Monitoring, planning, and self-efficacy during learning with hypermedia: The impact of conceptual scaffolds

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Abstract

Self-report data and think-aloud data from 37 undergraduates were used to examine the impact of conceptual scaffolds on self-efficacy, monitoring, and planning during learning with a commercial hypermedia environment. Participants, randomly assigned to either the No Scaffolding (NS) or Conceptual Scaffolding (CS) condition, used a hypermedia environment for 30 minutes to learn about the circulatory system. Think-aloud data collected during this learning task was used to measure participants' self-regulated learning (SRL) with hypermedia. Additionally, participants completed a self-efficacy questionnaire at three points during the learning task (immediately prior to the 30-minute hypermedia learning task, 10 minutes into the learning task, and 20 minutes into the learning task). Results indicated that participants from both conditions reported higher levels of self-efficacy immediately before the hypermedia learning task, and that they decreased their use of SRL processes related to monitoring as they progressed through the hypermedia learning task. In addition, results also indicated that participants in the CS condition used, on average, more SRL processes related to planning during the hypermedia learning task than participants in the NS condition.

Keywords: self-regulated learning, hypermedia, self-efficacy, motivation, cognitive processes, science, mental models, mixed methodology

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Recently, research has examined processes related to learning with computer-based learning environments (CBLEs), such as hypermedia (e.g., Azevedo, Cromley, Winters, Moos, & Greene, 2005). Hypermedia, which can contain textual information, static diagrams, audio, and digitized video clips, provides visually rich and interactive learning environment. In order to effectively navigate and learn in this flexible, nonlinear learning environment, students need to use certain self-regulatory processes related to *planning* (e.g., prior knowledge activation), *monitoring* (e.g., monitoring emerging understanding), and *strategies* (Azevedo, Guthrie, & Seibert, 2004a; Azevedo, Winters, & Moos, 2004c; Moos & Azevedo, 2006). As such, this line of research has used self-regulated learning (SRL) theory (Pintrich, 2000; Winne 2001; Winne & Hadwin, 1998; Zimmerman, 2001) to examine how students learn with hypermedia (Azevedo et al., 2005). Furthermore, research has begun to examine the relationship between scaffolding and SRL (e.g., Moos & Azevedo, 2006), as well as the temporal sequencing of SRL (Witherspoon et al., 2007) during learning with hypermedia.

Self-regulated learning theory

Research in the field of educational psychology has examined what processes successful students possess, specifically processes related to *monitoring*, *planning*, and *strategy use* (Alexander, 2004; Bransford, Zech, & Schwartz, 1996; Brown, 1990; Pressley, Wharton-McDonald, & Allington, 2001; Shraw, 2006; Shraw & Sinatra, 2004). During the 1970s, research revealed that successful students use monitoring and planning processes that are fundamentally different than their peers who are less academically successful in school. These processes were characterized as having self-regulatory components (Paris & Newman, 1990). The earlier views of self-regulated learning (SRL) focused on isolated learning, while approaches to SRL in the 1980s presented more comprehensive and multifaceted models. These SRL models offered a perspective that viewed students as proactive and strategic learners, as opposed to passive learners in their environment. To explain this proactive, strategic orientation, researchers appealed to social, behavioral, motivational, and cognitive variables in several instructional contexts. These SRL models have evolved over the last twenty years, driven in part by the considerable research examining SRL in academic achievement (see Boekaerts, Pintrich, & Zeidner, 2000; Zimmerman & Schunk, 2001). Recently, research has used SRL theory to examine how students learn with CBLEs, such as hypermedia environments (Azevedo, 2005; Azevedo & Hadwin, 2005; Graesser, McNamara, & VanLehn, 2005; Lajoie & Azevedo, 2006; Quintana, Zhang, & Krajcik, 2005; White & Fredriksen, 2005). However, there are three issues with this line of research. First, while recent literature has advocated collecting SRL data during learning (Azevedo, 2005; Perry, 1998; Winne, 2005; Winne & Perry, 2000; Winne & Jamieson-Noel, 2003; Winne et al., 2005), empirical research examining *when* students use SRL processes during learning with hypermedia is limited. The second issue concerns the need for more empirical research examining *why* students self-regulate their learning. The third issue is related to the mixed results from research that has examined the impact of scaffolds on SRL with hypermedia. These three issues are addressed in the following sections.

Measuring SRL

The first issue is related to the measurement of self-regulatory processes. When designing a methodology to measure *when* students self-regulate their learning with hypermedia, it is necessary to account for the properties of SRL. Winne (1997) and Winne and Perry (2000) proposed that SRL can be viewed as having one of two properties, *aptitude* or *event*. Orientation to either of these properties determines, in part, the methodology used to examine SRL. For example, an aptitude is a relatively enduring trait of an individual, and measurement of this trait can be used to predict future behavior. Furthermore, when SRL is considered an aptitude, it is assumed that a single measurement aggregates a quality of SRL based on multiple events (Winne & Perry, 2000). This assumption suggests an individual's self-perception of his or her metacognitive and/or cognitive processes is an accurate measurement of SRL. These perceptions often are derived from responses to questionnaires, with self-report questionnaires being the most frequently used protocol for measuring SRL as an aptitude (Winne & Perry, 2000).

On the other hand, self-regulation as an event suggests that SRL unfolds within particular contexts (Boekaerts et al., 2000). Perry, VandeKamp, and Mercer (2002) suggested that self-regulatory processes should be examined in *real* time because SRL is an ongoing process that unfolds within particular contexts. Thus, protocols that measure SRL as an event are designed to capture the dynamic nature of SRL and are typically based on an information-processing model of SRL (i.e. Winne, 2001; Winne & Hadwin, 1998). Some recent research has strongly advocated viewing SRL as an event (e.g., Azevedo & Cromley, 2004; Moos & Azevedo, 2006; Witherspoon et al., 2007), and that SRL data collected *during* learning is a more accurate measurement of processes related to SRL (Azevedo, 2005; Perry, 1998; Winne, 2005; Winne & Perry, 2000; Winne & Jamieson-Noel, 2003).

