Computers in Human Behavior 52 (2015) 293–306

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Short- and long-term effects of students' self-directed metacognitive prompts on navigation behavior and learning performance

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ARTICLE INFO

Article history:

Keywords:
Metacognition
Metacognitive skills
Metacognitive prompts
Self-directed prompts
Knowledge acquisition
Long-term effects

ABSTRACT

This study seeks to promote learning in computer-based learning environments utilizing students' self-directed metacognitive prompts. Such prompts are based on the idea of instructing students to design their own metacognitive scaffolds and learn with them afterward. In a pre-post experimental design, students in the experimental group ($n = 35$) were instructed to configure their own metacognitive prompts before learning whereas students in the control group ($n = 35$) learned without prompts. Log file analysis of navigation behavior indicates that students who learned with their individually designed, self-directed prompts visited relevant webpages significantly more often and spent a longer time on them compared with students in the control group. Moreover, participants in the experimental group attained better transfer performance immediately after learning. The long-term effect in transfer performance was even greater in a follow-up learning session conducted after three weeks without any instructional support in either group. These results are consistent with theories of metacognition and self-regulated learning and indicate that self-directed prompts can lead to sustainable effects.

1. Introduction

As current research in learning and instruction demonstrates, learners often have difficulties in spontaneously applying adequate metacognitive activities during learning, thereby leading to lower learning outcomes (Azevedo, 2009; Azevedo, Johnson, Chauncey, & Graesser, 2011; Bannert & Mengelkamp, 2013; Greene, Dellinger, Tüysüzoglu, & Costa, 2013; Winne & Hadwin, 2008; Zimmerman, 2008). Hence, the aim of our study is to foster learning and learning outcomes by metacognitive instructions and scaffolds. One possibility in reaching this goal is to present metacognitive prompts during learning in Computer-Based Learning Environments (CBLEs) because such prompts direct learnerś attention to their own thoughts and to monitoring their own learning activities during learning. We assume that such reflective prompts allow activation of metacognitive knowledge and skills that support learning and transfer (Azevedo & Witherspoon, 2009; Bannert, 2009; Lin, 2001).

This assumption was confirmed in a series of experiments in which metacognitive and self-regulated learning skills were prompted during hypermedia learning (e.g., Bannert & Mengelkamp, 2013; Bannert & Reimann, 2011). As described in more detailed below, results confirm the positive effects of all investigated types of metacognitive prompts on learning behavior and on transfer performance, which was assessed immediately after learning. However, no long-term effects were investigated, and in general, there is less research on the follow-up effects of metacognitive scaffolds and prompts. In addition to the positive (short-term) effects on learning behavior and transfer performance, it was also shown that in all experiments, only half of the participants in the experimental groups addressed metacognitive support in an optimal manner. Consequently, further research is required to investigate how to increase students' compliance with the provided instructional support (e.g., Clarebout & Elen, 2006; Schworm & Gruber, 2012) and to analyze the short-term as well as the long-term effects of metacognitive scaffolds and prompts, such as improved navigation behavior and better learning outcomes.

Therefore, based on recent theories of metacognition and self-regulated learning (e.g., Azevedo, 2009; Hadwin & Oshige, 2011; Pintrich, 2000; Veenman, 2011; Winne & Hadwin, 2008, 2013; Zimmerman, 2008; Zimmerman & Moylan, 2009), we have conceptualized a new type of metacognitive support: *Students' self-directed metacognitive prompts*. These prompts are based on the idea of instructing students to design their own metacognitive

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http://dx.doi.org/10.1016/j.chb.2015.05.038
0747-5632/

prompts and to learn with them afterward. For example, students may arrange the content of prompts and decide at what points they should be provided during learning. Because of their self-involvement in designing the prompts, students' compliance with metacognitive prompts should be enhanced and lead to better learning behavior and increased learning performance. Experiencing the benefits of better learning behavior should further provoke students to show better learning behavior in other learning situations (i.e., in a follow-up session). Overall, the aim of this study is to investigate the short- and long-term effects of self-directed metacognitive prompts, which will be described in more detail below.

2. Research on metacognition and metacognitive instruction

Metacognition refers to different aspects and components of cognition. Most researchers agree on the broad definition of *metacognition* as cognition about cognition (Flavell, 1981; Nelson & Narens, 1990) and to the general function of metacognition as regulating one's own cognition. Nelson and Narens (1990) differentiate cognition into an object-level and a meta-level. On the meta-level, students build a mental representation of the object-level, that is, the cognitions of the person her/himself. Whereas *monitoring* is the process leading to such a mental representation of one's own cognition, *control* refers to processes that alter the cognition at the object-level. In addition to this distinction between the object- and meta-levels of cognition, metacognition can be further divided into the components of metacognitive knowledge, metacognitive experiences, and metacognitive skills (e.g., Brown, 1978; Efklides, 2008; Ertmer & Newby, 1996; Pintrich, Wolters, & Baxter, 2000; Schraw, 2001; Veenman, 2005). Metacognitive prompts focus on the activation of metacognitive skills. Thus, we will next elaborate more on metacognitive skills.

