

# Are high-coherent concept maps better for prior knowledge activation? Differential effects of concept mapping tasks on high school vs. university students

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## Abstract

We investigated whether and how prior knowledge activation improves learning outcomes for high school (less experienced learners) and university students (experienced learners) in a hypertext environment. Map coherence was defined as the extent to which relationships between the concepts in the map were made explicit. Therefore, we classified the mapping task of creating and labelling lines as low-coherent, and the mapping task of labelling provided lines as high-coherent. Learners were randomly assigned to the conditions of (1) high-coherent knowledge activation; (2) low-coherent knowledge activation; and (3) a baseline condition without prior knowledge activation. We found an overall effect for prior knowledge activation, learning experience, and an interaction between learning experience and the coherence of the prior knowledge activation task on learning outcomes. High school students benefited most from labelling provided lines, while university physics majors benefited most from creating and labelling lines. This interaction effect and effects of the specific mapping tasks on process measures support the claim that different prior knowledge activation tasks are suited for different groups of learners.

## Keywords

prior knowledge activation, coherence, concept mapping, hypermedia, hypertext, mental set.

## Introduction

Is it enough for an instructor to assume that prior knowledge is activated automatically when reading, for example, a web page? And if it turns out that it is better to explicitly activate prior knowledge, how should it be activated? Is prior knowledge activation only the activation of specific concepts in long-term

memory or does the specific activity of the task used for prior knowledge activation matter? Should prior knowledge activation be different for learners with different learning experience (e.g. high school vs. university level)?

To shed some light on these important questions for self-regulated learning, **this study examined whether and how prior knowledge activation with two different concept mapping tasks elicits qualitatively different processes and learning outcomes.** In the following, we first outline the importance of prior knowledge, and we then discuss how prior knowledge can be activated using an instructional method focusing on the macro-structure of the contents to be learned. As the proposed benefits of prior knowledge activation should be

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especially relevant in less structured learning environments, we reviewed recent studies about hypermedia that showed the relevance of prior knowledge activation, self-evaluation and planning for self-regulated learning. Considering the complexity of prior knowledge activation, we then turn to the question of whether and how different tasks used to activate prior knowledge influence learning processes and learning outcomes for high school vs. university students differently. **In this context, we conceptualize prior knowledge as the learner's content knowledge related to the domain studied, which is present before the implementation of a particular instruction** (see also Dochy 1992).

### The importance of prior knowledge for learning

Prior knowledge is one of the most important, if not the most important, prerequisite for learning (e.g. Ausubel 1968; Schneider *et al.* 1989; Weinert & Helmke 1998). Investigating the role of domain-specific prior knowledge, Weinert and Helmke showed that correlations between prior knowledge and mathematics learning performance remained strong, even when intelligence was partialled out. Their longitudinal study also showed that the influence of prior knowledge on performance improvement increased while the influence of intelligence as a source of performance differences decreased with time. Schneider *et al.* showed that prior knowledge compensated for low aptitude, while high aptitude could not compensate for low prior knowledge. On the basis of dozens of studies, Dochy (1992) concluded that a learner's prior knowledge overrules all other variables and explains between 30% and 60% of the variance in learning outcomes. Thus, he emphasized that more attention should be paid to this crucial prerequisite of learning.

While prominent learning theories such as the construction–integration theory of text comprehension (Kintsch 1988), the constructivist theory about narrative text comprehension (Graesser *et al.* 1994) and the theory of multimedia learning (Mayer 1997) all more or less acknowledge the importance of prior knowledge, only the assimilation theory of meaningful learning (Ausubel 1968) places prior knowledge at its core. According to this theory, meaningful learning occurs when learners connect new information to the existing knowledge structure. This learner-controlled process is called assimilation. Meaningful learning has at least three components: the learners' prior knowledge, mean-

ingful material, and the learners' intent and ability to use their prior knowledge.

### Prior knowledge and self-regulated learning with hypertexts

The influence of prior knowledge on learning should increase, the more control of the learning process is left up to the learner, because external instructional guidance is low. Hypertexts are an example of learning environments in which learners have to self-regulate their learning to a substantial degree. Such texts contain information pages with multiple links between information units (Rouet & Levonen 1996). These structures allow different paths and thereby 'information diets', offering learners navigational choices and enabling them to decide which information to access. However, hypertexts often fall short of the expectations directed to the learners' constructive knowledge building (Unz & Hesse 1999; for reviews, see Dillon & Gabbard 1998; Shapiro & Niederhauser 2004). Learners' access to and control over the text with which they interact may only be beneficial if they know what information they need (Jonassen 1986; Dee-Lucas & Larkin 1995). Otherwise, learners may stumble through the 'information jungle' and get disoriented or 'lost in hyperspace'. Several studies showed the positive influence of prior knowledge on learning outcomes with hypertext environments (e.g. Gerjets & Scheiter 2003; Potelle & Rouet 2003). Other studies looked at the strategies learners use (e.g. Hill & Hannafin 1997; Azevedo *et al.* 2004b), the effects of training self-regulated learning (e.g. Azevedo & Cromley 2004) and the value of scaffolds *during* the learning phase (e.g. Shapiro 1999; Potelle & Rouet 2003; Azevedo *et al.* 2004a). The findings of these studies indicated that learners often do not activate relevant prior knowledge spontaneously, have difficulties organizing related 'pieces' of information, and hardly plan or engage in metacognitive monitoring of what they already know and do not know. Scaffolds have shown positive effects mainly among learners with low prior knowledge, while benefits of scaffolds for learners with a higher level of prior knowledge were low or non-existent (e.g. Shapiro 1999; Potelle & Rouet 2003). It remains an open question whether this is due to the fact that learners with high prior knowledge do not need additional support, or whether the type of support does not fit the special needs of those learners.