The think aloud protocol offers a process methodology that measures cognitive and metacognitive SRL processes during learning (Azevedo, 2005). The think aloud protocol has been most popular in reading comprehension (see Pressley & Afflerbach, 1995) and has been shown to be a powerful tool in gathering verbal accounts of SRL and mapping out these processes during learning (Chi, Glaser, & Farr, 1988; Ericsson, 2006; Ericsson & Smith, 1991; Azevedo et al., 2005; Moos & Azevedo, 2006; Witherspoon et al., 2007). The think aloud has an extensive history in cognitive psychology and cognitive science (see Ericsson, 2006; Ericsson & Simon, 1994; Feltovich, Ford, & Hoffman, 1997; Newell & Simon, 1972 for an extensive review) in which both concurrent and retrospective think aloud protocols have been used as data sources for cognitive and metacognitive processes (Anderson, 1987). Concurrent think-alouds assume that thought processes are a sequence of states, and that information in a state is relatively stable (Ericsson & Simon, 1994). Consequently, verbalizing thoughts during learning will not disrupt the learning process. However, it is important, “that subjects verbalizing their thoughts while performing a task do *not* describe or explain what they are doing (Ericsson & Simon, 1994, pg. xiii).” If subjects are not asked to reflect, describe, and/or explain their thoughts during learning, but rather are asked to simply verbalize thoughts entering their attention, then it is assumed that the sequence of thoughts will not be disrupted. Empirical evidence has supported this assertion. For example, Deffner (1989), Heydemann (1986), and Rhenius and Heydemann (1984) all found that the think aloud protocol was not related to significant changes in cognitive processes, as reflected in the performance of participants in these studies.

Furthermore, research has used the concurrent think aloud protocol to examine learning processes with hypermedia. For example, Azevedo et al. (2004a) used the think aloud methodology to examine how SRL fostered conceptual understanding of complex systems, while Azevedo et al. (2004b), Moos and Azevedo (2006), and Witherspoon and colleagues (2007) used the think aloud to examine how students plan, monitor, use strategies, and handle task difficulties while learning about a challenging science topic with hypermedia. In sum, the proven capacity of the think-aloud protocol to capture SRL processes in a dynamic learning situation provides support for the use of this protocol (Azevedo, 2005). However, while this line of research has provided rich data on *what* SRL processes students use during learning with hypermedia, this line of research has focused on cognitive and metacognitive processes. Processes related to motivation have received much less empirical attention (Moos & Azevedo, 2006). Empirically examining theoretically grounded motivation constructs will advance the field of SRL with hypermedia. This study attempts to address this issue by empirically examining self-efficacy, a theoretically grounded construct of motivation (Bandura & Schunk, 1981; Holladay & Quiñones, 2003; Shapka & Ferrari, 2003).

Motivation and SRL with hypermedia

As previously highlighted, there is a positive relationship between knowledge development with hypermedia and SRL processes related to cognition and metacognition (Azevedo et al., 2005). However, as suggested by a number of researchers, motivation is also a critical factor in learning with hypermedia (Moos & Azevedo, 2006). Motivation, defined as physiological processes involved in the direction, vigor, and persistence of behavior (Eccles, Wigfield, & Schiefele, 1998; Wigfield & Eccles, 2002), is particularly relevant in learning environments which afford the student some degree of control over the sequencing of information. Hypermedia is such an environment because of its nonlinear nature. However, while research has identified a number of motivational constructs in non-hypermedia environments (see Greene & Ackerman, 1995; Murphy & Alexander, 2000 for extensive reviews), there has been a call for more research that empirically examines theoretically grounded constructs of motivation in the context of learning with hypermedia (Lepper & Woolverton, 2004).

Self-efficacy, a theoretically grounded motivation construct (Murphy & Alexander, 2000), is a particularly valid construct to examine in the context of learning with hypermedia. Self-efficacy, defined as an individual's self-perception of their capability to meet situational demands (Bandura, 1997; Wood & Bandura, 1989), has been routinely shown to be positively related to students' direction, vigor, and persistence of behavior (Bandura, 1997; Eccles, Wigfield, & Schiefele, 1998; Wigfield & Eccles, 2002) in a wide variety of domains (Pajares, 1996; Pintrich & De Groot, 1990; Schunk, 1983, 1984, 1991; Wigfield, Guthrie, & Tonks, 2004; Zimmerman, Bandura, & Martinez-Pons, 1992). However, while self-efficacy has received considerable empirical attention in non-hypermedia environments, the examination of self-efficacy during learning with CBLEs is an emerging area of study (Moos & Azevedo, 2006).

The few studies that have empirically examined self-efficacy during learning with CBLEs have found results similar to non-CBLE environments. In particular, this line of research has found that self-efficacy predicts learning outcomes with such technology environments as simulations (Holladay & Quiñones, 2003; Mitchell, Hopper, & Daniels, 1994). However, hypermedia is a distinct learning environment from simulations because students are often faced with decisions about which information to access when they learn with this particular type of CBLE. These decisions may be strongly influenced by their self-efficacy (Debowski, Wood, & Bandura, 2001). Furthermore, it has been suggested that self-efficacy may fluctuate when students are learning in contexts that require the use complex cognitive processes (Bandura, 1997), such as learning with hypermedia. As suggested by Bandura (1997), self-efficacy is, in part, related to an understanding of the task demands. Furthermore, it has been argued that in the face of situational unpredictability, individuals may report differing levels of self-efficacy even if there is adequate knowledge of task demands. This scenario arises when the nature of a learning task is misleading because complex cognitive processes are embedded in seemingly easy tasks (Bandura & Schunk, 1981). Hypermedia may present such a scenario as research has demonstrated that learning with this environment requires the use of complex cognitive processes, particularly those related to SRL. Thus, self-efficacy may fluctuate during learning with hypermedia as the understanding of what complex cognitive processes are necessary may not be readily apparent. Rather, this understanding may develop as students progress through a learning task. However, limited research has used process data to examine the fluctuation of self-efficacy during learning with hypermedia.

