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Authors
Hübner, Sandra
Nückles, Matthias
Renkl, Alexander

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Prompting Cognitive and Metacognitive Processing in Writing-to-Learn Enhances Learning Outcomes

Sandra Hübner (huebner@psychologie.uni-freiburg.de)
Matthias Nückles (nueckles@psychologie.uni-freiburg.de)
Alexander Renkl (renkl@psychologie.uni-freiburg.de)
University of Freiburg, Educational Psychologie, Engelbergerstr. 41
79085 Freiburg, Germany

Abstract

Learning protocols are a promising follow-up course work. A learning protocol is a written explication of one's learning processes and outcomes. According to the self-regulation view of writing-to-learn, such writing assignments have to be supported. In this study, learning protocols were structured by prompts to elicit important learning activities as they are postulated in a cyclical model of self-regulated learning. An experiment (N = 103) was conducted in which students received either (a) no prompts, (b) cognitive prompts, (c) metacognitive prompts, (d) mixed prompts without planning-of-regulation prompts or, (e) mixed prompts including planning-of-regulation prompts. The groups with prompts outperformed the control group on comprehension and retention measures. Furthermore, prompting all essential sub-processes of self-regulated learning (mixed prompts including planning-of-regulation prompts) was most effective.

Keywords: writing-to-learn; self-regulated learning; prompts; cognitive and metacognitive learning processes; learning journals

Introduction

Typically, lesson or lecture contents "evaporate" rather quickly, for after the students have left the classroom, only a few continue to reflect on the learning contents. The students rarely elaborate and organize learning contents in a meaningful and coherent fashion. For example, they seldom come up with examples to put abstract concepts into effect. Also, students neither routinely monitor their understanding nor employ corresponding remedial activities. The writing of learning protocols is a method that helps to overcome these shortcomings (McCrindle & Christensen, 1995). A learning protocol represents a written explication of one's own learning processes and outcomes. When such protocols are written in an extended period of time (e.g., a whole term or school year) we call it a "learning journal" (cf. McCrindle & Christensen). Learning protocols are especially appropriate for follow-up course work. They help students apply the previously mentioned cognitive and metacognitive activities. The writing of learning protocols has been shown to be effective in improving students' learning across various educational settings and subjects (Cantrell, Fusaro, & Doughtery, 2000; McCrindle & Christensen, 1995). However, there is also evidence that without appropriate instructional support, students do not apply the learning protocol method in an optimal way (Nückles, Schwonke, Berthold, & Renkl, 2004). To bridge this gap, we have developed an instructional support procedure for writing learning protocols. We present an experiment that analyzed the effects that various types of instructions for writing a learning protocol had on understanding and retention. Furthermore, we examined how the specific instructions are reflected in the learning protocols.

Theoretical Approaches to Writing-to-Learn

Learning by writing can be considered from different theoretical perspectives (Bangert-Drowns, Hurley, & Wilkinson, 2004). According to the *strong text view* of writing-to-learn (e.g., Emig, 1977), the processes involved in writing share intrinsic similarities with thinking and learning processes. It is assumed that writing inherently fosters thinking and learning. In line with this assumption, empirical studies generally showed a superiority of learning journal groups over non-writing groups (Connor-Greene, 2000). However, following the meta-analysis of Bangert-Drowns et al., most writing-to-learn assignments yielded rather small effects, typically showing an effect size of .20 on average. Hence, writing *per se* does not necessarily foster learning to a practically relevant degree. Rather, following Bangert-Drowns et al. conclusions, it is the specific type of writing assignment that strongly influences the learning processes and outcomes. In their meta-analysis, the most important moderator variable was the presence of prompts that stimulated metacognitive processing such as monitoring and regulation of one's own learning processes. Bangert-Drowns et al. concluded that the available evidence clearly supports a *self-regulation view* of writing-to-learn rather than the *strong text view*. According to the self-regulation view, writing as such does not produce learning. Nevertheless, writing may serve as medium that facilitates the application of beneficial cognitive and metacognitive learning activities. However, as argued by Bangert-Drowns et al. (2004), students should explicitly be prompted to elicit the desirable learning activities to a satisfactory degree. For example, Nückles et al. (2004) analysed "naïve" learning protocols of students who had only received brief and informal advice on how to write their protocols. They found that cognitive and metacognitive learning activities did not occur frequently. These results underscore the necessity to support the writing of learning protocols.

