Enhancing Self-Regulated Learning: Immediate and Follow-up Effects of Cognitive Prompts

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Abstract

The need to identify methods to support self-regulated learning has raised the interest of researchers in recent years. Cognitive prompts are considered very promising instructional tools for developing self-regulatory abilities. The present study aims to investigate the usefulness of several types of cognitive prompts in activating learning strategies for studying an educationally relevant content by psychology students. Two empirical investigations were conducted in a realistic learning environment to test an instructional strategy which integrates cognitive prompts. The first experiment tested the effectiveness of prompts to stimulate deep and shallow processing, measuring immediate learning effects. The second experiment focused on long-term effects of the strategy. The findings indicate that prompts activating deep learning strategies resulted in a slightly improvement in students' performance, but this enhancing effect diminished over time. Cognitive prompts encouraging a deep learning approach can support the comprehension of complex content in a psychology course. Future research is suggested to identify conditions that facilitate long-lasting learning effects. Cognitive prompts may be an effective method for teaching psychology to support students' efforts to understand a complex content. For enhancing the long-term impact of the method, teachers should explore other learning strategies.

Keywords: self-regulated learning, cognitive prompts, learning strategies, deep learning

Introduction

Self-regulated learning (SRL) is one of the most valued aims of higher education. The ability to learn autonomously deeply and reflectively is a crucial educational competence and is considered a key skill in all learning environments. The need to identify the most diverse methods to support and promote SRL skills has raised the interest of researchers in recent years. However, many facts still remain unknown regarding which particular

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aspect of SRL interventions has a more significant positive impact on academic performance. Regarding this issue, the literature revealed that cognitive prompts are very promising instructional tools for guiding the self-regulatory effort of learners. Based on these findings, the present study focuses on the role of cognitive prompts in activating and maintaining SRL strategies in a realistic learning environment.

SRL and cognitive prompts

SRL has been conceptualised differently in various approaches and theoretical models, but there is a broad agreement regarding the fundamental assumptions of SRL. A self-regulated learner can perform activities that directly contribute to learning (e.g., memorising or organising information). Moreover, they set learning goals, plan, monitor and adjust their own learning process. Therefore, self-regulated learners are able to use a variety of cognitive and metacognitive learning strategies in order to regulate their learning.

Many students, however, experience numerous difficulties in adequately self-regulating their own learning in various instructional contexts (Engelmann et al., 2021). These students lack a variety of self-regulatory skills or, even if they possess them, they apply them only sporadically, and these difficulties negatively affect their learning performance.

However, there are several interventional approaches available to successfully teaching SRL skills. One of the ways promoted as an instructional strategy for supporting learners' self-regulation efforts is the provision of scaffolds. These are tools that support the learning process and help learners acquire higher levels of understanding beyond their existing abilities (Simons & Klein, 2007). A special category of scaffolds are cognitive prompts. There is a large and consistent body of research demonstrating the effectiveness of cognitive prompts as instructional tools to support students to self-regulate their learning and thus achieve increased learning performance (Endres et al., 2017; Glogger et al., 2013).

Cognitive prompts can be simple questions, incomplete sentences, performance instructions, or pictures and graphics presented to learners during the learning process, so as to induce and stimulate cognitive activities (Bannert, 2009). In teaching activities, prompts can be integrated successfully into various instructional methods - journal writing, reading, problem solving, reflective writing (Endres et al., 2017; Glogger et.al., 2013; Nückles et al., 2020). Research in the field has demonstrated the usefulness of prompts in facilitating learning with different materials and learning contexts – in an introductory psychology course (Berthold et al., 2007), in a biology introductory course (Smith et al., 2010), in mathematics and biology lessons (Glogger et al., 2013).

Despite the advantages of using prompts, there are few studies focusing on their role in activating the learning strategies that students use in studying scientific texts. The understanding of scientific content is closely related to the types of learning strategies that are used, as they are crucial for facilitating retention and deep understanding. When studying a text, generating inferences, coherently relating ideas, constructing connections between new and prior knowledge depends on the type and quality of learning strategies used to process that content (Leopold & Leutner, 2015).

