Can Prior Knowledge Adequately Predict the use of Metacognitive Processes during Hypermedia Learning?

Researchers in the field of learning sciences and self-regulated learning are increasingly investigating the impact of one's prior knowledge on learning outcomes (see Ericson et al., 2006; Sawyer, 2006; Zimmerman & Schunk, 2011). Few studies, however, have focused on how prior knowledge can impact how a student self-regulates during learning about complex and challenging topics with advanced learning technologies. It is important for us to understand how students with differing prior knowledge levels self-regulate various cognitive, metacognitive, motivational, and affective processes during learning so that we can adapt instructional methods in order to suit their individual needs (Azevedo et al., 2012). In this study, we investigated how students with high- and low- prior knowledge about the human circulatory system engage in different metacognitive processes while learning about the topic with MetaTutor.

Theoretical Perspective

Models of SRL (e.g., Winne & Hadwin, 2008) emphasize prior knowledge as a key factor in self-regulation, however, there is little empirical support demonstrating the advantages of prior knowledge, nor is there a descriptive, process-oriented model that explicitly describes how prior knowledge differentially impacts monitoring and control of cognitive and metacognitive processes during hypermedia learning. When students learn difficult material, they gain a great opportunity to learn deeply when they effectively self-regulate their learning. Moreover, there has been a rising interest in studying how students self-regulate their learning in hypermedia environments. Moos and Azevedo (2008) explained that students with different levels of prior knowledge learn in a different manner in such environments. Furthermore, Scheiter et al. (2009) investigated how student characteristics, for example prior knowledge, can moderate how they interact with a hypermedia environment. As such, our study aims to extend current empirical research by assessing if a difference in prior knowledge can impact how students self-regulate their learning in a hypermedia environment.

Research Questions

Based on previous work examining prior knowledge and on the research using MetaTutor and assessing self-regulated learning (Azevedo et al., 2010, 2011, in press), three research questions were generated: (1) Are there significant differences between the relevant and irrelevant pages visited by students during learning based on their level of prior knowledge? (2) Are there significant differences in the distribution of self-initiated and PA-initiated use of the SRL palette based on the students' level of prior knowledge? And (3)Are there significant differences regarding the duration of the use of the metacognitive strategies in the SRL palette based on the students' level of prior knowledge?

Method

Participants

Forty-eight (N=48; 71% female) undergraduate students from two universities in North America participated in this study. Participants ranged from 18 to 30 years old, where the mean age was 21.42 (SD = 2.77). Participants were compensated with $10 an hour, up to $40 for completing the two-day, 4 hour experiment.

Prior Knowledge

Participants in the high prior knowledge group (n = 24) had pre test scores ranging from 23 to 25 out of 25 (with one participant with a score of 21), with a mean score of 23.58.

Participants in the low prior knowledge group had pre test scores ranging from 9 to 16 out of 25, with a mean score of 12.75. See Data Scoring and Analysis section for a detailed description of how the two groups were formed, based on the pretest scores.

MetaTutor: Multi-Agent Adaptive Hypermedia Learning System

MetaTutor, is a multi-agent adaptive hypermedia learning environment (Azevedo et al., 2012), which includes material related to the human circulatory system The program includes 38 pages of text and diagrams, and is organized by a table of contents displayed on the screen. On the right pane, students are provided with an SRL palette, whuch they can choose to use to engage in different SRL strategies The environment also includes a timer, and a text box containing the overall learning goal, which is to learn about the circulatory system; and the two sub-goals learners set, Furthermore, there are four pedagogical agents; Gavin, Pam, Mary, or Sam who are successively displayed on the screen during learning, and can provide varying degrees of prompting and feedback. See figure 1 for a screen shot of the MetaTutor interface.

The SRL palette is one of the many features embedded within the MetaTutor environment. This palette provides the students with opportunities to engage in SRL strategies; such as, judgment of learning (JOL), feeling of knowing (FOK), and content evaluation (CE). The participants are permitted to use any of the tools provided in the palette; and, the pedagogical agents are programmed to prompt the students to use some of these metacognitive strategies. The use of these SRL strategies, therefore, can be both initiated by the student interacting with the system, or by one of the PAs who is present to aid and scaffold the student.