How should the writing of learning protocols be supported? Following current models of self-regulated learning (Winne, 1996; Zimmerman, 1999), students should be assisted to elicit both cognitive and metacognitive learning activities. They should start with organizing and elaborating the learning contents. Organizational activities (e.g., identifying main points) help establish *internal links,* that is, finding a meaningful structure of the learning contents. Elaboration activities (e.g., generating examples) serve to build *external* links that relate the new material to the learner's prior knowledge (Mayer, 1984). Additionally, students should continuously monitor their cognitive activities in order to prevent illusions of understanding that might inhibit further learning (Chi, DeLeeuw, Chiu, & LaVancher, 1994). Such metacognitive activities help to identify knowledge gaps, comprehension difficulties or impasses. For example, work on cognitive skill acquisition found that impasses were often associated with learning (VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003). If impasses are detected, students endeavour to actively construct a better understanding. Therefore, they plan regulation activities to overcome the impasses. In the context of this regulation students go back to remedial organizational and elaborative activities. Following Zimmerman (1999), this sequence of cognitive and metacognitive activities can ideally be conceived of as a cyclical and interactive process (see Figure 1).

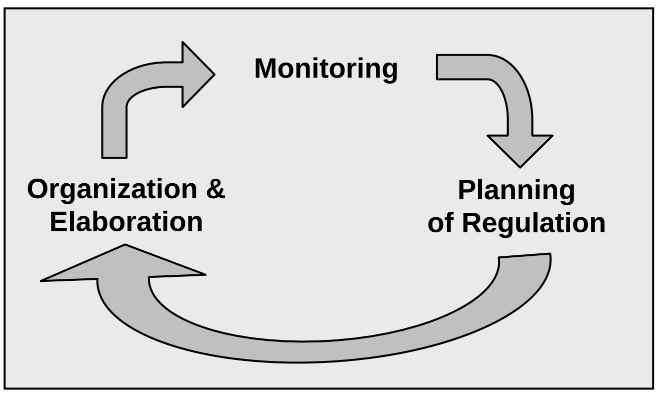

Figure 1: Cyclical model of self-regulated learning.

Berthold, Nückles, and Renkl (2004) conducted an experiment in which they prompted the use of cognitive and metacognitive learning activities in writing a learning protocol. In their study, students received one of four instructions for writing a learning protocol about a videotaped lecture they had previously viewed. The instruction either included six cognitive (i.e., organizational and elaborative) prompts (e.g., "How can you best organize the structure of the learning content?"), six metacognitive prompts (e.g., "Which main points haven't I understood yet?"), a mixture of three cognitive and three metacognitive prompts, or no prompts at all (control condition). Results showed that learners who received cognitive, or cognitive *and* metacognitive prompts significantly outperformed the control group with regard to (a) the amount of cognitive and metacognitive activities in the learning protocols, (b) the learning outcomes on both an immediate comprehension test and a seven-days delayed retention test. These findings show that it is possible to prompt productive learning activities in learning protocols. However, only the elicitation of cognitive activities or the simultaneous elicitation of both cognitive and metacognitive activities fostered learning success. Although the metacognitive prompts yielded a higher amount of metacognitive activities in the learning protocols, this increase in metacognitive activities did not result in a greater learning advantage. Hence, it may be the case that metacognitive strategies alone do not contribute to learning success. In order to be effective, metacognitive strategies apparently had to be applied in combination with cognitive learning strategies. On the other hand, it has to be acknowledged that the experimental setting did not provide ample opportunity for metacognitive activities to become effective. Although the metacognitive prompts induced the students to monitor their comprehension and to detect difficulties, the opportunities for engaging in regulation were rather limited. For example, it was neither possible for the learners to study critical parts of the videotaped lecture once again nor to read the text on which the lecture was based. The inefficacy of metacognitive activities could therefore alternatively be explained by the assumption that the cycle of self-regulation (see Figure 1) was interrupted. According to this model of self-regulated learning, remedial activities could actually be planned, but in this case, there was no possibility to carry them out. To answer the question whether metacognitive activities *per se* do not improve learning success we conducted another experiment. An experimental procedure was applied that was nearly identical to Berthold et al. (2004). First, the students watched a videotaped lecture. Next they wrote a learning protocol about the lecture contents. However, in contrast to the Berthold et al. study, the participants in our experiment were then given ample opportunity to engage in regulation activities. After the students had produced a first draft of their learning protocol, they received an instructional text that was based on the lecture they had just viewed. Hence, the participants had the opportunity to resolve their comprehension problems with the help of the lecture text. If they detected a comprehension problem during the monitoring of their cognitive learning processes, they could plan and realize concrete regulation activities, such as reading a specific passage in the lecture text.