Metacognitive skills refer to the self-regulation activities occurring in learning and problem solving (Brown, 1978; Veenman, 2005) such as processes of planning, orientation, goal setting, learning strategy selection and use, monitoring the execution of strategies, checking, and reflection (e.g., Azevedo, 2009; Pintrich et al., 2000; Veenman, 2007). The role of metacognitive skills is described in more detail in various theories of metacognition and self-regulated learning (e.g., Azevedo, 2009; Hadwin & Oshige, 2011; Pintrich, 2000; Veenman, 2007, 2011; Winne & Hadwin, 2008, 2013; Zimmerman, 2008; Zimmerman & Moylan, 2009). For example, Zimmerman (2008) described a cyclical model of three interactive phases. In the *forethought phase*, students analyze a task (task analysis), thereby setting goals (goal setting) and planning their strategies for proceeding (strategic planning). Further, self-motivational beliefs such as self-efficacy, outcome expectations, task interest, and goal orientation play a role in this phase. In the *performance phase*, students control their learning using different strategies such as self-instruction, imagery, and time management. Self-observations (e.g., metacognitive monitoring and self-recording) thereby influence the use of these strategies and allow students to adapt their strategies during the learning process. Finally, the *self-reflection phase* contains self-judgments and self-reactions, the processes that follow the performance phase but further influence the following forethought phase. Students may render self-evaluations and causal attributions of their learning outcomes that affect, for example, their outcome expectations in future forethought phases. As current research in learning and instruction shows, learners often do not spontaneously apply such metacognitive skills during learning, leading to lower learning performance (Azevedo, 2009; Azevedo, Johnson, Chauncey, & Graesser, 2011; Bannert & Mengelkamp, 2013; Greene et al., 2013; Winne & Hadwin, 2008; Zimmerman, 2008). Hence, our research focuses on the support of students' metacognitive skills by adequate metacognitive support.

Metacognitive support is realized by systematic instruction to increase students' learning competence; not only their learning behavior but also their learning performance should be significantly improved (Bannert, 2007; Hasselhorn & Hager, 1998). Research shows that effective metacognitive instruction is *integrated* into the learning domain (embedding principle). Moreover, the application and usefulness of instructed metacognitive strategies are *explained* in detail (explanation principle), and *sufficient practice* (practice principle) is provided to implement and automate the metacognitive activities (e.g., Veenman, 2007).

Our research seeks to improve learning in CBLEs by providing such appropriate metacognitive support that leads not only to short-, but also to long-term effects, by allowing students to create self-directed metacognitive prompts for learning. We assume that especially technology-enhanced learning renders students' reflective behavior regarding their own manner of learning more striking (Azevedo, 2005; Azevedo & Aleven, 2013; Lin, 2001; Lin, Hmelo, Kinzer, & Secules, 1999). For instance, students must constantly make decisions regarding what to do and where to go next. Further, they must constantly evaluate how the information retrieved is related to their actual learning goal (Schnotz, 1998). Research reveals that many students do not spontaneously exhibit such strategic and metacognitive learning behavior (e.g., Azevedo, 2009; Azevedo, Johnson, Chauncey, & Graesser, 2011; Bannert & Mengelkamp, 2013; Simons & De Jong, 1992; Winne & Hadwin, 2008; Zimmerman, 2008), which leads to the general purpose of our research: The aim is to provide metacognitive support for learning through metacognitive prompts that produce short- and long-term effects in respect to improved navigation behavior and learning performance.

2.1. Metacognitive prompting

Generally *prompts* are defined as recall and/or performance aids, which could vary from general questions (e.g., 'What are the reasons for your decision?' or 'What is your learning goal?') to explicit execution instructions (e.g., 'Read the introduction first', Bannert, 2009). The underlying assumption is that students have previously acquired the concepts and/or processes but do not recall or execute them spontaneously in a specific learning situation (so-called *production deficit*, Veenman, 2007; Veenman, Van Hout-Wolters, & Afflerbach, 2006). More specifically, *instructional prompts* are scaffolds to induce and stimulate students' cognitive, metacognitive, motivational, volitional and/or cooperative activities during learning (Bannert, 2009). *Metacognitive prompts* support students' monitoring and control of their learning processes by inducing metacognitive and regulative activities that are described in models of self-regulated learning (SRL; e.g., Zimmerman, 2008; Zimmerman & Moylan, 2009) such as orientation, goal specification, planning, monitoring and control, and evaluation strategies (Bannert, 2007; Veenman, 1993), e.g., 'Is this in line with my learning plan?'.

In the last two decades, several prompting studies have been conducted showing positive short-term effects of this metacognitive support (e.g., Azevedo, Cromley, Moos, Greene, & Winters, 2011; Ge, 2013; Johnson, Azevedo, & D'Mello, 2011; Kramarsky & Michalsky, 2013; Lin & Lehman, 1999; Simons & De Jong, 1992; Veenman, 1993; Winne & Hadwin, 2013), but did not investigate long-term effects. Lin and Lehman (1999) utilized a pop-up window at certain times in a computer-based simulation environment to prompt students to give reasons for their actions when conducting biology experiments. The results showed significantly higher far-transfer performance for the prompted students. Veenman (1993) also prompted students in a computer-based simulation