In sum, prior knowledge activation and the processes of self-evaluation and planning, which both build on activating and evaluating one's own (prior) knowledge, are important processes for self-regulated learning. Since they often do not occur spontaneously, it seems to be fruitful to investigate specific methods for instructional prior knowledge activation.

### **Prior knowledge activation using concept mapping tasks**

Based on Ausubel's work (e.g. Ausubel 1968), Novak & Gowin (1984) described hierarchical concept maps as a tool for students to examine their prior knowledge before studying new materials. Concept maps provide an external network-like representation of knowledge structures and consist of spatially grouped nodes with keywords representing concepts, connecting lines representing the semantic connection of concepts, and labels on the lines to specify the kind of the semantic relation. As one of the main functions of maps is highlighting the macrostructure, they may be used to facilitate focusing on important information (O'Donnell *et al.* 2002). Activating relevant concepts and connections may trigger or enhance the integration of new information into existing knowledge structures. Furthermore, prior knowledge activation with concept mapping tasks can help learners to identify what they do not know yet. For example, learners may realize that although they know the definitions of two concepts, they might not know whether and how these concepts are related. This may lead to a self-regulated planning of further learning activities, such as the generation of questions to be answered later on and an active search for lacking information. This benefit should be especially relevant in less structured learning environments, such as hypertexts, where learners have been found to be particularly vulnerable to disorientation and information overload.

### **Effects of task characteristics**

Although concept maps are generally considered to aid learning (for an overview, see O'Donnell *et al.* 2002), the specific mapping task and learner characteristics determine the relevant learning processes. With respect to the task, it is important to consider that concept maps may be created entirely by the student, or instructors

can prepare incomplete maps that require learners to perform specific activities, such as filling in nodes or labelling links. Chang *et al.* (2001) compared computer-based 'free-construction', 'construct-on-scaffold' and 'free-construction by paper-and-pencil' mapping tasks. The 'free-construction' groups had to construct concept maps by themselves without construction-scaffolding. The 'construct-on-scaffold' group received an incomplete expert concept map within which some nodes and links had to be completed. All groups were provided with a concept list and a relation list which contained all the concepts and relations to be used. The post-test showed that the computer-based 'construct-on-scaffold' group outperformed the computer-based 'free-construction' and 'free-construction by paper-and-pencil' groups, with no differences between the computer-based and the paper-based 'free-construction' groups. **These findings showed that different mapping tasks lead to differences in learning outcomes** (for similar results, see Hauser *et al.* 2006).

Questioning the uniformity of cognitive processes during different concept mapping techniques, a thinking-aloud study by Gurlitt *et al.* (2006) investigated prior knowledge activation processes elicited by different mapping tasks. Maps with and without given links were compared. The mapping task of creating and labelling lines elicited fewer elaborations (defined as processes to connect new knowledge with existing knowledge structures). However, the creating and labelling of provided lines elicited more processes of organization (defined as processes dealing with relations between two concepts). In addition, the creating and labelling of provided lines also led to more model-construction processes, that is, to more thoughts about the interrelations between clusters of concepts. Model-construction processes thus focus on higher-order relations and should be especially useful for topics with interacting relations. While this study by Gurlitt *et al.* provided insights into elicited differential cognitive and metacognitive processes, no learning phase and learning outcome measures were included.

### **Effects of different groups of learners and possible interactions with instructional materials**

Investigating differences between experts and novices, Chi *et al.* (1981) found substantial differences in the categorization and representation of physics problems. For

example, in the first study, advanced PhD students from the physics department (experts) and undergraduates who had just completed a semester of mechanics (novices) participated in a problem-sorting task. Results showed qualitatively different problem classifications; while the experts seemed to sort problems by underlying principles, the novices relied more on surface characteristics of the problem. Meanwhile, it is commonplace in research on learning and instruction that such individual differences in knowledge or domain experience are relevant when selecting the appropriate instructional methods or procedures (see Kalyuga 2007).