Given that the modified experimental setting better allowed for the realization of regulation activities, we were further interested in ascertaining if those regulation activities would occur spontaneously or if they had to be explicitly prompted. Therefore we extended the design of Berthold et al. (2004). In their experiment, the "combination group" (cognitive and metacognitive prompts) did not receive planning-of-regulation prompts to support this particular metacognitive activity. In our study, we additionally introduced another "combination group". Following the cyclical model of self-regulated learning (cf. Figure 1), this group received prompts stimulating all three essential sub-processes: a) prompts for organization and elaboration, b) prompts for monitoring, and c) prompts for planning of regulation. Accordingly, this group should perform the highest compared with all other groups. Furthermore, if regulation activities (i.e., remedial cognitive activities) do not occur spontaneously in our modified experimental design, but have to be explicitly prompted, the group who received mixed prompts *including* planning-of-regulation prompts should outperform the participants who received only a mixture of cognitive and metacognitive prompts *without* planning-of-regulation prompts.

Research Questions

Based on these theoretical considerations, we addressed the following four research questions: (1) Do cognitive prompts and the combination of cognitive and metacognitive prompts foster learning outcomes? This question basically investigates whether the results of the Berthold et al. study (2004) can be replicated. (2) Can metacognitive prompts foster learning outcomes if the experimental setting allows for the realization of remedial regulation activities? (3) Will a mixture of cognitive and metacognitive prompts *including* planning-of-regulation prompts produce the highest learning outcomes in comparison to all other conditions? (4) Does the mixture of cognitive and metacognitive prompts *including* planning-of-regulation prompts lead to higher learning outcomes than the combination of cognitive and metacognitive prompts *without* planning-of-regulation prompts, because planning of regulation has to be explicitly prompted?

Furthermore, we analyzed whether the various combinations of prompts did in fact elicit the corresponding activities in the learning protocols. Accordingly, we assumed that (5) organization and elaboration prompts would increase the amount of organizational and elaborative activities in the learning protocols, and (6) monitoring prompts would successfully stimulate monitoring activities. We further expected that (7) planning-of-regulation prompts would raise students' planning of regulation activities in the initial version of their learning protocol and accordingly help them realize remedial cognitive activities ("realized regulation") in the revision of the learning protocol.

Method

Participants and Design

Undergraduate students (N = 103) from different departments of the University of Freiburg participated in the experiment. Most of them attended courses in Educational Psychology as part of their studies. Only students who had no relevant prior knowledge with regard to the concrete learning material provided in the videotaped lecture were eligible for participation. For the experiment, we used a one-factorial between-subjects design that comprised five different experimental conditions. In the first condition, the participants received a brief and rather informal advice on protocol composition without any prompts at all. This was our control group ("no prompts condition", n = 22). In the second condition, the participants additionally obtained six cognitive prompts including organization and elaboration prompts ("cognitive prompts condition", n = 21). The instruction in the third condition presented six metacognitive prompts including monitoring and planning-of-regulation prompts ("metacognitive prompts condition", n = 20). The instruction in the fourth condition existed of a combination of three cognitive (organization and elaboration) and three metacognitive prompts, whereas the metacognitive prompts existed only of monitoring prompts and did not include planning-of-regulation prompts ("mixed prompts without planning-of-regulation prompts", n = 20). The instruction in the fifth condition presented two cognitive prompts (organization and elaboration) and four metacognitive prompts, whereas two monitoring and two planning-of-regulation prompts were included ("mixed prompts including planning-of-regulation prompts", n = 20). Dependent variables encompassed students' knowledge acquisition and measures of learning activities in the learning protocol.

Materials and Instruments

Videotaped lecture and pretest A videotaped lecture (duration: ca. 30 min) on Cognitive Load Theory (Sweller, van Merrienboer, & Paas, 1998) was presented. This assured that the lecture content and the presentation were standardized across all experimental conditions. A pretest assessed the students' prior knowledge about Cognitive Load Theory. It consisted of four open-ended questions (e.g., "What is the meaning of the notion of cognitive overload? How it is related to knowledge acquisition?").