A deeper understanding of how prompts can be organised and structured to stimulate active and deep learning strategies is therefore extremely important in supporting the efficient study of scientific content. In addition, if we want to support the transfer of learning strategies into everyday learning routine, it is necessary to investigate the effects of prompts in natural learning conditions not only in laboratory studies.

Prompts and learning strategies

There is a wide variety of prompts and conditions under which prompts can be presented. Theoretical models of SRL provide the foundation for the design of prompts, so prompts vary according to the dimensions of SRL they aim to develop (cognitive, metacognitive, motivational, cooperative). In the present study, the analysis focuses on prompts that support cognitive aspects of SRL learning by activating cognitive learning strategies. We focused on the cognitive components because they are most directly related to learning outcomes and performance.

Learning strategies are considered key components in the cognitive regulation of learning (McDaniel et al., 2021). Typically, they are classified into cognitive and metacognitive learning strategies (Weinstein & Mayer, 1983). Cognitive strategies, which are the main focus of the present study, involve direct processing of learning materials. Studies indicates that cognitive learning strategies differ in their potential to activate deep versus surface processing of text contents (Leopold & Leutner, 2015). Surface-level processing is focused on the accumulation and reproduction of factual knowledge, without promoting the understanding of relationships between knowledge and its connection to prior knowledge. In contrast, deep level means in-depth processing and understanding of content.

Strategies such as elaboration and organisation are considered to facilitate in-depth processing of information. By focusing on building and integrating information, elaboration and organisation strategies ensure coherence and structure in the content learned, thus facilitating deeper understanding. The in-depth approach is associated with high-quality learning outcomes and successful studying.

Repetition and rote learning are typical strategies illustrating a surface processing. They focus the learner's attention only on the surface aspects of the material to be learned (e.g., number of paragraphs, position of a particular concept on the page) and not on grasping its meaning.

Quantity and quality of strategies

A challenging topic in studies of learning strategies concerns two important aspects of their application—quantity and quality. These aspects have a significant impact on the evaluation of SRL and deep understanding. Studies (Glogger et.al., 2013; Leopold & Leutner, 2015) indicate that learning outcomes are affected not only by the frequency/quantity of the utilised strategies but, more importantly, by their quality or the extent to which they perform their specific function (Leopold & Leutner, 2015). Thus, strategic learning behaviour means both using the right strategy with a certain frequency in relation to the intended purpose and applying it at a high-quality level. Consequently, considering the quality of the learning strategies used and measuring the differences in the quality of their application relative to their specific purpose can be an important factor in explaining learning outcomes.

Objectives and hypotheses

The present study aims to investigate the usefulness of various types of cognitive prompts in supporting SRL in a realistic learning environment. More exactly, we designed an ad hoc instructional strategy by integrating cognitive prompts into an educationally relevant complex content in a compulsory psychology course. We hypothesized that cognitive prompts activating deep learning strategies will generate better results than cognitive prompts activating shallow learning strategies at a real academic exam. This work reports on two experiments — Experiment A directly assesses our hypothesis and Experiment B evaluates the temporal dynamics of the effect that we observed in Experiment A. More specifically, in experiment A and B, we tested the immediate and long-term impact of cognitive prompts in supporting self–regulated learning in an ecological educational context.

Experiment A

Objective

The first study aims to investigate the short-term impact of cognitive prompts in supporting learning strategies.

Methods

Design and participants

The intervention was conducted in a real-world educational setting and a quasi-experimental design was used. The participants were 125 students, (73 female and 51 male). enrolled in a mandatory Psychology course.

Instruments and materials

The learning content consisted of a specific chapter ("Memory") from a coursebook which students could access via the online platform used by the university. The learning content was designed in two different versions (in Appendix): a deep level version and a surface level version. The deep level version was developed by integrating in the content of the textbook several prompts designed to activate deep learning strategies (elaboration, organisation). In contrast, the surface level version integrated the same number of prompts in the same content sections but was focused on activating surface learning strategies (rehearsal). The procedures used for developing these two different versions were similar. The first step was the formulation of instructional learning outcomes in accordance with a revised version of Bloom's taxonomy (Anderson & Krathwohl, 2001). The second step consisted in the elaboration of prompts. Specific prompts were developed, in connection with the agreed upon learning outcomes. The prompts were designed based on the model proposed by Glogger et al. (2013).