In research on learning from texts, McNamara *et al.* (1996) showed that high-knowledge readers learned more after reading a low-coherent text, while low-knowledge readers benefited more from a high-coherent text (see also McNamara & Kintsch 1996; O'Reilly & McNamara 2007). High coherence was operationalized by inserting linking words for better argument overlap, making important references explicit and rearranging sentences in a way that learners encountered information they already knew prior to the new information to be connected (see also Britton & Gulgoz 1991). The interaction effect between knowledge and text characteristics can be explained by the construction-integration model (Kintsch 1988), which predicts 'problem-solving' activities if coherence cannot be established more or less automatically.

Interactions between instructional materials and different levels of experience were also shown in research about presentation formats. ChanLin (2001) investigated the effects of presentation format (animation, still graphics, text) and the students' prior knowledge on learning a computer-based physics lesson. Eighth-grade (novice learners) and ninth-grade students (experienced learners) were randomly assigned to different treatments on a class basis. Results revealed an interaction between presentation format and experience with respect to learning outcomes. Among novices, still graphics were advantageous compared to text in declarative learning, and better than text and animation in procedural learning. No differences were found for experienced students.

In a nutshell, a different instructional task design seems to be optimal depending on how advanced the specific learners are. This also suggests that for a different educational setting (e.g. high school vs. university), a different task design might be optimal.

## Overview of current study and hypotheses

Although Ausubel (1968) emphasized the importance of prior knowledge 40 years ago, there is still a lack of theoretical, empirical and practical knowledge about tasks, processes and effects of prior knowledge activation. To our knowledge, there have been no studies about effects and interactions of different prior knowledge activation tasks with learning experience (for reviews, see Mayer 1979; Luiten *et al.* 1980; Dochy 1992; Preiss & Gayle 2006). Effects of different prior knowledge activation tasks on comprehension are likely, given the differential effects of cognitive and metacognitive processes elicited when working with specific concept mapping tasks (see also Chang *et al.* 2001; Ruiz-Primo *et al.* 2001; Gurlitt *et al.* 2006).

While 'text coherence is the extent to which the relationships between ideas in a text are explicit' (McNamara 2001, p. 51), map coherence can be defined as the extent to which relationships between the concepts in the map are made explicit. Therefore, we regard the mapping task of creating and labelling lines as low-coherent and the mapping task of labelling provided lines as high-coherent prior knowledge activation. Interactions between the coherence of the prior knowledge activation task and different learning experience are suggested by coherence effects found in learning from texts (McNamara & Kintsch 1996; McNamara *et al.* 1996).

According to theoretical models of self-regulated learning (see Boekaerts *et al.* 2000) and the detailed empirical analysis of hypertext learning, for example, by Azevedo (e.g. Azevedo *et al.* 2004a), prior knowledge activation, the subsequent self-evaluation of one's own knowledge and the planning of further learning are key self-regulation processes. Thus, concerning learning processes, it remains an open question whether and how prior knowledge activation tasks elicit the generation of questions, influence navigation (i.e. a data-driven or focused search) and active processing of information in a hypertext environment.

Therefore, the present experiment tested the effects of prior knowledge activation on learning processes and on learning outcomes in the context of hypertext learning for high school and university students (here physics major students). More specifically, the following research questions were addressed:

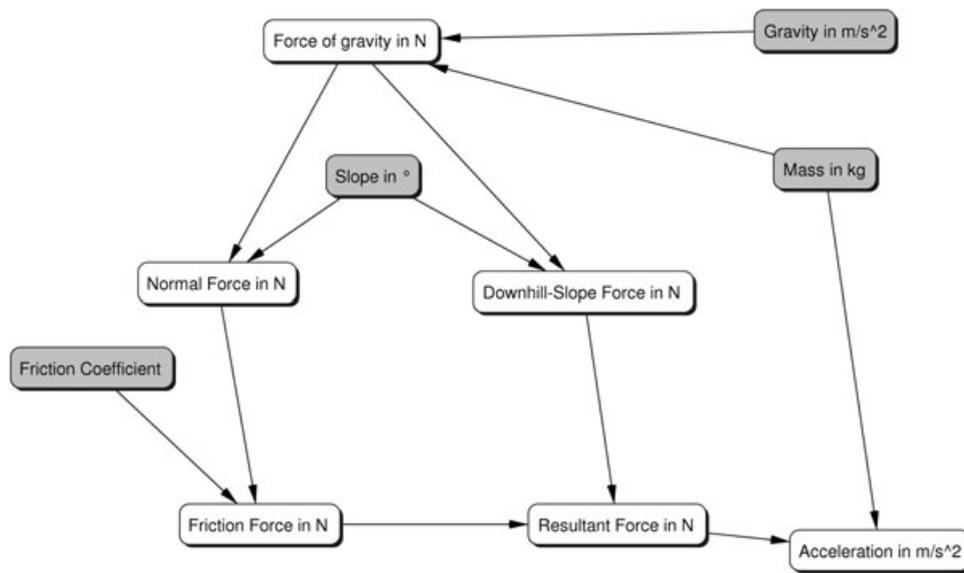


Fig 1 High-coherent prior knowledge activation task: labelling provided lines (translated by the first author).