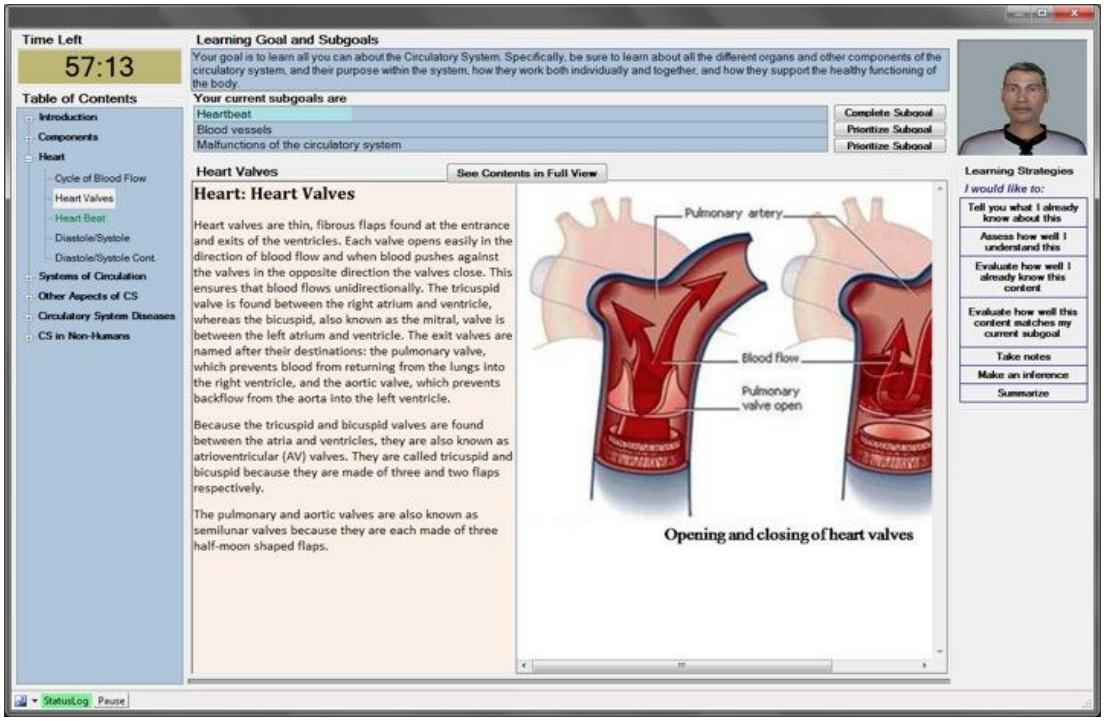

Figure 1: screen shot of the MetaTutor interface

Procedure

Data collection consisted of a two-day session. On the first day, participants filled out 6 self-report measures (about emotions and motivation; e.g., AEQ [Academic Emotions Questionaire] Pekrun et al., 2011) and demographics questionnaires about their thoughts towards

university life. They also completed a 25-item pre test to assess their level of knowledge of the science topic prior to the learning session. On the second day, participants set up 2 sub goals with one of the pedagogical agents, Pam the Planner; used to determine the relevant pages visited. Next, they used MetaTutor for one hour to learn about the human circulatory system. During learning, we collected concurrent think-alouds, log files, eye-tracking, and physiological data from each participant. Following learning, participants were given a 25-item post test.

Data Scoring and Analysis

In order to examine high prior knowledge, we examined the pre test scores completed by participants on day 1 of the experiment. We calculated the median of test score, which was a score of 20; and then divided participants into 2 groups. We then omitted students with scores that were too close to the median; i.e., students with scores of 18, 19, 21 and 22 were omitted from the data set. Following this, we omitted another 12 participants with the highest scores from the low prior knowledge group (consisting of 11 students with scores of 17 out of 25 and 1 student with a score of 16 out of 25) in order to obtain equal sample sizes in both groups. After this data omission, we were left with 2 groups of 24 students each, and a total sample size of 48 participants.

Frequency and time data used in the analyses were extracted from the log files, which are created as each participant interacts with the system. We also used log-file data to extract the number of relevant and irrelevant pages the participants visited, including how long they spent on each page. The log file data provides rich, time-stamped information, which gives us a way to examine the processes students use as they learn with MetaTutor. In this paper, we do not report the other data types (i.e., concurrent think-alouds, eye-tracking, and physiological data).

Results

Research Question #1: Are there significant differences between the relevant and irrelevant pages visited by students during learning based on their level of prior knowledge?

To test the frequency of relevant and irrelevant pages the participants visited in MetaTutor, we performed a 2x2 chi-square analysis. The results indicated a non-significant result; $\chi^2(1) = .001$; $p = .98$, meaning that students with high and low prior knowledge did not significantly differ on the amount of relevant and irrelevant pages they visited during learning. In addition, we performed a repeated-measures ANOVA to test the effect of prior knowledge on number of relevant pages visited. Results showed no main effect for relevancy; $F(1,46) = .63$, $p = .43$; no main effect for prior knowledge; $F(1,46) = .75$, $p = .39$; and no significant interaction effect; $F(1,46) = .003$, $p = .95$. This informs us that a student's prior knowledge does not affect their navigation to relevant or irrelevant pages. Furthermore, we performed a repeated-measures ANOVA to test the significance of the duration students spent on relevant compared to irrelevant pages. The results from this analysis revealed a significant main effect for time spent on relevant compared to irrelevant pages; $F(1,46) = 7.99$, $p=.007$. We did not find a significant main effect for prior knowledge, $F(1,46) = 3.49$, $p =.068$; nor did we obtain a significant interaction effect, $F(1,46) = .056$, $p.81$.