A multiple choice test for the final exam was used to assess the potential of our prompting learning strategies to support learning. A bank of low- and high-level multiple-choice items was developed in accordance and aligned with course learning outcomes.

Procedure

Students were instructed to study the prompted content from their online textbooks and to respond to the prompts. The study task lasted 3 weeks and was integrated into regular teaching and learning activities. At the end of the study period (next week), students' learning performances were measured with a multiple choice test. This test was a part of students' requirements for the course.

Rating of student responses to the study tasks

The categories of learning strategies that we expect to be activated by deep version prompts were organisation (e.g., identifying the most important ideas, connecting important ideas) and elaboration (explaining, linking new information to previous topics or to previous personal experiences, challenging the learning content, exemplification). In the surface version, prompts were used to activate mostly rehearsal strategies (reviewing main principles, reproducing definitions).

The quality of learning strategies was assessed by surveying students' responses to prompts incorporated in the learning content. The quality of each student response was interpreted as an indicator of the quality of having applied the learning strategy activated by a prompt. The quality of rehearsal, organisation and elaboration was rated on a 4-point scale ranging from 0 (low quality) to 1 (high quality). The interval between the minimum score and the maximum score that could be obtained by a participant was between 0 and 17 points (17 prompts of 1 maximum point/prompt). We considered that a participant who obtained a total strategy score above the mean (8,5 points) effectively employed quality learning strategies in their study process. These scores were considered for further analysis and the ones below the mean were excluded from the analysis. This quality check was carried out in order to ensure that only the quality strategies would be considered in examining the students' learning performances.

Results and discussion

Data were collected from a total of 125 participants, divided into two groups: the Deep Processing group (DP; n = 61, 57 females, mage = 19.78 years, sd = 1.88) and the Shallow Processing group (SP; n = 66, 61 females, mage = 19.56 years, sd = 1.89). After applying our quality checks (see the methods section above), we included in analysis 37 data sets of the DP group and 61 datasets of the SP group. Data used to generate the analyses presented in the paper are accessible via a publicly available data repository https://osf.io/2n9ac/?view_only=6f9c404880e34d41ab8e85713404b5c7.

Preliminary data screening of the valid data sets (i.e., data sets passing our quality checks) showed that Levene's test was not statistically significant (F = 0.95, p = .33), indicating that the assumption of homogeneity of variance was met. However, a statistically significant Shapiro-Wilk test for the Shallow Processing group (p = .004) indicated that this data violates the assumption of normality. Consequently, instead of using a parametric paired-samples t test, a Mann-Whitney U test was performed to evaluate whether a deep level of processing results in better performance on a real-life academic exam compared to a shallow level of processing. The test provided marginally significant evidence to argue that the DP group scored higher than the SP group, U = 1279.5, p = .06. These results indicate that cognitive prompts are indeed an effective method to foster deep learning. Prompts function as strategy activators and this could support the application of productive learning strategies which, in turn, influences students' learning outcomes. These results are in accordance with existing studies regarding the prompts' effectiveness in optimising various instructional methods and in supporting learning (Nückles et al., 2020; (Roelle et al., 2014). More than this, the present results showed that some types of cognitive prompts are more reliable than other cognitive prompts in activating deep processing strategies, which ultimately leads to better learning outcomes. The results reveal a marginally significant difference between the deep processing group and the surface processing group. It is important to be mentioned here that the present study was conducted in a realistic educational context. In this setting, various variables could not be rigorously controlled as in a lab-based context, for example, other learning strategies could be used by participants with the prompting-based learning strategies alike and to diminish or to enhance the level of processing of the content. Therefore, these results are encouraging, suggesting that an instructional strategy that uses specific prompts aimed to activate deep learning strategies functions marginally better than a strategy based on prompts activating surface strategies and better than any other learning strategies that might be employed by participants to study in a university course. Whereas, prompting studies are usually conducted in artificial learning conditions, there are studies which confirm the potential of prompts for supporting deep learning and cognitive aspects of SRL in real-life educational settings (Baars et al., 2022).