- 1 Does prior knowledge activation with concept maps improve learning outcomes at all?
- 2 Do university physics major students benefit from a low-coherent prior knowledge activation task, while high school students benefit from a high-coherent prior knowledge activation task?
- 3 Do low- and high-coherent prior knowledge activation tasks influence learning processes, such as question generation before learning or superficial processing during learning?

## Method

### Participants and design

We used a  $3 \times 2$  design. The between-subject factor 'prior knowledge activation' included a low-coherent and a high-coherent prior knowledge activation condition, as well as a baseline condition without prior knowledge activation. The second between-subject factor, learning experience, consisted of university physics major and high school students, respectively. 'High school' refers to the *Gymnasium*, the highest of three tracks in the German school system, which leads to admission to German universities. University physics majors had also graduated from a *Gymnasium*. Forty-three high school students (mean age:  $M = 17.6$  years; 21 female, 22 male) from the grades 11 to 13 and 45 uni-

versity physics majors (age:  $M = 21.6$  years, 14 female, 31 male) participated in this study. As all participants took physics in high school, all participants had some background knowledge (to be activated) about physics concepts and their relations. The German curriculum provides the possibility to learn physics from 8th to 13th grade. High school students had a mean of 4.37 years of physics education while physics majors had a mean of 7.84 years. Part of the topic to be learned in the present study ('motion on inclined plane') is taught in the 11th grade. Physics majors have had additional lessons about this topic at the university level.

The experiment took approximately 1 h and 15 min, and participants received EUR 10. The participants were randomly assigned to one of the following conditions: (1) The high-coherence group activated prior knowledge by a labelling-provided-lines task (see Fig 1), reflected about possible knowledge gaps and studied a hypertext about motion on an inclined plane. (2) The low-coherence group activated prior knowledge through a creating-and-labelling-lines task (as in Fig 1 but without connecting lines), reflected about possible knowledge gaps and studied a hypertext. (3) To estimate the effects of prior knowledge activation with concept maps and reflection about one's own knowledge, a baseline condition was included. This group just studied a hypertext about motion on an inclined plane without prior knowledge activation.

### Procedure and materials

The experiment was conducted in a computer lab. For each session, three to five learners participated. The participants in the prior knowledge activation groups first received written instructions that explained concept mapping. The instructions included an example from biology. It explained how to label the lines ('+' for a positive relationship, e.g. more photosynthesis leads to more oxygen; '-' for negative relationships, e.g. more bacteria leads to less oxygen; '?' if undecided between the two). Using the same example, participants also completed a label-provided-lines mapping task and a create-and-label-lines mapping task on the computer to familiarize themselves with the mapping software used in this study (Easy-Mapping Tool, see <http://www.cognitive-tools.com>). This mapping software was specifically adapted for the present study so that concepts could not be changed, rearranged or added. The only possible actions for participants were drawing and labelling lines.

An expert concept map with connecting lines and labels was developed, together with a university physics professor and a high school physics teacher. For the high-coherent prior knowledge activation, the labels were removed; for the low-coherent prior knowledge activation, labels and connecting lines were removed.

Both experimental groups were informed about the goal of the mapping task, that is, to find out for themselves what they already knew and what they did not know yet. After 6 min of mapping, learners in the prior knowledge activation groups had 4 min to reflect on their knowledge gaps. They were told that they could formulate questions if they wanted to do so. These questions could be typed in a corresponding note box. This opportunity to generate questions was incorporated to bridge the gap between the two activities, the mapping task and the following hypertext. The possibility of self-generating questions was also available in the hypertext. The hypertext and self-generated questions were presented on a split screen: The left side of the split screen included the hypertext about motion on inclined plane, while the right side incorporated the voluntarily generated questions inside a text area. Participants were not specifically instructed or 'forced' to answer their previously generated questions. During learning with the hypertext, this text area could also be used to write down notes or to copy and paste information from the hypertext. Learners of the baseline condition used the

same split screen. They could also make notes; however, they only studied the hypertext without prior knowledge activation.

Learners studied the hypertext for 20 min. It contained definitions, relations, principles and examples of the topic. All concepts mentioned in the prior knowledge activation task were included as headings and in the content of the hypertext. Altogether, the hypertext consisted of 82 short pages. The navigation bar on the top was segmented in definitions, relations, principles, and examples (and also included a search button). The hypertext also included links within one category so that learners could navigate, for example, from the definition of 'gravity' to the definition of 'acceleration'. In addition, it included cross-links between categories.

A clock counting down from 20 min was provided inside the learning environment. One minute before the end of the learning phase, learners were reminded of the time. When the time was up, learners were told to stop reading and work on the post-test. The available time for answering the open post-test questions was visualized and controlled by the computer. The learners were automatically reminded to finish up 30 s before the allotted time had expired.