Types of prompts Except for the control group, the participants in the other groups received instructions that included specific combinations of cognitive and metacognitive prompts as described previously. Cognitive prompts were intended to stimulate organizational activities (e.g., "How can you best organize the structure of the learning content?") and elaboration activities (e.g., "What example can you think of that illustrates, confirms, or conflicts with the learning contents?"). We applied two types of metacognitive prompts. Whereas monitoring prompts were meant to elicit monitoring activities (e.g., "Which main points haven't I understood yet?"), planning-of-regulation prompts were provided to support regulation activities (e.g., "What possibilities do I now have to overcome my comprehension problem?").

Posttest A comprehension test was administered that consisted of nine open-ended questions (e.g. "What is the meaning of the modality effect? How is it related to knowledge acquisition?"). In order to measure retention of the learning contents, the same test was administrated once again seven days later ("delayed retention test").

Procedure

The experiment consisted of two sessions. In the first session the participants took the pretest assessing their prior knowledge. Next, they attended the videotaped lecture on Cognitive Load Theory. Then, the participants spent 30 minutes writing an initial version of their learning protocol.

They received one of the five instructions. When the students had finished the first draft of their learning protocol, all participants obtained an instructional text on which the videotaped lecture was based. They were told that they could use the text to revise their learning protocol. The students then spent another 30 minutes on this revision. The initial instruction was still available. No additional prompts were provided. Immediately after the completion of their revisions, students were asked to complete a comprehension test. In the second session seven days later, the students completed the delayed retention test.

Analyse and Coding

Immediate and delayed test Two independent raters scored the level of comprehension in the students' answers to the nine open-ended questions in the immediate comprehension test and in the delayed retention test. The level of comprehension was assessed by using the SOLO Taxonomy ("**S**tructure of **O**bserved **L**earning **O**utcome") proposed by Biggs and Collis (1982). According to the SOLO Taxonomy, for each answer we differentiated six levels of knowledge structure ranging from 1 (= *no central points, no relation to the Cognitive Load Theory, incoherent*) to 6 (= *all central points, high relation to the Cognitive Load Theory, very coherent*). The interrater reliability as determined by the intraclass-coefficient was very high (ICC = .94).

Learning protocols For the content analysis of the learning protocols, a coding scheme was developed that aimed at identifying the cognitive and metacognitive activities displayed in Figure 1. Therefore, statements concerning the purpose of structuring the contents in a meaningful way (e.g., organizing the learning content) and statements in order to relate new material to prior knowledge (e.g., generating examples) were assigned to the category *Organization & Elaboration*. To measure the different types of metacognitive activities (monitoring and planning of regulation) we conducted two metacognitive categories. The category *Monitoring* comprised of statements indicating the level of understanding (e.g., "I did not understand the concept germane load.") and comments concerning the reason for those problems ("This section in the lecture was confusing."). In order to identify articulated planned regulation in the initial version of the protocol (e.g., "I could refer this in a textbook.") we used the category *Planning of Regulation.* The category *Realized Regulation* included cognitive activities in the second draft of the protocol that are executed by the students to solve problems or to overcome impasses. As a preparation for the coding, the learning protocols were first segmented into single statements as the coding unit. To this purpose, we used a procedure originally suggested by Erkens, Kanselaar, Prangsma, and Jaspers (2003). The sentences of each learning protocol were split into smaller units on the basis of grammatical and organizational markers such as and, or, because, for example, such as, and that is. Every single unit was assigned to one of the four categories that the coding scheme existed of. Disagreements between raters were resolved by discussion. The interrater reliability was high (ICC = .85) as determined by the intraclass-coefficient.

Results

Learning Outcomes

A one-factorial ANOVA revealed that there were no significant differences between the conditions with respect to prior knowledge, $F < 1$. Table 1 shows the mean scores and standard deviations of the outcome measures (first two rows) and the applied learning activities in the learning protocols separately for the five experimental conditions.

Table 1: Means and Standard Deviations (in Brackets) of the Dependent Variables of the Experiment.