Experiment B

Based on the results obtained in the first experiment, we consider that our prompting strategy was quite effective in a realistic learning context. The following research question that naturally resulted in assessing an educationally relevant context was aimed at gauging the stability of the gained effect over time. Therefore, the authors decided to design the second experiment with a 5 months follow-up phase (next semester) after the first evaluation phase of the learning process. In this way, we tested not only the immediate but the long-term impact of the developed prompting strategy on students' learning performance in a psychology course, as well.

Objective

This experiment aims to assess the temporal trajectory of the marginally significant advantage exhibited by the DP group compared to the SP group in learning a scientific content in a psychology course. We assess whether this learning advantage amplifies, attenuates or maintains over time.

Methods

Design and participants

To pursue our objective, we extended the design presented in experiment 1 by administering a 5 months follow up for both the DP and SP groups. Sixty-three out of the previous 125 participants decided to enrol in this second phase of the study.

Instruments and materials

The instrument used in the second experiment consisted of a follow-up multiple choice test. The follow-up test was an equivalent version of the final test used in the first experiment for assessing students' learning performances.

Procedure

The follow-up test was administered 5 months after the first evaluation phase. In the interval between the final test and the follow-up test no participants were involved in formal learning activities in the present study.

Results and discussion

Preliminary screening of the collected data showed that the Levene's test was not statistically significant ($F = 0.01$, $p = .91$), indicating that the assumption of homogeneity of variance was met. Consequently, statistically non-significant Shapiro-Wilk tests for the DP group ($p = .16$) and for the SP group ($p = .19$) indicated that these data satisfy the assumption of normality. Consequently, a parametric paired-samples t test was performed to evaluate whether the DP group scored higher than the SP group at a 6-months follow-up after the post-test exam. Paradoxically, the DP group scored lower ($m = 4.46$, $sd = 2.02$) than the SP group ($m = 4.52$, $sd = 1.93$). However, the difference is not statistically significant $t(47) = -0.11$, $p = .92$, Cohen's $d = -0.03$, 95% CI = [-1.2 – 1.08]. Based on this finding, it may seem that the advantage of the DP group lasts less than six months. However, it is important to note that null hypothesis significance testing (NHST) cannot support this interpretation. As Altman & Bland (1995) argue, the absence of evidence for an effect does not prove or disprove its existence. NHST procedures do not directly compare support for the alternative hypothesis with support for the null hypothesis. Thus, it would be useful to determine if our hypothesis is actually false, suggesting that cognitive prompts triggering deeper levels of processing do not have a lasting effect on academic test performance. Accordingly, Bayesian inference has gained traction in psychological research. This approach provides a continuous measure of confidence in an alternative hypothesis relative to a null hypothesis (Lakens et al., 2020). Thus, a description of our rationale for crafting a Bayesian test for this hypothesis is desirable.

In a Bayesian test, the null hypothesis can be confirmed but, in order to do so, one must first specify a distribution of the effect sizes that one is looking for. This step is best informed by prior relevant research. However, in our case, there is little work as such already available. Therefore, we resorted to modelling our distribution of priors by employing the room to move heuristically (Dienes, 2019). Next, we contextualised our implementation. We began by deriving the maximum plausible difference between the SP (shallow processing) and DP (deep processing) groups. Using this rough maximum value, we then modelled our distribution of priors.

According to the room to move heuristic if cognitive prompts targeting deep processing result in longer-lasting memory traces compared to prompts targeting shallow processing, we would expect the mean performance of the DP group to fall between the mean of the SP group and the maximum extreme of the measurement scale. In our case, the maximum expected performance of the DP group cannot exceed 4.48 points more than the performance of the SP group (9, the maximum scale value, minus 4.52, the mean of the SP group). However, we lack grounds to assert that this is the exact expected value. In fact, it is highly implausible for the differences between the two groups to be so consistent. To address this, we proceeded to model our prior distribution in a conservative manner. Thus, we employed only a half of the normal distribution with a mean of 0 (indicating a higher likelihood of finding no difference between the groups) and a standard deviation of half the maximum theoretical difference between the two groups. Considering the above, the corresponding Bayes factor for our test is BH(0; 2.26) = 0.25. This factor can be interpreted as indicating that our data is 0.25 times more likely to be valid under our hypothesis than under the null model. Following conventions, any Bayes value between 0 and 0.33 can be regarded as confirming the null hypothesis.