### Instruments and measures

Since we investigated prior knowledge activation effects, we did not use a pre-test (which would have been also a type of prior knowledge activation). Two raters categorized the questions that participants noted after prior knowledge activation. The categories were related to the ones Gurlitt *et al.* (2006) used previously in the analyses of thinking-aloud during concept mapping: (1) *organization questions* were defined as questions asking if two concepts were related; (2) *elaboration questions* were defined as reflecting about the details of the relationships between two concepts; (3) *model-construction questions* were defined as questions about the interrelations in clusters of variables; and (4) *definition questions* referred to the definitions of certain concepts. Interrater agreement for the categories, shown by the intraclass correlation coefficient (ICC), was good (organization questions:  $ICC_{2,2} = 0.80$ ; elaboration questions:  $ICC_{2,2} = 0.93$ ; model-construction questions:  $ICC_{2,2} = 0.87$ ; definition questions:  $ICC_{2,2} = 0.95$ ).

As another learning process parameter, we recorded the number of pages visited. The parameter indicated

whether the hypertext was explored in a focused (less pages) or more explorative way (more pages). Learners were also asked to rate on a 6-point rating scale whether they used a goal-oriented approach or whether they were rather led by the links (1 being ‘I was led by the links the whole time’ and 6 being ‘I searched for specific information the whole time’). We also recorded the number of times learners copied and pasted content from the hypertext into the text area. This amount of pasting during learning was used as an indicator of superficial processing (e.g. Priemer & Schön 2004).

A post-test evaluated learners’ understanding of the learning contents rather than purely their computational skills in this content sub-domain. It included three open format questions and six multiple-choice items. Newtonian mechanics applied to the motion on inclined plane includes relations between mass, gravity, slope, inertia, friction and forces. These processes can only be fully understood if their complex interdependencies are considered. Therefore, the open questions in the post-test focused on understanding relationships between concepts. The first open question asked participants to explain in 5 min the relationship between mass and acceleration (this question takes into account the complex interplays between multiple variables such as inertia vs. gravity, force of gravity, slope and the resultant downhill-slope force). The second and third open questions gave participants 3 min to write about the effects of gravity increase and of friction increase. We also asked six questions on relationships in a multiple-choice format, for example, ‘The greater gravity the . . . the acceleration.’ Students had to decide between ‘greater’, ‘lesser’, ‘equal’, ‘not enough information to decide’ and ‘I don’t know’. The latter was used to improve the chance for honest answers and reduce the occurrence of guessing.

Multiple-choice questions were scored either correct or incorrect. All open questions were rated with scores between 0 and 5. Raters judged the quality of the answers by considering whether answers showed simple recall of isolated concepts or a deeper understanding

of relations between concepts. The maximum score (five) was assigned for a logical and clear argumentation chain considering relations and relations between relations. The minimum score (one) was assigned if the answer did not show an understanding of any relation between concepts. All written answers to the open questions were scored independently by two raters. Interrater agreement was high ( $ICC_{2,2} = 0.94$ ). As all of these post-test items measured conceptual understanding, they were aggregated to an overall score of learning outcomes. The post-test showed acceptable reliability (Cronbach’s  $\alpha = 0.71$ ).

**Results**

An  $\alpha$  level of 0.05 was used for all statistical tests. As an effect size measure, we used partial  $\eta^2$ , qualifying values  $<0.06$  as small effects, values in the range between 0.06 and 0.13 as medium effects, and values  $>0.13$  as large effects (see Cohen 1988).

**Learning outcomes**

Table 1 provides an overview about the influence of different prior knowledge activation tasks and different learning experience on the post-test. An analysis of covariance (ANCOVA) was performed, using the control measure ‘average physics grade in the last two years in high school’ as a covariate. The between-subjects factors were prior knowledge activation task (baseline, create and label the lines, label provided lines) and learning experience (university physics major, student at high school). The covariate met the homogeneity of regression slopes requirement (no significant differences between slopes) and had a statistically significant effect on the post-test,  $F_{1,81} = 22.43, P < 0.001$ .

Does prior knowledge activation with concept maps at all improve learning outcomes? Consistent with our expectation, an ANCOVA yielded a statistically significant difference for an *a priori* defined contrast (the pooled activation groups vs. baseline group) in favour of

Table 1. Means and standard deviations (in parentheses) of the learning outcomes.