Thus, a promising direction for the field of hypermedia is to empirically examine self-efficacy during learning. In addition for the need of more empirical research on metacognitive, cognitive (i.e. monitoring, planning, and strategy) processes *and* motivational (i.e. self-efficacy) processes, there has been a call to examine how the provision of different types of support is related to these processes during learning with hypermedia (Azevedo & Hadwin, 2005). This support, termed scaffolding, has become a critical issue in this line of research (Azevedo, 2005).

Conceptual scaffolds and self-regulated learning with hypermedia

In order to address some of the difficulties students face when self-regulating their learning with hypermedia, researchers have examined the potential benefit of providing different types of contextual support during learning. This type of support (i.e. scaffolding) is designed to assist students with elements of a task that are beyond their capacity, and help them concentrate on elements of task that are within their range of competence (Wood & Middleton, 1975; Wood, Bruner, Ross, 1976). While various types of scaffolds exist, recent research in the field of learning with hypermedia has focused on conceptual scaffolds. This type of scaffold is designed to aid in the development of domain knowledge (Hannafin, Land, & Oliver, 1999). However, results from research examining the potential benefit of providing students with conceptual scaffolds during learning have been slightly mixed. For example, some research has found that the provision of conceptual scaffolds, in the form of structured interactive overviews, fosters conceptual knowledge development for students with low prior knowledge of the topic (Shapiro, 1999, 2000). Other research has demonstrated that students who received conceptual scaffolds did not significantly outperform those who did not receive this type of scaffolding. For example, Azevedo et al. (2005) found that young students who received conceptual scaffolding, in the form of 10 domain specific questions designed to guide their learning about the circulatory system, used fewer key SRL processes during learning than students who did not receive scaffolding. Because this line of research has produced mixed results, future research is needed that clarifies the impact of conceptual scaffolds on SRL with hypermedia.

Current Study

As highlighted by previous research, a number of factors are related to learning with hypermedia. In particular, research has demonstrated that certain SRL processes are related to learning with hypermedia. However, there are three issues that should be addressed in future research. First, recent research has called for methodologies that empirically measure SRL processes *during* learning with hypermedia. Second, there is a need for research to empirically examine theoretically grounded constructs of motivation, such as self-efficacy, *during* learning with hypermedia. Third, there is a need for more research that examines the relationship between conceptual scaffolds and SRL with hypermedia.

The following two research questions were addressed in order to examine these three issues: 1) What is the relation between conceptual scaffolds and self-efficacy during learning with hypermedia? and, 2) What is the relation between conceptual scaffolds and use of self-regulatory processes during learning with hypermedia?

Method

Participants

Thirty-seven (*N* = 37) education college majors from a large public university were participants in this study. These participants, all of whom were undergraduate students, were recruited from education classes at the public universities. Participants received extra credit in their classes (as determined by their individual professor) for participation in this study. Other than being enrolled in the education classes, there were no additional criteria for inclusion in this study. Additionally, it should be noted that the time intensive nature of the data collection and analyses of this study (in particular, the think-aloud protocol) were the reasons for this sample size.

The sample consisted of six sophomores (16%), 14 juniors (38%), and 17 seniors (46%). The average age of the participants was 21.05 (*SD* = 1.83); there were 27 females (73%) and 10 male (27%), and their average GPA was 3.09 (SD = .38). The 37 participants were randomly assigned to one of two conditions: No Scaffolding (NS; *n* = 18) or Conceptual Scaffolding (CS; *n* = 19).

Measures

Self-efficacy. The self-efficacy scale from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991) was used to measure participants' self-efficacy. This scale consists of eight self-report questions that are answered on a seven point Likert scale (see Appendix A for self-efficacy scale used in this study). The wording of these eight questions was slightly modified in this study to ensure that the questions were specific to the learning task. For example, the question, "I believe I will receive an excellent grade in this course" was modified to, "I believe I will receive an excellent posttest score after learning about the circulatory system with this computer program." Participants answered the eight questions from this scale at three time points during the experimental session: Immediately before starting the 30 minute hypermedia learning task, 10 minutes into the hypermedia learning task, and 20 minutes into the hypermedia learning task. Asking participants to complete the self-efficacy scale at three different points allowed for an examination of the fluctuation of self-efficacy during learning. The Cronbach's alpha for the self-efficacy scale used in this study was as follows: $\alpha = .91$ (self-efficacy scale administered before the learning task), $\alpha = .96$ (self-efficacy scale administered 10 minutes into the learning task), and $\alpha = .98$ (self-efficacy scale administered 20 minutes into the learning task). This high reliability is consistent with reliability reported in previous research that used the self-efficacy scale from the MSLQ (e.g., Pintrich et al., 1991).

Self-Regulated Learning. Participants' use of SRL processes was measured with a think-aloud protocol methodology (Ericsson, 2006; Ericsson & Simon, 1994). Modified codes developed by Azevedo and colleagues (2004a) were used to code participants' SRL processes during learning, as captured by the think-aloud protocol. Their model was based on several recent models of SRL (Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998; Zimmerman, 2000, 2001). The modified coding scheme includes 27 SRL processes from the three SRL categories of *planning, monitoring,* and *learning strategies*[1].

