Examining the fluctuation of strategy use during learning with hypermedia

Dan Moos, Roger Azevedo, University of Maryland, Department of Human Development, 3304 Benjamin Building, College Park, MD 20742
E-mail: danmoos@msn.com, razevedo@umd.edu

Abstract: *What* strategies do students use when given conceptual scaffolds while learning with hypermedia and *when* do students use these strategies during learning? We collected think-aloud, pre-test, and posttest data from 37 undergraduates to examine these two research questions. Participants were randomly assigned to either the No Scaffolding (NS) or Conceptual Scaffolding (CS) condition, and individually completed one 30-minute learning task during which they used hypermedia to learn about the circulatory system. Results suggest that students in both conditions used some strategies inconsistently during learning. Specifically, the frequency with which students took notes, re-read, and selected new informational sources significantly fluctuated throughout the 30 minute learning task. Results also indicate that students in the conceptual scaffolding condition summarized significantly more during the 30-minute learning task. Discussion of how these findings are related to previous literature examining learning with hypermedia is provided.

Introduction

Computer-based learning environments, such as hypermedia, have been used in classrooms to help students develop conceptual understanding of challenging topics (Azevedo, 2005; Jacobson & Kozma, 2000; Lajoie, 2000; Lajoie & Azevedo, in press). Hypermedia allows students to explore units of information in different ways (Goldshalk, Harvey, & Moller, 2004) and provides multiple representations such as text, audio, and video clips. Though these characteristics should allow students to actively participate in the development of conceptual knowledge (Jonassen & Reeves, 1996; White & Frederiksen, 2005), research has begun to question the effectiveness of these learning environments (see Azevedo, 2005; Jacobson & Archodidou, 2000; Jacobson & Wilensky, 2006; Jonassen & Land, 2000). Studies in this line of research have focused on three subprocesses of learning with hypermedia: 1) Students' ability to develop *conceptual understanding* when using hypermedia, 2) Students' ability to use specific aspects of hypermedia, including *multiple representations*, and 3) Students' ability to manage *cognitive load* during learning with hypermedia (see Figure 1). This study extends this line of research by examining: 1) *What* strategies students use when addressing these three subprocesses of learning with hypermedia, and 2) *When* students use these strategies during learning with hypermedia.

Conceptual Understanding

While some students are able to effectively use hypermedia to learn about challenging topics, other students have difficulty using this learning environment to develop conceptual understanding. Research from the field of self-regulated learning (SRL) has examined the role of self-regulatory processes in developing conceptual knowledge with hypermedia, and has illuminated why some students have difficulty learning with hypermedia (e.g., Azevedo & Cromley, 2004). Recent SRL research has found that while the use of specific strategies are integral in developing conceptual understanding of challenging topics, some students have difficulty effectively using these strategies (Azevedo, 2005; Hmelo-Silver & Azevedo, 2006; Jacobson, & Archodidou, 2000; Jacobsson & Wilensky, 2006). For example, research has found that there is a positive relationship between the use of high level strategies, such as summarizing and inferencing, and learning outcomes with hypermedia (e.g., Azevedo, Cromley, Winters, Moos, & Greene, 2005; Azevedo, Cromley, & Siebert, 2004). Based on previous literature, we argue that the following strategies are related to students' development of conceptual understanding with hypermedia: Summarizing, making inferences, and re-reading (see Figure 1).

Multiple External Representations

Research has also examined how contextual factors of hypermedia may affect learning. For example, multiple external representations (MERs) are a defining contextual factor in hypermedia environments. MERs, which can include text, audio, and video clips, serve three distinct functions in learning with hypermedia – to construct, constrain, and complement. Despite the potential benefit of these functions, research has found mixed results on the effectiveness of MERs. Research in learning with both hypermedia and non-hypermedia environments has shown that some students do not effectively coordinate MERs and also have difficulty understanding the relationship between MERs (Ainsworth & Loizou, 2003; Azevedo & Cromley, 2004; Hmelo-Silver, & Pfeffer, 2004). Based on this line of research, we argue that the following strategies are involved in the use of MERs: Coordinating multiple representations and selecting new informational sources (see Figure 1).