	No prior knowledge activation (baseline)	Creating and labelling lines	Labelling provided lines
High school students	5.73 (2.71)	6.89 (3.71)	8.89 (4.07)
Physics majors	9.07 (2.45)	12.33 (2.89)	10.97 (3.58)

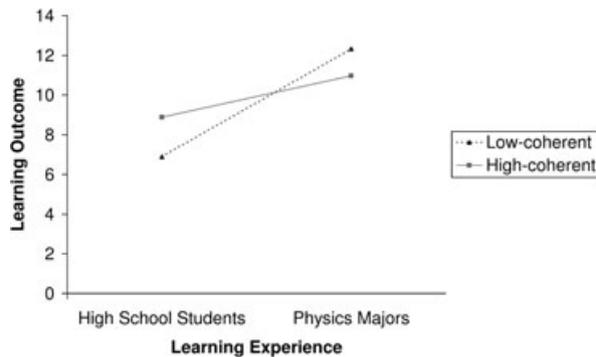


Fig 2 Learning outcomes of high school students and university physics major students (means).

prior knowledge activation,  $F_{1,81} = 7.47$ ,  $P < 0.05$ ,  $\eta^2 = 0.08$  (medium effect). Both physics majors and high school students benefited from prior knowledge activation, and there was no interaction between prior knowledge activation and learning experience  $F_{1,81} < 1$ .

Do university physics major students benefit from low-coherent prior knowledge activation, while high school students benefit from high-coherent prior knowledge activation? Figure 2 shows the corresponding significant interaction,  $F_{1,81} = 5.02$ ,  $P < 0.05$ ,  $\eta^2 = 0.06$  (medium effect). **Physics majors performed better when creating and labelling lines, while high school students performed better when just labelling provided lines.** As expected, an ANCOVA test for differences in group means yielded a statistically significant difference in favour of the university physics major students,  $F_{1,81} = 7.89$ ,  $P < 0.05$ ,  $\eta^2 = 0.09$  (medium effect).

### Effects on learning processes

To investigate the effects of different prior knowledge activation tasks on question generation,  $2 \times 2$  analyses of variance (ANOVAs) were performed using prior knowledge activation tasks (create and label the lines, label provided lines) and learning experience (university physics major, student at high school) as factors (see also Table 2).

We found a significant main effect of different prior knowledge activation tasks on model-construction questions. Participants creating and labelling lines asked more model-construction questions ( $M = 0.52$ ,  $SD = 0.74$ ) than their peers labelling provided lines ( $M = 0.13$ ,  $SD = 0.40$ ),  $F_{1,54} = 5.98$ ,  $P < 0.05$ ,  $\eta^2 = 0.10$  (medium effect). As high school students did not ask

Table 2. Means and standard deviations (in parentheses) of the questions learners voluntarily asked themselves.

	Definition questions	Model-construction questions	Reflection about single relationships	Organization questions
<b>Creating and labelling lines</b>				
High school students	1.36 (1.10)	0.46 (0.63)	1.11 (1.20)	0.71 (0.87)
Physics majors	0.60 (0.93)	0.57 (0.84)	0.90 (1.06)	0.20 (0.46)
<b>Labelling provided lines</b>				
High school students	1.07 (1.55)	0.00 (0.00)	2.18 (2.44)	0.32 (0.64)
Physics majors	0.97 (0.90)	0.27 (0.53)	1.60 (1.30)	0.13 (0.40)

themselves any model-construction questions after the high-coherent prior knowledge activation, we also used the non-parametric Mann–Whitney test to confirm these possible group differences. Results were similar to the results obtained by the ANOVA. **We found a significant main effect of different prior knowledge activation tasks on model-construction questions.** Participants creating and labelling lines asked more model-construction questions (Mdn = 34.1) than their peers labelling provided lines (Mdn = 24.9),  $U = 287$ ,  $P < 0.05$ ,  $\eta^2 = 0.12$  (medium effect). We did not find an effect for learning experience or a significant interaction between the prior knowledge activation task and learning experience for model-construction questions.

We found an effect of different prior knowledge activation tasks on reflection about single relationships. Participants labelling provided lines asked more questions about single relationships ( $M = 1.89$ ,  $SD = 1.92$ ) than their peers creating and labelling lines ( $M = 1.00$ ,  $SD = 1.11$ ),  $F_{1,54} = 4.54$ ,  $P < 0.05$ ,  $\eta^2 = 0.08$  (medium effect). We did not find an effect for learning experience nor a significant interaction between the prior knowledge activation task and learning experience on reflection about single relationships.

We also obtained an effect of learning experience on organization questions. High school students asked more questions on whether two concepts were related ( $M = 0.52$ ,  $SD = 0.78$ ) than physics major students ( $M = 0.17$ ,  $SD = 0.42$ ),  $F_{1,54} = 4.75$ ,  $P < 0.05$ ,  $\eta^2 = 0.08$  (medium effect). We did not find an effect of the prior knowledge activation task or a significant interaction between the prior knowledge activation task and learning experience on organization questions.