Prior domain knowledge. Lastly, participants' prior domain knowledge of the circulatory system was measured with a pretest. The pretest included two sections, a matching section and a mental model essay. The matching section asked students to match 13 words with their corresponding definitions, while the mental model essay asked students to, *"Please write down everything you can about the circulatory system. Be sure to include all the parts and their purpose, explain how they work both individually and*

[1] The 27 SRL variables were grouped into three categories: *planning, monitoring,* and *learning strategies*. The *planning* category consists of goal setting, planning, prior knowledge activation, and recycling goals into working memory. The *monitoring* category consists of content evaluation (plus), content evaluation (minus), expecting adequacy of information (plus), expecting adequacy of information (minus), feeling of knowing (plus), feeling of knowing (minus), judgment of learning (plus), judgment of learning (minus), monitoring progress towards goals, monitoring use of strategies, and time monitoring. The *learning strategies* category consists of controlling video, coordinating informational sources, drawing, knowledge elaboration, memorizing, reading notes, re-reading, summarizing, using inference, searching, and taking notes.

together, and also explain how they contribute to the healthy functioning of the body." The matching section measured prior declarative knowledge while the mental model essay measured conceptual knowledge. These measures have been extensively used in previous research examining how students learn about the circulatory system with hypermedia (see Azevedo et al., 2005), and are based on extensive work done by Chi (2000, 2005) and Chi et al. (1994). An independent t-test indicated that there were no significant differences between conditions on the pretest ($p > .05$). These results suggested that participants randomly assigned to the NS and CS condition did not significantly differ in their prior declarative and conceptual knowledge of the circulatory system.

Procedure

The first author individually tested all participants. First, participants were given 15 minutes to complete the pretest. Next, participants were provided the instructions for the learning task. For students randomly assigned to the NS condition, the instructions were, "*You are being presented with an electronic encyclopedia, which contains textual information, static diagrams, and a digitized video clip of the circulatory system. We are trying to learn more about how students learn from electronic encyclopedia environments, like Encarta. Your task is to learn all you can about the circulatory system in 30 minutes. Make sure you learn about the different parts and their purpose, how they work both individually and together, and how they support the human body. In order for us to understand how you learn about the circulatory system, we ask you to "think aloud" continuously while you read and search Encarta. Say everything you are thinking* *and doing. I'll be here in case anything goes wrong with the computer and the equipment. Please remember that it is very important to say everything that you are thinking and doing while you are working on this task."* The instructions for the CS condition were identical, except they also included a statement indicating that five guiding questions would be administered during the 30 minute learning task. These five guiding questions were designed to foster participants' conceptual understanding of the circulatory system[2].

Participants were then given a five-minute training session of the hypermedia environment, Microsoft Encarta Reference Suite™ (2003), during which they practiced using the hyperlinks and search functions in the environment. Encarta contains multiple representations, including text (16,900 words), audio (1 video), and diagrams (35 illustrations) in the three articles related to the circulatory system. In addition, these multiple representations are located in different sections of the environment (18 in total), and are hyperlinked (107 hyperlinks in total).

Next, participants were given five minutes to complete the self-efficacy scale from the MSLQ (Pintrich et al., 1991). After completing this scale, participants were then given 30 minutes to learn about the circulatory system with Encarta. In both conditions,

[2]The five guiding questions included: *1) What are the most important things the circulatory system does to keep us alive? 2) How do the parts of the circulatory system do those important things you just mentioned? 3) When blood leaves the right side of the heart it goes to one place, and when the blood leaves the left side of the heart it goes to a different place. What does the blood do when it leaves the right side of the heart? 4) What does the blood do when it leaves the left side of the heart? and, 5) Imagine you are a blood cell in the right side of the heart. Explain all the parts you would go through to leave and eventually get back to the right side of the heart.*

the researcher reminded participants to keep verbalizing when they were silent for more then three seconds (e.g., *"Say what you are thinking"*). The participants' verbalizations during the 30-minute learning task were recorded and later used to analyze their self-regulated learning related to *planning*, *monitoring*, and *learning strategies*. In addition to thinking aloud during the hypermedia learning task, participants from both conditions completed the eight questions from the self-efficacy scale at two time points during the learning task (10 minutes into the learning task and then again 20 minutes into the learning task).

Coding, scoring, and inter-rater reliability

In this section, the coding, scoring, and inter-rater reliability of the participants' self-efficacy and SRL are described.

Self-efficacy. This self-efficacy scale consists of eight questions answered on a seven point Likert scale (1 = not at all true of me, 7 = very true of me). The scoring of this self-efficacy scale followed the scoring procedure used for the complete MSLQ (see Pintrich et al., 1991). The score was calculated by dividing the sum of the participant's answers to all of the self-efficacy questions (possible range = 8 to 56) by eight (the total number of questions in the self-efficacy scale). Thus, each participant had one self-efficacy score (possible range = 1 to 7) for each of the three time points (immediately before the 30-minute hypermedia learning task, 10 minutes into the hypermedia learning task, and 20 minutes into the hypermedia learning task).

SRL. The first author individually transcribed and then coded all transcriptions in order to analyze the frequency of the SRL processes each participant verbalized during the 30-minute learning task. This phase of data analysis yielded a total of 1,570 coded

SRL segments for all participants (M_{SRL} = 42 per participant). For the data analysis, the raw frequencies of the individual coded SRL processes for each participant were first collapsed into their corresponding SRL category, and then were identified as occurring in one of three time episodes during the 30-minute learning task: Time 1 (0 to 10 minutes), Time 2 (10 to 20 minutes), or Time 3 (20 to 30 minutes). For example, participant UG17 had one recoded recycle goal (*planning*), two coded sub-goals (*planning*), one coded time monitoring (*monitoring*), three coded take notes (*learning strategies*), and one coded memorization (*learning strategies*) in the first 10 minutes of the learning task. Collapsing the individual SRL codes into the corresponding SRL category indicated that this participant had three *planning* codes, one *monitoring* code, and four *learning strategies* codes during the first 10 minutes of the hypermedia learning task (Time 1). This methodological approach allowed for an examination of the fluctuation of SRL processes *during* learning.

Inter-rater reliability was established for the coding of the participants' SRL by comparing the individual coding of the first author, who was trained to use an adapted version of Azevedo et. al's (2005) coding scheme, with that of the second author (for complete details of coding scheme, see Azevedo & Cromley, 2004). Thirty-two percent of the transcripts (n = 12) were used for inter-rater reliability, and there was agreement on 399 out of 403 coded SRL segments, yielding a reliability coefficient of .99. Disagreements on the coding of SRL processes were resolved through discussion.