Overall, these results suggest that prior knowledge does not have an effect on how students select relevant and irrelevant material. Students did significantly differ on the amount of time they spent reading relevant and irrelevant pages, but such a difference was not dependent on prior knowledge. Prior knowledge, therefore, may not be as strong an indicator as once thought in predicting self-regulation strategies.

Table 1. Frequencies for Relevant and Irrelevant Pages by Prior Knowledge

	Relevant	Irrelevant
High PK	451	407
Low PK	381	343

Table 2. Descriptive Statistics for Repeated-Measures ANOVA (Relevancy)

		M	*SD*
Relevant Pages	High PK	18.79	17.40
	Low PK	15.88	11.18
Irrelevant Pages	High PK	16.96	12.32
	Low PK	14.29	11.94

Table 3. Descriptive Statistics for Repeated-Measures ANOVA (RelevancyTime)

		M	*SD*
Time on Relevant	High PK	2455.48	1049.96
	Low PK	2481.13	1013.22
Time on Irrelevant	High PK	1563.73	1015.04
	Low PK	1727.62	1014.38

Research Question #2: Are there significant differences in the distribution of self-initiated and PA-initiated use of the SRL palette based on the students' level of prior knowledge?

In order to test for significant differences between the frequencies of self vs. agent prompting of SRL strategies, we performed a 2x2 chi-square analysis. The SRL processes examined were judgment of learning (JOL), feeling of knowing (FOK), and content evaluation (CE). Frequency counts indicated low levels of FOK and CE, such that they could not be statistically tested. We therefore only tested for significant differences for the use of JOL. Results indicated a non-significant difference $\chi^2(1) = .021$, $p = .89$, meaning there were no significant differences in the distribution of self- vs. agent-initiated prompts based on prior knowledge. Overall, these results suggest that prior knowledge may not be valid in predicting how students interact with the SRL palette in MetaTutor. Prior knowledge may not be, therefore, an adequate indicator of how students will perform when learning with hypermedia.

Table 4. Frequencies for Self- vs. Agent-Initiated JOL Moves by Prior Knowledge

	Self-Initiated JOL	Agent-Initiated JOL
High PK	20	13
Low PK	28	17

Research Question #3: Are there significant differences between the duration of the use of the metacognitive strategies in the SRL palette based on the students' level of prior knowledge?

To answer this question, we performed several *t*-tests. First, we conducted a repeated-measures *t*-test to examine the differences between prior knowledge groups on the duration of engagement in JOL, and whether this differed based on self or agent prompted-use. Results indicated that there were no significant differences between groups; $t(14) = -1.54$; $p = .15$, which informs us that students in the high and low prior knowledge groups did not significantly differ on the duration spent using JOL. From our data, we determined that students were not prompted by the agents to engage in FOK or CE, and to assess the duration spent on those, we conducted

two independent samples *t*-tests. Our results indicated no significance, which implies that students in the high and low prior knowledge groups did not differ based on the duration spent engaging in FOK and CE; $t(46) = -.47$, $p = .64$ for FOK and $t(46) = .35$; $p = .73$ for CE. We therefore determined that the duration spent engaging in these metacognitive processes did not significantly differ based on students' level of prior knowledge. Overall, these results once again suggest that prior knowledge may not accurately predict how and when students engage in SRL processes in a hypermedia learning environment.

Table 5. Descriptive Statistics for Repeated-Measures *t*-test

	M	*SD*
DurationJOL – Self-Initiated	8.74	15.52
DurationJOL – PA-Initiated	29.98	47.33

Table 6. Descriptive Statistics for Independent Samples *t*-test

	Duration of FOK	*M*	*SD*
High PK	89.279	3.72	8.94
Low PK	129.124	5.38	14.75
	Duration of CE	*M*	*SD*
High PK	70.4	2.93	8.09
Low PK	52.7	2.30	6.33

Educational and Scientific Importance

The results from this study have important implications for research and education. Research on self-regulated learning has expanded to many subject areas, and has focused on prior knowledge as an important individual differences factor (Zimmerman & Schunk, 2011). However, few studies have investigated prior knowledge as an individual differences variable that may impact the manner in which learners monitor and regulate their cognitive and metacognitive processes during hypermedia learning. This study investigated how students with different levels of prior knowledge engage in metacognitive processes; and the results challenge past findings. It may be, however, that students with high prior knowledge differ in some way when engaging in these metacognitive strategies compared to students with low prior knowledge; and future research should focus on examining where these differences may lie. Our processs data will be examined for specific behavioral signatures that may be indicative of the specific SRL processes used by low- and high- prior knowledge learners.

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