There were no effects of different prior knowledge activation tasks or learner experience on definition questions. In sum, the major difference in question generation between mapping conditions was that **a low-coherent map led to more consideration of complex interrelations in concept clusters, whereas the high-coherent map led to greater reflection on the details of interrelation between two concepts.**

Does prior knowledge activation influence the number of pages visited in the hypertext and the perceived goal orientation? For the navigation and the perceived goal orientation, we performed a  $3 \times 2$  ANOVA with the factors prior knowledge activation (none, create and label the lines, label provided lines) and learning experience (university physics major, student

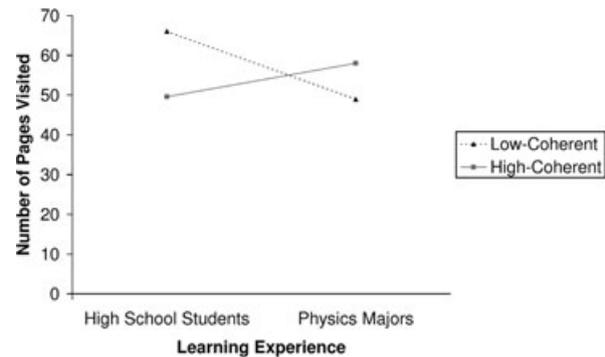


Fig 3 Number of pages visited in the hypertext (means).

at high school). The control variable ‘average physics grade in the last two years in high school’ did not show a significant relation with the dependant measures (i.e. navigation and perceived goal orientation) and was therefore excluded from these analyses.

For the analyses of navigation, **six participants had to be excluded because their log files were not recorded due to technical difficulties.** ANOVA yielded a statistically significant difference in the number of pages visited for an *a priori* defined contrast (the pooled activation groups vs. baseline group),  $F_{1,76} = 18.75$ ,  $P < 0.05$ ,  $\eta^2 = 0.20$  (large effect). Participants with prior knowledge activation ( $M = 56.04$ ,  $SD = 22.21$ ) visited fewer pages than participants in the baseline group ( $M = 79.50$ ,  $SD = 30.03$ ). **This result indicated that prior knowledge activation led to a more focused and less explorative approach in hypertext reading. In addition, we found a tendency among physics majors to inspect the hypertext in a more focused way** (i.e. fewer pages visited) after the low-coherent prior knowledge activation. High school students, in contrast, did so after high-coherent prior knowledge activation (Fig 3). However, the corresponding interaction effect reached only the 10% level of significance,  $F_{1,75} = 3.91$ ,  $P < 0.1$ ,  $\eta^2 = 0.05$  (small effect), so that this finding has to be interpreted with caution.

The reduced number of pages visited in the conditions with prior knowledge activation is reflected by the self-rating of goal orientation. Participants with prior knowledge activation ( $M = 3.50$ ,  $SD = 1.25$ ) perceived themselves as more goal oriented than participants in the control group ( $M = 2.47$ ,  $SD = 1.22$ ),  $F_{1,81} = 14.29$ ,  $P < 0.05$ ,  $\eta^2 = 0.15$  (large effect). In addition, we found that physics majors rated themselves as less goal oriented ( $M = 2.83$ ,  $SD = 1.27$ ) than high school students

( $M = 3.43$ ,  $SD = 1.34$ )  $F_{1,81} = 6.30$ ,  $P < 0.05$ ,  $\eta^2 = 0.07$  (medium effect).

Does prior knowledge activation lead to less superficial processing in the form of copying and pasting? Learners with prior knowledge activation tended to copy and paste less often ( $M = 2.20$ ,  $SD = 3.08$ ) than learners without prior knowledge activation ( $M = 4.33$ ,  $SD = 7.03$ ). The corresponding main effect of prior knowledge activation reached, however, only the 10% level of significance,  $F_{1,75} = 3.90$ ,  $P < 0.1$ ,  $\eta^2 = 0.05$  (small effect), so that this finding has to be interpreted with caution.

## Discussion

The present findings can be summarized as follows: First, prior knowledge activation with concept mapping tasks improved learning outcomes compared to a baseline condition without prior knowledge activation. Second, as expected, physics major students outperformed high school students. Third, and most important, we found empirical evidence for the claim that different mapping tasks are suited for different groups of learners. Participants with higher learning experience (i.e. higher educational level) benefited more from low-coherent prior knowledge activation, while participants with lower learning experience (i.e. lower educational level) benefited more from high-coherent prior knowledge activation. Fourth, we found evidence that the different mapping tasks had different effects on question generation and superficial processing.