Results

Research Question #1: What is the relation between conceptual scaffolds and self-efficacy during learning with hypermedia? The participants' responses to the self-efficacy scale at three time points during the learning session (immediately before the learning task, 10 minutes into the learning task, and 20 minutes into the learning task) were used for this research question. A repeated measures ANOVA was used, with participants' self-efficacy at the three different time points as a within-subjects factor, and scaffolding condition (NS and CS) as a between-subjects factor. The sphericity assumption was not met, so the Huynh-Feldt correction was applied. The main effect of time on the participants' self-efficacy was significant, $F(1.722, 60.258) = 3.708$, $p = .036$, $\eta^2 = .10$, the main effect of condition was not significant, and the interaction between time on self-efficacy and condition was not significant. A follow-up pairwise comparison of self-efficacy at different time points indicated that participants in both conditions reported significantly higher levels of self-efficacy before the hypermedia learning task when compared to their self-efficacy at 10 minutes and 20 minutes into the hypermedia learning task ($p < .05$). See Figure 1 for the fluctuation of the participants' mean self-efficacy over time, by condition. See Table 1 for participants' mean (and standard deviation) self-efficacy over time, by condition.

Research Question #2: What is the relation between conceptual scaffolds and use of self-regulatory processes during learning with hypermedia? The participants' SRL was analyzed using repeated measures ANOVA with the frequencies of coded SRL utterances at three different time episodes during the 30-minute learning task (Time 1: 0 to 10 minutes; Time 2: 10 to 20 minutes; Time 3: 20 to 30 minutes) as a within-subjects factor, and scaffolding condition (NS and CS) as a between-subjects factor. Three separate repeated measures ANOVA analyses were conducted for each of the three SRL categories of the coding scheme: Monitoring, planning, and learning strategies. The sphericity assumption was met for all three analyses.

Monitoring. The main effect of time on the participants' use of monitoring processes was significant, $F(2, 70) = 3.359$, $p = .040$, $\eta^2 = .09$, the main effect of condition was significant, $F(1, 35) = 5.396$, $p = .026$, $\eta^2 = .13$, and the interaction between time on use of monitoring processes and condition was not significant. A follow-up pairwise comparison indicated participants in both conditions used significantly more monitoring processes at the beginning of the hypermedia learning task (Time 1) when compared to their use of monitoring processes towards the end of the learning task (Time 3; $p = .017$). However, while participants in both conditions decreased their use of monitoring processes as they progressed through the learning task, participants in the CS condition used, on average, more monitoring processes than students in the NS condition ($p < .05$). See Figure 2 for the fluctuation of monitoring processes over time, by condition. See Table 2 for participants' mean use of monitoring processes over time, by condition.

Planning. The main effect of time on the participants' use of planning processes was not significant, the main effect of condition on planning was significant, $F(1, 35) = 17.255$, $p < .001$, $\eta^2 = .33$, but the interaction between time on planning and condition was not significant. This finding indicated that participants in the CS condition used, on average, significantly more planning processes throughout the learning task than participants in the NS condition. See Figure 3 for the fluctuation of planning processes over time, by condition. See Table 3 for participants' mean use of planning processes over time, by condition.

Learning Strategies. The main effects and interactions for SRL processes related to learning strategies were not significant ($p > .05$). See Table 4 for participants' mean use of strategies processes over time, by condition.

Overall, results from these two research questions indicated that participants from both conditions reported higher levels of self-efficacy immediately before the hypermedia learning task, and that they decreased their use of SRL processes related to monitoring as they progressed through the hypermedia learning task. In addition, results also indicated that participants in the CS condition used, on average, more SRL processes related to planning during the hypermedia learning task than participants in the NS condition.

Discussion

While previous research has highlighted the importance of measuring SRL in *real* time (Perry et al., 2002), there has been limited empirical research examining when students use SRL processes during learning with hypermedia (see Azevedo, 2005). Furthermore, the studies that have used process data to measure SRL during learning have focused on cognitive (e.g., prior knowledge activation) and metacognitive (e.g., feeling of knowing) processes (Azevedo et al., 2005; Moos & Azevedo, 2006; Witherspoon et al., 2007). Conversely, motivational processes in learning with hypermedia have received limited empirical attention. As suggested by Mayer (2003), there is a need for scientific research that examines processes involved in learning with CBLEs, including cognitive, metacognitive, *and* motivational processes. This study assumes this line of research by examining self-efficacy, monitoring, planning, and learning strategies during learning with hypermedia and the extent to which the provision of conceptual scaffolds affects these self-regulatory processes. The following sections first discuss each research question and then follow with potential implications of these findings.

Research question one examined the relation between conceptual scaffolds and self-efficacy during learning with hypermedia. Results from this research question provide data on the fluctuation of self-efficacy during learning about a challenging topic with hypermedia. Results indicated that that participants in both conditions reported significantly higher levels of self-efficacy before the hypermedia learning task when compared to their self-efficacy 10 minutes and 20 minutes into the hypermedia learning task. However, participants' self-efficacy leveled off between 10 and 20 minutes as their reported self-efficacy did not significantly differ between these times. In other words, participants' self-efficacy, on average, fluctuated and they reported their highest level of self-efficacy immediately before using the hypermedia environment to learn about the circulatory system.

A closer examination of self-efficacy, as proposed by Bandura (1997), provides a possible explanation of why participants in this study reported, on average, higher self-efficacy immediately before the hypermedia learning task. In the case of this study, participants were asked to learn about the circulatory system with a hypermedia environment. As such, factors influencing self-efficacy in this study may be derived from both the learning environment (hypermedia) and the domain (circulatory system). While learning about the circulatory system may be perceived as manageable task, research has demonstrated that learning with hypermedia requires complex cognitive and metacognitive processes related to SRL. However, an understanding of the complex SRL processes needed to meet the learning goal with hypermedia may not be fully realized until an individual is involved in the learning task. Thus, the nature of the learning task in this study may have been misleading because complex cognitive processes are embedded in seemingly easy tasks (Bandura & Schunk, 1981). In other words, participants may have initially attended to the overall learning goal (a relatively manageable task), and not the complex SRL processes needed to meet this learning goal. However, once the participants began the learning task with the hypermedia environment, the SRL processes necessary to meet the learning goal may have become more apparent. This explanation may address why participants from both conditions reported, on average, higher self-efficacy immediately before the hypermedia learning task when compared to their reported self-efficacy during the hypermedia learning task.

