gain of factual knowledge. However, as expected, the groups differed with respect to their comprehension of the topic human embryo research. Many studies have found that studying worked-out examples is superior compared to solving problems (e.g., Atkinson et al., 2003; Renkl, 2005). Cognitive load theory explains this phenomenon with the fact that working memory is overloaded by the demand of the problem solving task. Thus, no capacities are left for learning and building schemata (Sweller & Cooper, 2005). We found such a worked-out map effect in this study: the group learning by self-explaining worked-out expert maps performed best in the comprehension test. The identification of main points was especially enhanced compared to our other experimental conditions. Following O'Donnell et al. (2002), reducing a learning topic to its main points is one of the important functions of concept mapping. Also, the coherence function of concept mapping was supported by studying a worked-out expert map.

Other than Chang et al. (2002), the group correcting errors in incorrect concept maps did not have a better result than learners generating concept maps on their own or learners who did not engage in a follow-up activity for text learning. Thus, our assumption that a correction task should especially foster the metacognitive function of concept mapping and therefore foster learning was not confirmed. A post-hoc analysis of learners' answers indicates that the correction group even learned incorrect knowledge from the incorrect worked-out maps. Learners in the correction group made the highest amount of mistakes in the comprehension test. The amount of mistakes in the comprehension test generally was quite small (control group: $M = .05$, $SD = .22$; mapping group: $M = .15$, $SD = .37$; correction group: $M = .50$, $SD = .69$; expert map group: $M = .10$, $SD = .31$). However, the differences between the amount of mistakes in the four groups was significant, $F(3, 76) = 4.43$, $p = .01$, $\eta^2 = .15$ (large effect). A post-hoc Tukey HSD analysis revealed that learners in the correction group made more mistakes in the comprehension test than learners in the mapping group ($p = .019$) and learners in the expert map group ($p = .019$). The amount of mistakes did not differ between the expert map group, the mapping group and the control group (all $p > .05$).

The problems of learners in the correction group could have several reasons. Chang et al. (2002) found that learners who had learned with a correction task performed better than learners completing partially worked-out concept maps. However, these authors provided the learners feedback about the correctness of their activities. In future studies, it would be interesting to take the possibility of providing feedback into account. Another reason for the unexpected result of the correction group could be that the learners' prior knowledge about human embryo research was not enough to be able to detect the mistakes in the map, not even after reading the learning text. Following Siegler (2002), learners may profit from learning with incorrect solutions by identifying and explaining the errors themselves and thus avoid these errors when solving problems on their own. However, as Große and Renkl (2007) argue, self-explaining errors in order to overcome them would only be possible, if learners had enough prior knowledge. As the pretest showed, prior knowledge about human embryo research was quite small in this study. The assumption that this could have hindered learning with a correction task is supported by a closer look at the corrections the learners made in the incorrect concept maps: On average, learners only found 42% of the errors that were included in the map. Große and Renkl (2007) highlighted the errors in the examples they used in their studies. Future studies on learning by correcting errors in worked-out concept maps as a follow-up strategy for learning from text could also try to highlight the errors. Based on the prior knowledge learned from the text, this could allow a deeper processing of the presented concept map.

For instructors, the results of this study suggest that learners should rather study a worked-out expert map than correcting errors in an incorrect concept map. However, although the employment of worked-out concept maps is a promising method, they are often unavailable and laborious for instructors to construct. 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. Therefore, it would be interesting to analyze how learners can be trained to effectively generate concept maps for learning. Especially the introduction of a fading procedure could be helpful for learners to use concept mapping for learning. This issue will be taken up in further studies.

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