The beneficial effect of prior knowledge activation is evidence for the claim that it is not enough to assume that prior knowledge is activated automatically, for example, when reading an instructional text. One theoretical explanation for the general beneficial effect of prior knowledge activation may be the intentional activation of specific concepts from long-term memory. In this sense, provided concepts may have pre-activated certain concepts or schemata and focused learners on the most important aspects. This explanation is based on assimilation theory assuming that prior knowledge activation allows learners to add more information to long-term memory because more ‘anchors’ for assimilation are activated (see Mayer 1979). However, this explanation is not able to explain the interaction between learning experience and the tasks used for prior knowledge activation, in particular as both the

low- and high-coherent prior knowledge activation conditions used the same concepts. As university physics majors performed better in a condition with less information (no connecting lines between provided concepts), this may be explained by different processes elicited through the low- and high-coherent prior knowledge activation. One possible explanation can be provided by the following view of prior knowledge activation: In addition to the ‘automatic’ activation of content-related knowledge structures, prior knowledge activation may also establish distinctive ‘mental sets’ (see Luchins 1942; Schuck 1981) for the learning phase. On a broader level, the ‘mental set’ should determine the kind of information focused upon (e.g. Machiels-Bongaerts *et al.* 1995). On a finer level, different activities using the same concepts may elicit different cognitive and metacognitive processes (Gurlitt *et al.* 2006) and thereby foster different learning outcomes. However, only learners with the right preconditions (e.g. knowledge, available learning strategies) may be able to activate and benefit from specific processes elicited during prior knowledge activation. Similarly, this suitability of prior knowledge and instructional material is mentioned by McNamara *et al.* (1996) in reference to learning with low- and high-coherent texts. This view about establishing a distinctive ‘mental set’ with specific prior knowledge activation is also supported by the differential amount of model-construction questions vs. reflections about single relationships.

In addition, the more pre-structured task (the high-coherent condition) reduced the possibility to express one’s own conceptual model (if existent) and therefore reduced opportunities to detect relational knowledge gaps. Thus, experienced learners in the high-coherent condition may not have used their free cognitive capacity for deep processing because ‘easy learning environments’ include the risk that learners reduce the amount of invested mental effort (Salomon 1984). This is compatible with the expertise reversal effect postulated within Cognitive Load Theory (e.g. Kalyuga *et al.* 2003; Kalyuga 2007), which describes the finding that more information and structure is favourable for inexperienced learners, whereas less information and structure is favourable for experienced learners.

However, the particular tasks presented should not suggest that creating lines or labelling the lines between provided concepts are the only or most beneficial ways

for prior knowledge activation. Further research may provide comparisons between different kinds of prior knowledge activation such as concept maps and text-based advance organizers (e.g. Ausubel 1960). A comparison of different instructional methods used for prior knowledge activation may shed further light on the question to which extent schema-completion tasks are useful for prior knowledge activation in specific learning settings.

Although caution is recommended when generalizing the present results, we can provide the following tentative recommendation to teachers for activating and examining prior knowledge with the mapping tasks: Generating and labelling connection lines is more beneficial for experienced learners (e.g. university level), whereas the process of labelling connection lines on existing relationships is more beneficial for less experienced learners (e.g. high school level). It remains an open question whether an even less pre-structured map such as a 'free-construction' condition would have been even more beneficial for experienced learners. Tsai *et al.* (2001) provide an overview about possible advantages and disadvantages of 'free-construction' vs. pre-structured maps. On the one hand, less structured maps afford more possibilities to find out what one does not know and allow more flexibility for learners to represent their knowledge structure. On the other hand, students in general do not have relevant knowledge and skills about concept mapping; therefore, the 'free-construction' may overload the average student without concept map training (see also Hilbert & Renkl 2008) and without a higher level of prior knowledge. Considering the theoretical aspect about additional workload of free-construction, Chang *et al.* (2001) showed that although learners in the 'free-construction' condition had more knowledge initially, they gained less through the concept mapping and feedback learning phase compared to the 'construct-on-scaffold' condition. As an interesting outlook, Chang *et al.* also proposed the possibility that the semi-structure may be faded out as learners become more and more sophisticated. Further research may also examine possible combinations with other instructional methods as for example prompts. It also seems promising to look closer at the actual processes during and after prior knowledge activation. We admit that the number of pages visited in the hypertext and the amount of pasting are relatively crude indicators for learning processes.

Goals might also be investigated in much more detail, for example, whether they are directed towards definitional content or towards establishing higher-order structures.

To conclude, the questions from the introduction can be answered as follows: As the concepts shown in the prior knowledge activation task were included as headings and in the content of the hypertext, we suggest that it is not enough to assume that activities such as reading a web page will automatically activate prior knowledge. We presented empirical evidence that concept mapping tasks are a useful tool for prior knowledge activation. The importance of the question 'how prior knowledge may be activated' is underlined by the fact that the tasks used for prior knowledge activation make a difference: High school students benefited most from labelling provided lines, university physics majors benefited most from creating and labelling lines in a concept mapping task. This interaction effect on learning outcomes and the effect of the specific mapping task on the type of questions generated support the hypothesis that different mapping tasks elicit qualitatively different processes. Further research on prior knowledge activation and concept mapping may use more detailed measurements (e.g. ratings of thinking-aloud data), different tasks (e.g. the mentioned 'free-construction'), different learning domains and different groups of learners. This would increase knowledge about the complex relationships between learning experience, tasks used for prior knowledge activation, learning processes and learning outcome measures.

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