Research question two examined the relation between conceptual scaffolds and use of self-regulatory processes during learning with hypermedia. Results from this research questions indicated that participants' use of monitoring processes, regardless of condition, significantly decreased as they progressed through the learning task. Monitoring processes, such as feeling of knowing and judgment of learning, have been shown to be critical SRL processes in learning with hypermedia (Azevedo & Cromley, 2004). However, results from this study indicated that participants used fewer of these key processes as they progressed through the hypermedia learning task. The muscle metaphor, as proposed by some SRL researchers (Pintrich & Zusho, 2002), may explain these results. According to this metaphor of SRL, acts of volition and self-control, such as the use of SRL processes, require a certain amount of self-control "strength" and this strength is limited. As such, the ability to continually use SRL processes decreases over time, regardless of the domain. Data from this study partially supports this assertion as participants from both conditions used fewer monitoring processes towards the end of the learning task. According to the muscle metaphor, the participants in this study were not able to sustain their use of monitoring processes over the 30-minute hypermedia learning task because SRL is a resource that depletes over time. This SRL muscle metaphor is certainly interesting and continued research which employs methodology that measures SRL *during* learning will further advance our understanding of whether students do indeed have difficulty sustaining the use of certain SRL processes over time when learning with hypermedia.

Results also indicated that SRL processes related to the use of planning and monitoring significantly differed between conditions. These results address the impact of conceptual scaffolds on SRL processes with hypermedia. Though examining the role of conceptual scaffolds in learning with hypermedia has become a critical issue (Azevedo, 2005; Azevedo & Hadwin, 2005; Pea, 2004; Puntambekar & Hubscher, 2005), empirical evidence of how scaffolds affect learning with hypermedia has been slightly mixed. The results from this study indicated that participants who received conceptual scaffolds during learning tended, on average, to use more planning and monitoring processes. Examining the raw frequencies of the SRL processes, by condition, sheds light on how participants from these two conditions differed in their use of planning processes. As evidenced in Table 5, participants who received conceptual scaffolds tended, on average, to *activate prior domain knowledge* and *recycle goals* more frequently than participants who did not receive conceptual scaffolds during the hypermedia learning task. Given the nature of the conceptual scaffolds provided to the participants in this study, these findings are not surprising. Five guiding questions served as conceptual scaffolds in this study, and these questions were designed so that each one fostered an increasingly complex understanding of the circulatory system. In order to answer each increasingly complex question, participants needed to recall what they had learned for the previous question. Such an approach is consistent with the literature from elaborative interrogation (e.g., Martin & Pressley, 1991). This line of research indicates that asking students higher-ordered questions allow them to anchor newly acquired knowledge in prior knowledge. As suggested by Willoughby and Wood (1994, p. 139), conceptual scaffolds that ask students increasingly higher-ordered questions allow them "to connect new information in their own richly developed knowledge base." Data from research question two supports this assertion as participants from the CS condition tended to activate their prior domain knowledge frequently which may have allowed them to answer increasingly higher-ordered questions as they progressed through the learning task.

Implications

In addition to potentially offering contributions to the scientific community, this study also potentially offers educational implications. Results from previous research on how students self-regulate their learning has provided rich and valuable data that has advanced our understanding of the complex processes involved in learning with hypermedia. From this line of research, researchers have been able to determine *what* SRL processes are related to learning with hypermedia. However, in order to address difficulties students may face when trying to self-regulate their learning with hypermedia, it is critical to also understand *when* students use SRL processes during learning. This study is able to potentially address this issue through a relatively unique methodological approach that allowed for the examination of how SRL processes fluctuate. Results indicated that participants from both conditions decreased their use of monitoring processes as they progressed through the learning task. This finding raises important implications because it suggests that students may need assistance in the process of monitoring their learning with hypermedia, especially as they near the end of a hypermedia learning task.

However, while students tended to decrease their use of monitoring processes during learning, there was not a significant decrease in their use of strategies. A closer examination of the frequencies in which participants used specific strategies provides important implications. Seventy-eight percent of the total SRL codes were related to strategies, while 17% were related to monitoring processes, and only 5% were related to planning processes for participants in the NS condition. Similarly, the majority of the total SRL codes were related to strategies (67%), while 20% were related to monitoring processes, and 13% were related to planning processes for participants in the CS condition. Clearly, participants from both conditions more frequently relied on learning strategies, as opposed to monitoring and/or planning processes. However, the vast majority of these learning strategies are considered “low-level” because they have been shown to be related to surface-level processing (Alexander et al., 1995). In particular, 43% of the coded learning strategies were re-reading, summarization, or note-taking for participants in the NS condition. Similarly, 53% of the coded learning strategies were re-reading, summarization, or note-taking for participants in the CS condition. While students heavily relied on these learning strategies, other “higher-order” learning strategies were used much less frequently. For example, research has empirically demonstrated that the use of inferences is strongly related to learning challenging topics, especially science-related topics (McNamara, 2004). However, inferences only accounted for a mere 1% of the learning strategy codes for participants in the NS condition, and only 2% of the learning strategy codes for the participants in the CS condition. These data suggest that while students may rely on learning strategies during learning with hypermedia, the variety is quite limited.

Future Directions

Though this study provides data on processes related to learning with hypermedia, future research could extend this line of research to further our theoretical understanding. In particular, it has been suggested that there is a need for more research that uses process data to examine learning in real time (e.g., Azevedo et al., 2004a, 2004b; Moos & Azevedo, 2006; Winne & Perry, 2000). As such, this study attempted to address this issue by using think-aloud protocols and self-report measures during learning. However, this study did not also include a posttest measure, and thus the data do not provide evidence on learning outcomes. As other lines of research have demonstrated, examining the relationships between processes of learning and learning outcomes with hypermedia offer a more comprehensive picture of the complexities of learning in this type of environment (e.g., see Azevedo et al., 2005). As such, we propose that a fruitful direction for future research is to examine the relationship between the fluctuation of processes during learning and learning outcomes with hypermedia.