These results show that the effects induced by cognitive prompts in the deep level processing group, in the previous phase (post-test phase), are not stable over time. Comparing the follow–up scores of the deep processing group with those obtained by the shallow processing group there is no significant difference between the two groups. These findings indicate that prompting strategies for activating deep learning would not be sufficient for preserving a learning advantage in the long run. Even though the learning strategies employed by the DP group were high quality learning strategies, they do not have consistent effects over a long period of time. These results manage to confirm other studies, conducted in laboratory conditions, that used prompting learning strategies and indicate that cognitive prompts are less powerful pertaining to their long-term effect on knowledge transfer than metacognitive or motivational prompts (Daumiller & Dresel, 2019; Schumacher & Ifenthaler, 2021).

At the same time, we must take into consideration that participants were involved in a 3 weeks study period, but they were not exposed to the learned content in the period from the administration of the post-test to the follow-up (5 months). It seems that retention of the content over longer periods of time requires more learning processes to be involved (e.g., memory and fluency), than understanding and sense making which are supported by our prompting strategy. Studies developed in laboratory conditions (Ryan & Koppenhofer, 2022) show similar results regarding the limits of self-explanations to induce the long term-retention. A very reasonable explanation to this is that different learning processes are supported by different instructional principles (Koedinger et al., 2012). For example, understanding could be facilitated by self-explanation (Chi et al., 1994), whereas memory and fluency could be increased by spacing and retesting. Even though that in our prompting strategy a variety of instructional principles (organization, elaboration, explanation) were involved, these principles were mainly focused on understanding and sense-making.

Therefore, we consider that one possibility to increase the impact of cognitive prompts over time is to complement the prompting strategy with other learning strategies, such as practice testing and distributed practice. At the same time, taking into account the self-regulation literature, and important direction might be the use of cognitive prompts alongside other categories of prompts (metacognitive prompts, motivational prompts). Future research should be guided by the need to clarify the conditions that facilitate long-lasting learning effects.

Conclusions

The main purpose of the present study was to explore the potential of cognitive prompts to regulate the learning process of students enrolled in a compulsory psychology course. Though any conclusions should be approached with caution due to the marginal statistical significance of the data, the results suggest that prompting strategy supports learning of a complex scientific content but failed to confirm its long-term retention. More research is needed to advance our understanding of the role of cognitive prompts in supporting long –term retention.

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Appendix

Example of Learning Material and Cognitive Prompts of Shallow and Deep Processing Groups

The following section contains an example of a learning content extracted from a cognitive psychology manual. This text was presented to participants in both the Shallow and Deep Processing groups:

"6. 4. Episodic memory and semantic memory

6. 4. 1. The main theoretical-experimental results

A clear distinction between "episodic memory" and "semantic memory" was proposed by E. Tulving (1983, 1984), the difference later becoming accepted within cognitive psychology. Episodic memory refers to the memory of autobiographic events: when and where we lived a certain event. For example, memories of last New Year's Eve, the first day of school, what we did yesterday, how we spent our holidays, etc., all of this fit within the episodic memory category. This type of memory contains a series of information associated with specific temporal and spatial frames. It is vital for building our own identity, the identity of the self.

Semantic memory (often called "conceptual memory") refers to the general knowledge which we have about the environment in which we live. For example, we know that … is an important academic center, the chemical formula for water is H2O, that it was Shakespeare who wrote Hamlet, that the wine is an alcoholic beverage, etc. the knowledge within semantic memory is not (usually) associated with a specific temporal and spatial context. We do not know where and when we first heard the chemical formula of water, when and where we read that the author of Hamlet was Shakespeare etc. The great majority of the knowledge that books and courses offer us address semantic or conceptual memory. However, the experiences that we had along our lives represent the content of episodic memory."

After reading the text, participants responded to several prompts depending on the group they were allocated to. For instance, in Deep Processing group, some cognitive prompts were: "Explain the differences between episodic memory and semantic memory.", or "Think about and give your own example for each type of memory (episodic and semantic)". Some examples of cognitive prompts in Shallow Processing group were: "Define episodic memory", "Define semantic memory". All participants were then asked to write down their answers.