Cognitive Load

Research has also examined the role of working memory in learning with hypermedia (Grace-Martin, 2001). According to the Cognitive Load model, working memory has limited capacity and may be affected by three types of cognitive load – intrinsic cognitive load, extraneous cognitive load, or germane cognitive load (Sweller, 2004; van Merriënboer & Sweller, 2005). Of particular concern to students learning with hypermedia is extraneous cognitive load, which may be imposed upon a student's working memory when the student is faced with multiple sources of information in hypermedia (Gerjets & Scheiter, 2003; Kester, Kirschner, & van Merriënboer, 2005). For example, extracting information from both a diagram and text may overload a students' visual subprocessor of his/her working memory (Mayer & Moreno, 2003; van Merriënboer & Ayres, 2005). Furthermore, cognitive overload may impede learning because it limits available space in working memory (see Gerjets & Scheiter, 2003). Based on this research, we argue that note-taking, reading notes, and drawing are effective strategies for students to offload extraneous cognitive load and thus free up some working memory space (see Figure 1).

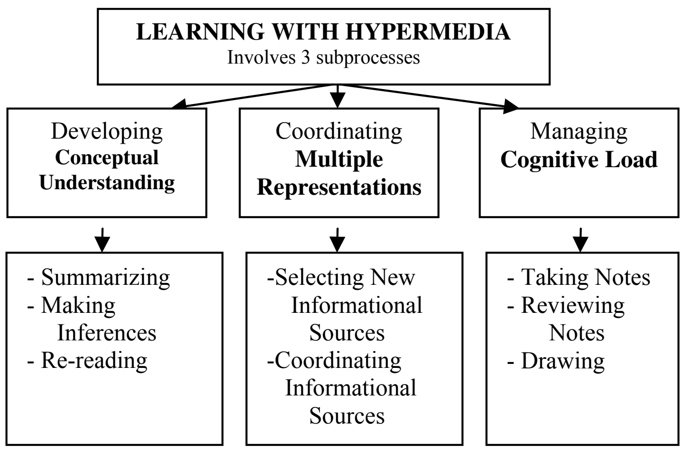

Figure 1. Nine strategies underlying three subprocesses of learning with hypermedia

Current Study

While previous research has examined what strategies students use for the three subprocesses of learning with hypermedia, there are three issues that should be addressed. First, this line of research has typically studied these three subprocesses independently rather than studying all three of these subprocesses concurrently. However, because these three subprocesses are interrelated and all affect learning with hypermedia, it is important for research to examine them simultaneously. Second, research has employed methodology to capture *what* strategies students use when learning with hypermedia (Azevedo et. al., 2005), but typically has not examined *when* students use these strategies during learning with hypermedia. That is, the fluctuation of strategy use during learning has been largely unaddressed. For example, previous research using a SRL framework (Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998) found that students who coordinated multiple informational sources during learning with hypermedia tend to demonstrate higher learning gains than those students who do not deploy this strategy (Azevedo & Cromley, 2004). However, it is presently unclear *when* students use specific strategies during learning with hypermedia. Third, in order to address difficulties some students face in deploying key strategies when learning with hypermedia, previous research has begun to examine the effectiveness of providing students with conceptual scaffolds. This line of research generally suggests that the provision of scaffolds in hypermedia creates an instructional context which fosters students' use of key self-regulatory processes, including strategies (Azevedo & Cromley, 2004; Jacobson, & Archodidou, 2000; Shapiro, 1999, 2000). However, this line of research has not examined how conceptual scaffolds affect strategy use related to all three subprocesses of learning with hypermedia.

This study furthers current research on learning with hypermedia by addressing these three key issues. Specifically, this study used process data from think-aloud methodology (Ericsson & Simon, 1993) to examine the impact of conceptual scaffolds on strategies used to develop conceptual understanding, coordinate multiple external representations, and manage cognitive load. The two research questions for this study are: 1) Is there a relationship between conceptual scaffolding and the fluctuation of strategies used during learning with hypermedia? and, 2) Is there a relationship between conceptual scaffolding and students' ability to shift to more sophisticated mental models of the circulatory system?

Method

Participants

The participants included thirty-seven (N=37) undergraduate education majors from the University of Maryland, College Park. Their average age was 21.51 (*SD* = 3.59); there were 27 women (73%) and 10 men (27%).

Measures

The paper-and-pencil forms consisted of a consent form, a participant questionnaire, a pre-test, and a post-test. The pretest and posttest were modified versions of measurements used in previous studies examining self-regulated learning of the circulatory system with hypermedia (Azevedo, Cromley, & Seibert, 2004). The pretest and posttest, which were identical, asked the participants to write an essay based on the instructions, *"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 together, and also explain how they contribute to the healthy functioning of the body."* The essay was used to assess students' mental model of the circulatory system before and after the learning task. Lastly, participants' use of self-regulatory processes while learning about the circulatory system was collected via a think-aloud protocol (Ericsson & Simon, 1993).

Hypermedia Learning Environment

The participants used Microsoft Encarta Reference Suite™ (2003) to learn about the circulatory system. This hypermedia environment contains three relevant articles to the circulatory system, and these articles are comprised of 16,900 words, 35 illustrations, 107 hyperlinks, and 18 sections. Participants could freely search all of Encarta while learning about the circulatory system.