Limitations

There are several limitations that need to be addressed. First, the results may be unique to the particular sample group of this study. While there was variability in the use of SRL processes with this sample of undergraduates, research has demonstrated developmental issues in both cognitive and metacognitive processes related to SRL. For example, elementary and middle school students may have limited capacity to self-regulate their learning (Pintrich & Zusho, 2002), particularly when asked to learn about a challenging topic such as the circulatory system. As such, it is currently unknown whether the results from this study would generalize to younger students. Future research is needed that examines the extent to which younger students use SRL processes *during* learning, and whether their use of these processes fluctuates. Furthermore, the limitations of the relatively small sample size need to be noted. The time intensive nature of the data collection and analyses resulted in this sample size. Our sample size was limited to 37 participants because the data collection and analyses for each participant took approximately five hours. Despite the small sample size, this study produced rich data. However, the small sample raises some concern regarding the extent to which these results can be generalized. This limitation can be addressed with future research that increases the sample size.

Additionally, though this study examines the theoretically grounded construct of self-efficacy, there are certainly other constructs of motivation that warrant consideration in the field of learning with hypermedia (e.g., goal orientation; see Moos & Azevedo, 2006). This study does not offer a comprehensive examination of motivation constructs and learning with hypermedia. The limited approach of this study could be addressed in future research that considers whether other motivation constructs fluctuate in the absence and presence of conceptual scaffolds during learning with hypermedia.

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Table 1. Mean (and standard deviation) of self-efficacy over time, by condition

	Condition	
Time	No Scaffolding (*n* = 18)	Conceptual Scaffolding (*n* = 19)
Time 1: Beginning of task	4.67 (0.97)	4.71 (1.11)
Time 2: 10 minutes into task	4.52 (0.81)	4.45 (0.96)
Time 3: 20 minutes into task	4.41 (1.01)	4.46 (1.21)

Possible range: 1 to 7.

Table 2. Mean frequency (and standard deviation) of monitoring processes used over time, by condition

	Condition	
Time	No Scaffolding (n = 18)	Conceptual Scaffolding (n = 19)
Time 1: Beginning of task	2.06 (3.30)	4.26 (2.62)
Time 2: 10 minutes into task	1.94 (2.44)	3.53 (2.93)
Time 3: 20 minutes into task	1.50 (1.76)	2.68 (2.36)

Table 3. Mean frequency (and standard deviation) of planning processes used over time, by condition

	Condition	
Time	No Scaffolding (n = 18)	Conceptual Scaffolding (n = 19)
Time 1: Beginning of task	0.72 (0.76)	2.84 (2.06)
Time 2: 10 minutes into task	0.67 (0.69)	2.37 (2.71)
Time 3: 20 minutes into task	0.56 (0.86)	1.53 (1.54)

Table 4. Mean frequency (and standard deviation) of strategies used over time, by condition

	Condition	
Time	No Scaffolding (n = 18)	Conceptual Scaffolding (n = 19)
Time 1: Beginning of task	7.06 (5.17)	9.16 (6.04)
Time 2: 10 minutes into task	5.17 (3.62)	8.00 (4.64)
Time 3: 20 minutes into task	5.67 (5.48)	7.05 (3.41)

Table 5. Total raw frequency of individual SRL processes used during learning, by condition

SRL Processes	No Scaffolding (n = 18)	Conceptual Scaffolding (n = 19)
Planning		
Planning	0	1
Prior Domain Knowledge Activation	8	28
Recycle Goal in Working Memory	8	64
Sub-Goals	20	24
TOTAL	**36**	**117**
Monitoring		
Content Evaluation (+)	7	22
Content Evaluation (-)	17	30
Expecting Adequacy (+)	8	16
Expecting Adequacy (-)	7	11
Feeling of Knowing (+)	29	33
Feeling of Knowing (-)	21	22
Judgment of Learning (+)	3	1
Judgment of Learning (-)	10	12
Monitoring Progress Toward Goals	6	19
Monitor Use of Strategies	5	4
Time Monitoring	5	8
TOTAL	**118**	**178**
Learning Strategies		
Coordinating Informational Sources	6	4
Draw	4	4
Free Search	19	21
Goal-Directed Search	13	19
Inferences	3	11
Knowledge Elaboration	3	11
Memorization	2	7
Read Notes	9	30
Re-Reading	54	59
Self-Test	0	4
Summarization	50	107
Taking Notes	131	146
TOTAL	**537**	**584**