	Experimental Condition				
Dependent Variable	No Prompt	Cogn. Prompt	Metac. Prompt	mix. Prompt without planning	mix. Prompt with planning
Immediate Test	3.18 (0.94)	3.84 (1.09)	3.96 (0.99)	3.93 (0.91)	4.41 (0.86)
Delayed Test	2.94 (0.91)	3.62 (1.23)	3.61 (0.99)	3.60 (0.87)	4.18 (0.70)
Organization & Elaboration	35.45 (12.09)	47.43 (22.05)	26.30 (15.86)	40.60 (14.99)	44.45 (17.63)
Monitoring	0.73 (1.35)	0.61 (1.38)	14.00 (7.51)	5.75 (4.74)	4.40 (4.06)
Planning of Regulation	0.00 (0.00)	0.00 (0.00)	5.55 (4.33)	0.10 (0.31)	1.55 (1.88)
Realized Regulation	1.18 (3.72)	0.19 (0.87)	7.05 (8.45)	3.10 (4.81)	7.60 (6.59)

To answer our research questions, we computed a series of a priori contrasts. Following Rosenthal, Rosnow, and Rubin (2000), such a contrast analysis is the preferred method if a set of theoretically derived predictions is to be tested. We analyzed the learning outcomes in the immediate comprehension test, in the delayed retention test, and the applied learning activities in the protocols.

(1) If the results from Berthold et al. (2004) can be replicated in the present experiment, the availability of cognitive prompts (cognitive prompts condition), just like the combination of cognitive and metacognitive prompts (mixed prompts without planning-of-regulation prompts), should

lead to an increased knowledge acquisition as compared with the no prompts condition. This prediction was represented by the following contrast: no prompts:-2, cognitive prompts:1, mixed prompts without planning-of-regulation prompts:1. The contrast was significant for the direct comprehension test, $F(2, 60) = 3.70$, $p = .009$, Cohen's $f = 0.35$ (medium to large effect), and for the delayed retention test, $F(2, 59) = 2.99$, $p = .018$, $f = 0.32$ (medium effect). Hence, the results from Berthold et al. were replicated indeed. When the students wrote their learning protocols, either with the help of cognitive or cognitive and metacognitive prompts, they reached a higher level of comprehension and retention as the control group.

(2) Our second research question investigated whether metacognitive activities alone would unfold its potential to improve learning success provided that the experimental setting allowed for the realization of regulation activities. Hence, it was assumed – in contrast to the Berthold et al. (2004) study – that the students who received metacognitive prompts would outperform the students in the no prompts condition. This hypothesis was represented by the following contrast: no prompts:-1, metacognitive prompts:1. The contrast was statistically significant for the direct comprehension test, $F(1, 40) = 6.88$, $p = .012$, $f = 0.42$ (large effect), and for the delayed retention test, $F(1, 39) = 5.12$, $p = .029$, $f = 0.36$ (medium to large effect). Metacognitive prompts clearly fostered learning when the experimental setting allowed for the realization of regulation activities, for example, when the students were given the opportunity to revise their learning protocol and to resolve their comprehension problems with the help of the lecture text.

(3) According to the third hypothesis, the combination of cognitive and metacognitive prompts including planning-of-regulation prompts should yield the highest learning success of all conditions because this mixture of prompts encouraged the students to engage in all three essential sub-processes involved in self-regulated learning. This prediction was represented by the following contrast: no prompts:-1, cognitive prompts:-1, metacognitive prompts:-1, mixed prompts without planning-of-regulation prompts:-1, mixed prompts including planning-of-regulation prompts:4. The test of this contrast was significant both for the immediate comprehension test, $F(4, 98) = 4.44$, $p = .006$, $f = 0.43$ (large effect), and also for the delayed retention test, $F(4, 97) = 4.26$, $p = .003$, $f = 0.42$ (large effect). Hence, students' performance in the comprehension and retention test was highest when the prompts they received for writing their learning protocol stimulated all three essential sub-processes involved in self-regulated learning.

(4) The fourth research question investigated whether mixed prompts including planning-of-regulation prompts would lead to higher learning outcomes than mixed prompts without planning-of-regulation prompts. To answer this question, we compared the *mixed prompts without planning-of-regulation prompts condition* with the *mixed prompts including planning-of-regulation prompts condition.* This contrast, however, failed to reach the conventional 5%-level of statistical significance in the immediate comprehension test, $F(1, 38) = 2.97$, $p = .093.$, $f = 0.29$ (medium effect). Nevertheless, in line with our predictions, it was statistically significant in the delayed retention test, $F(1, 38) = 5.30$, $p = .027$, $f = 0.37$ (medium to large effect). Hence, providing students with planning-of-regulation prompts, in addition to cognitive and monitoring prompts, proved to be particularly beneficial to learning in the long run in regards to sustained retention of the acquired knowledge.

Learning Activities in the Protocols

In order to investigate whether the different combinations of prompts elicited the corresponding learning activities, we computed a further series of a priori contrasts.