Conceptual Scaffolds

While all participants had access to a global learning goal (*Make sure you lean about the different parts and their purpose, how they work both individually and together, and how they support the human* body) during learning with hypermedia, participants randomly assigned to the CS condition received the following five guiding questions during learning with hypermedia: 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. These five questions were designed in consultation with a veteran science teacher who is familiar with the content provided in the hypermedia environment. These five guiding questions served as conceptual scaffolds by facilitating the participants' mental model shift during the learning task.

Procedure

Participants were randomly assigned to one of two conditions: No Scaffolding (NS; $n = 18$) and Conceptual Scaffolding (CS; $n = 19$), and were all individually tested by the first author. After completing the consent form and participant questionnaire, the participants were given 15 minutes to complete the pretest on the circulatory system. Next, the researcher provided instructions for the learning task. For 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 also included a statement indicating that five guiding questions would be given to the participant during the 30 minute learning task. Participants were then given 30 minutes to learn about the circulatory system with the hypermedia learning environment. While participants in both conditions had access to the overall learning goal during these 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*), participants in the CS condition also had access to the five guiding questions. In both conditions, the researcher remained nearby to remind participants to keep verbalizing when they were silent for more then three seconds (e.g., *"Say what you are thinking"*). Immediately following the 30-minute learning task, participants were given 15 minutes to complete the posttest. They independently completed the posttest without their notes, other instructional materials, or the hypermedia environment.

Coding and Scoring

In order to analyze the frequency of strategies each participant verbalized during the 30 minute learning task, the first author individually transcribed and then coded all transcripts. Then, in order to analyze when students used specific strategies, the coded strategies were tallied according to the time in which they occurred during the 30 minute learning task: Time 1 (0 to 8 minutes), Time 2 (8 to 16 minutes), Time 3 (16 to 24 minutes), and Time 4 (24 minutes to 30 minutes). This method of dividing the 30-minute learning task into different time episodes is a novel methodological approach in capturing the fluctuation of strategies. As such, it is exploratory in nature, with the goal of creating time episodes that simultaneously allowed for a fine grained analysis and provided substantial data. Inter-rater reliability was established for the coding of the participants' strategy use by comparing the individual coding of the first author, who was trained to use an adapted version of Azevedo et. al's (2004) coding scheme, with that of the second author (for complete details of coding scheme, see Azevedo & Cromley, 2004). Thirty-five percent of the transcripts ($n = 13$) were used for inter-rater reliability, and there was agreement on 1,496 out of 1,527 coded SRL segments, yielding a reliability coefficient of .98. In order to score the participants' pretest and posttest essays, we used previously established methods for scoring the students' mental models on the pretest and posttest essays (Azevedo & Cromley, 2004; Azevedo, Cromley, & Seibert, 2004), which is based on Chi and colleagues' research (Chi, 2000; 2005; Chi, de Leeuw, Chiu, & LaVancher, 1994). The first author coded all of the participants' mental models from the pretest and posttest, and a science teacher familiar with the mental model coding scheme recoded 33% of the participants' pretest and posttest mental models ($n = 28$). There was agreement on 27 out of 28 scored essays, yielding an inter-rater reliability of .96. Disagreements on the mental model scoring and coding of SRL processes were resolved through discussion.

Results

Question 1: Is there a relationship between conceptual scaffolding and the fluctuation of strategies used during learning with hypermedia?

The participants' use of strategies was analyzed using repeated measures ANOVA with the frequencies of coded strategies at four different time periods during the 30-minute learning task (Time 1: 0 to 8 minutes, Time 2: 8 minutes to 16 minutes, Time 3: 16 to 24 minutes, and Time 4: 24 to 30 minutes) as a within-subjects factor, and scaffolding conditions (No Scaffolding and Conceptual Scaffolding) as a between-subjects factor. Nine separate analyses were conducted for each of the nine strategies. The sphericity was not met for all analyses, so the Huynh-Feldt correction was applied.

Multiple Representations

The main effect of time on the participants' *selecting new informational* sources was significant, $F(2.37, 83.86) = 5.90$, $p < .01$, $\eta^2 = .14$, the interaction between time on selecting new informational sources and condition was not significant, and the main effect of conditions was not significant. A pairwise comparison indicates that participants across both conditions selected new informational sources more frequently at Times 1 and 3 than at Times 2 and 4 ($p < .01$). The main effect of time on the participants' *coordinating multiple representations* was not significant, the interaction between time on coordinating multiple informational sources and condition was not significant, and the main effect of conditions was not significant. More interesting, however, is that the frequency data also indicates the participants rarely coordinated multiple informational sources during the 30 minute learning task.