Figure 1. Fluctuation of self-efficacy over time, by condition

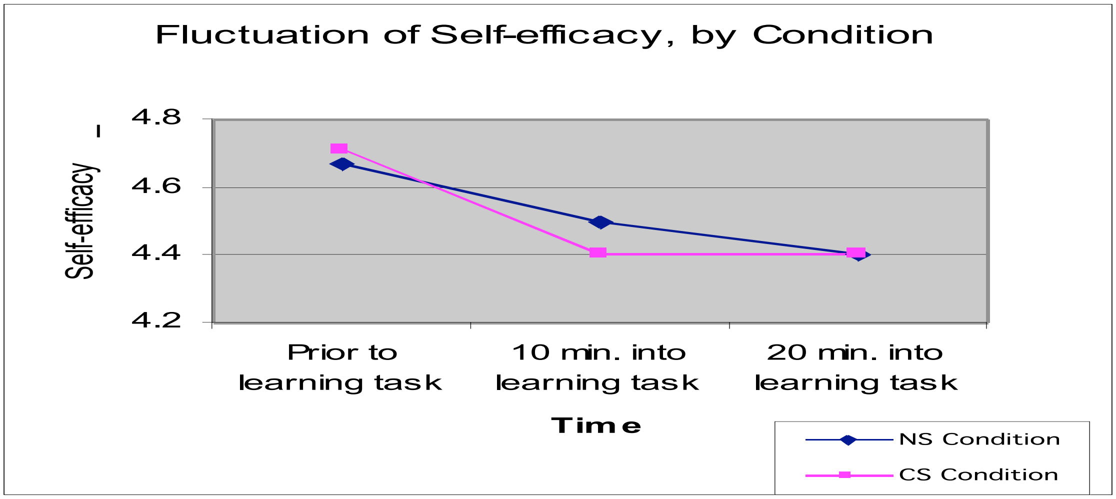


Figure 2. Fluctuation of monitoring over time, by condition

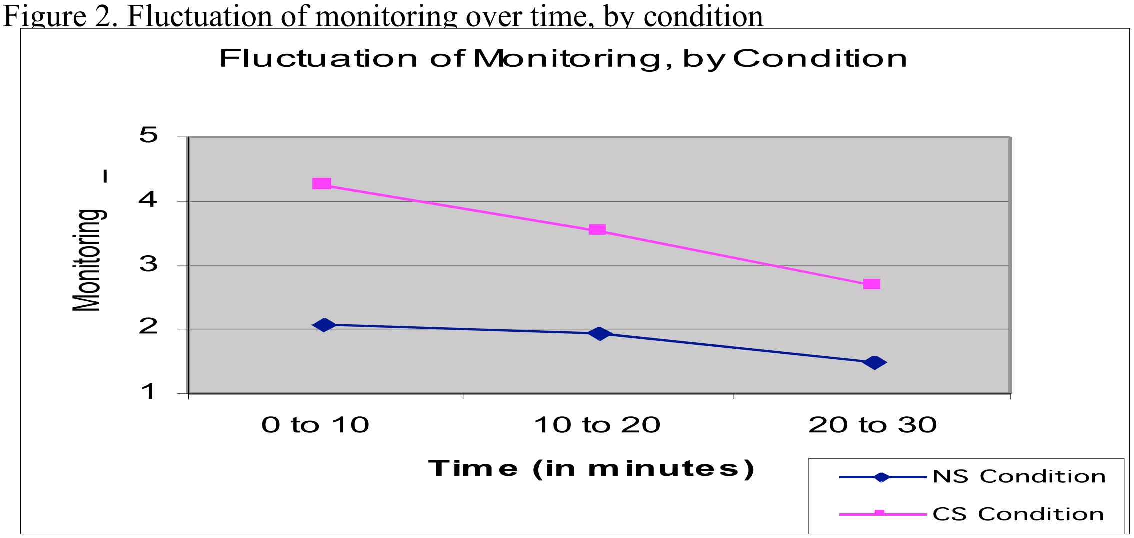
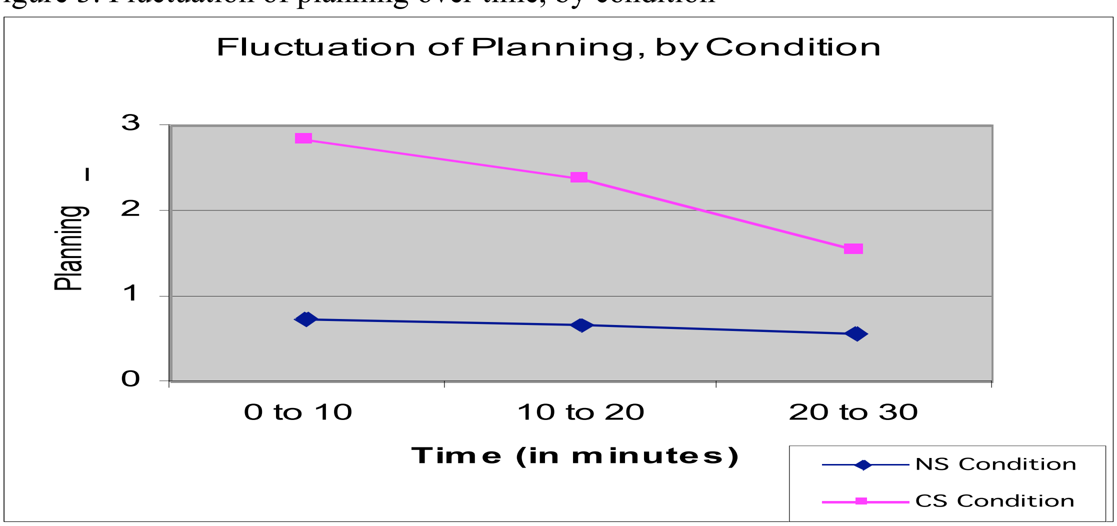


Figure 3. Fluctuation of planning over time, by condition



Appendix A. Self-efficacy scale used in the study (based on Pintrich et al., 1991)

Pre-task Questionnaire

The following questions ask about your motivation for and attitudes about this learning task. **Remember there are no right or wrong answers, just answer as accurately as possible.** Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If a statement if more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
not at all true of me						very true of me

1.	I believe I will receive an excellent score on the posttest after learning about the circulatory system with this computer program.	1	2	3	4	5	6	7
2.	I'm certain I can understand difficult material about the circulatory system presented in this computer program.	1	2	3	4	5	6	7
3.	I'm confident I can understand basic concepts about the circulatory system presented in this computer program.	1	2	3	4	5	6	7
4.	I'm confident I can understand the most complex material about the circulatory system presented in this computer program.	1	2	3	4	5	6	7
5.	I'm confident I can do an excellent job in meeting the goal for this task of learning about the circulatory system.	1	2	3	4	5	6	7
6.	I expect to do well learning about the circulatory system with this computer program.	1	2	3	4	5	6	7
7.	I'm certain I can master the material on the circulatory system presented in this computer program.	1	2	3	4	5	6	7
8.	Considering the difficulty of the material on the circulatory system, the computer program, and my skills, I think I will do well.	1	2	3	4	5	6	7