(5) To analyze whether organizational and elaborative prompts did indeed result in more cognitive activities in the corresponding prompted groups, the following contrast was computed: no prompts:-3, cognitive prompts:2, metacognitive prompts:-3, mixed prompts without planning-of-regulation prompts:2, mixed prompts including planning-of-regulation prompts:2. The contrast was statistically significant, $F(4, 98) = 4.98$, $p = .001$, $f = 0.45$ (large effect). Hence, cognitive prompts were shown to be effective in increasing cognitive learning activities while writing.

(6) In order to examine whether monitoring prompts increased corresponding activities in groups who received those prompts, we computed the following contrast: no prompts:-3, cognitive prompts:-3, metacognitive prompts:2, mixed prompts without planning-of-regulation prompts:2, mixed prompts including planning-of-regulation prompts:2. The test of this contrast was significant $F(4, 98) = 31.21$, $p = .001$, $f = 1.13$ (large effect). Monitoring prompts also turned out to be successful in promoting monitoring activities in learning protocols.

(7) To answer the question whether students demonstrated more planed regulation in the first draft of their learning protocol when given planning-of-regulation prompts and thus realizing more effective regulation activities in the second draft, we compared the groups who received planning-of-regulation prompts with those groups who did not receive those prompts. This question was represented by the following contrast: no prompts:-2, cognitive prompts:-2, metacognitive prompts:3, mixed prompts without planning-of-regulation prompts:-2, mixed prompts including planning-of-regulation prompts:3. This contrast reached statistical significance both for planning of regulation in the first version, $F(4, 98) = 26.65$, $p = .001$, $f = 1.04$ (large effect), and the realized cognitive regulation activities in the second version, $F(4, 98) = 7.81$, $p = .001$, $f = 0.57$ (large effect). The planning-of-regulation prompts increased planning activities in the first draft of the learning protocol and resulted in a higher degree of implemented regulation activities in the final version. In summary it can be ascertained that the manipulation check was succesful in demonstrating that prompts are an appropriate method to support students who are applying beneficial learning activities.

Discussion

The experiment presented in this paper successfully replicated results found in a previous study (Berthold et al., 2004). Supporting the writing of a learning protocol by means of cognitive or a combination of cognitive and metacognitive prompts fostered students' knowledge acquisition both on comprehension and retention measures. The prompts helped the students represent the learning contents in a more productive manner which enabled them to encode more and to better retain new information. In contrast to the results of Berthold et al., the present study further demonstrated that metacognitive prompts alone improved learning outcomes. Metacognitive prompts in our study seemed to prevent students from being caught by an illusion of understanding (Chi et al., 1994). In line with findings concerning cognitive skill acquisition (VanLehn et al, 2003), detecting impasses through monitoring appeared to be beneficial to learning. Furthermore, it was unequivocally a requirement to provide students with a better opportunity to engage in regulation activities. Accordingly, when the students detected a comprehension problem during the monitoring of their cognitive learning processes, they had the chance to realize concrete regulation activities, such as reading a specific passage in the lecture text that helped them solve their comprehension problem. Thus, one major implication of our study is the importance of ensuring students the opportunity to accomplish regulation activities in a learning environment. Simply offering the opportunity to engage in those activities, however, evidently did not result in the highest knowledge acquisition. Rather, our results suggest that it was particularly beneficial to explicitly prompt the students to plan regulation activities. Learning success was highest – especially with regard to the achieved level of retention – when students received prompts for writing their learning protocol that triggered all three essential sub-processes involved in self-regulated learning: (1) organization and elaboration activities, (2) monitoring of one's comprehension and (3) planning of regulation (cf. Figure 1). Finally, the content analyses of the learning protocols suggested that prompts are a profitable and very effective method to support students in applying beneficial cognitive and metacognitive learning activities.

Together, the results are in line with a cyclical model of self-regulated learning as it has been proposed, for example, by Zimmerman (1999). They provide empirical support for the self-regulation view of writing-to-learn (Bangert-Drowns et al., 2004) that emphasizes the important contribution of metacognitive activities within the learning process. In contrast to the strong text view of writing-to-learn (e.g., Emig, 1977), the self-regulation view assumes that writing as such does not necessarily entail learning. Rather, writing can function for students as a medium that facilitates the application of beneficial cognitive and metacognitive learning activities. Our results suggest that students are actually able to take part in these desirable learning activities when writing a learning protocol. However, they should be explicitly prompted to do so.

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