Cognitive Load

The main effect of time on the participants' *note-taking* was significant, $F(2.66, 93.01) = 11.99$, $p < .01$, $\eta^2 = .26$, the interaction between time on note-taking and condition was not significant, and the main effect of conditions was not significant. A pairwise comparison indicates that participants significantly decreased their note-taking as they progressed from Time 1 to Time 4 of the learning session ($p < .01$). However, the main effect of time on the participants' *reviewing notes* was not significant, the interaction between time on reviewing notes and condition was not significant, and the main effect of conditions was not significant. Furthermore, while the participants in both conditions frequently took notes in the beginning of the learning session, the frequency data indicates that they rarely, if ever, reviewed their notes during learning. The main effect of time on the participants' *drawing* was not significant, the interaction between time on drawing and condition was not significant, and the main effect of conditions was not significant. Furthermore, the frequency in which students used drawing to manage extraneous cognitive load during the 30-minute learning task suggests that they rarely used this strategy.

Conceptual Understanding

The main effect of time on the participants' *re-reading* was significant, $F(2.49, 87.02) = 2.83$, $p < .05$, $\eta^2 = .08$, the interaction between time on re-reading and condition was not significant, and the main effect of conditions was not significant. A pairwise comparison indicates that participants across both conditions more frequently re-read at Times 2 and 4 than at Times 1 and 3 ($p < .01$). The main effect of time on the participants' *summarizing* was not significant, the interaction between time on summarizing and condition was not significant, but the main effect of conditions was significant, $F(1, 35) = 3.96$, $p = .05$, $\eta^2 = .10$). A comparison of each condition's mean frequency for summarizing suggests that students in the NS condition summarized less frequently ($M_{NS} = 4.01$) than students in the CS condition ($M_{CS} = 7.58$) during the 30-minute learning task. Lastly, the main effect of time on the participants' *inferences* was not significant, the interaction between time on inferences and condition was not significant, and the main effect of conditions was not significant. Furthermore, the frequency in which the students made inferences during the learning sessions suggest that they used this high-level strategy infrequently during learning.

Question 2: Is there a relationship between conceptual scaffolding and students' ability to shift to more sophisticated mental models of the circulatory system? We used two 3 X 2 (mental model by condition) chi-square test to analyze changes in students' conceptual understanding. We first examined the students' mental models on the pretest. The chi-square test revealed a non- significant difference in the frequency distribution of the students' mental model by condition (χ^2 [2, $N = 37$] = 1.35, $p > .05$). This result indicates that the distribution of pretest mental model scores was not statistically significantly different between the NS and CS condition. We then examined the students' mental models on the posttest. The chi-square test revealed a significant difference in the frequency distribution of learners' mental model by condition (χ^2 [2, $N = 37$] = 10.714, $p < .01$). The results of this test indicate that the distribution of students in the NS condition and CS condition significantly differ on their mental model scores for the posttest. Of the 19 students in the conceptual scaffolding condition, 12 (63%) had a high mental model of the circulatory system on their posttest, 5 (26%) had an intermediate mental model on their posttest, and only 2 (11%) had a low mental model on their posttest score. On the other hand, of the 18 students in the NS condition, only 3 (18%) had a high mental model of the circulatory system on their posttest and 5 (28%) had an intermediate mental model on their posttest, while 10 (56%) had a low mental model on their posttest score.

Conclusions

By examining strategies that are related to different subprocesses of learning with hypermedia, this study offers both theoretical and methodological contributions to existing literature. First, this study highlights the potential of measuring students' use of strategies *during* learning. The empirical-based and theoretically driven analyses of this study provide trace data on the strategies students used during learning. The statistically significant main effect of time on three strategies suggest that students' note-taking, re-reading, and selecting new information sources fluctuated during the learning task, regardless of scaffolding condition. While the main effect for the other four strategies (coordinating information sources, reading notes, drawing, and making inferences) was not significant, and thus indicate that the use of these strategies did not fluctuate during learning, the mean frequencies of these strategies present informative findings. The mean frequencies, which range from .07 to 1.89 for both conditions, suggest that students are rarely deploying these strategies, which have been identified as key strategies in learning with hypermedia (Azevedo & Cromley, 2004). Lastly, the results suggest that providing students with conceptual scaffolds during learning affects both the process and product of learning. Students that received conceptual scaffolds summarized more frequently, on average, and demonstrated a higher mental model of the circulatory system on the posttest, on average, than students who did not receive conceptual scaffolding.

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