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## Note-taking while learning hypermedia: Cognitive and motivational considerations

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## ABSTRACT

The non-linear format of hypermedia requires the use of self-regulated learning (SRL) processes, including making decisions about which representation to access. The design of hypermedia environments can make these decisions difficult, and may result in extraneous cognitive load. Note-taking, a SRL strategy may offload extraneous cognitive load while learning with hypermedia. This study examined factors related to undergraduate students' note-taking while learning with hypermedia. Think-aloud, self-report, pretest, and posttest data were collected from 53 undergraduates while they learned about a challenging science topic for 30 min with hypermedia. Results indicated that participants' prior domain knowledge, as measured by the pretest, did not significantly predict the content of their notes. However, motivation, as measured by a self-report questionnaire, had a significant relationship with the content of the participants' notes. Specifically, intrinsic motivation had a significant negative relationship while extrinsic motivation had a significant positive relationship with the content of notes. Additionally, there was a significant interaction between the content of the participants' notes and their use of self-regulatory processes while learning with hypermedia.

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## 1. Introduction

Computer-based learning environments (CBLEs) have been used to assist students in learning about challenging topics (Derry & Lajoie, 1993; Lajoie & Azevedo, 2006). Some CBLEs are designed to foster active participation in the acquisition of knowledge by acting as intellectual partners with the learner so that critical thinking and higher order learning are facilitated (Jonassen & Reeves, 1996; Perez & Solomon, 2005). This approach embraces the concept of learning with CBLEs because learners are provided with a cognitive tool that supports knowledge construction and exploration. Cognitive tools are defined as tools that are developed with the aim of enhancing the cognitive capabilities of learners during problem solving, thinking, and learning (Derry & Lajoie, 1993; Jonassen & Reeves, 1996; Lajoie, 2000; Lajoie & Azevedo, 2006). Hypermedia, an example of a CBLE that has been used to enhance cognitive abilities (Lajoie, 2000; Lajoie & Azevedo, 2006), provides an environment in which learners are offered a high degree of control and access to multiple representations (Williams, 1996). Learners can access multiple representations, including audio, video, animation, text, and/or graphics, in a variety of sequences (Jonassen & Reeves, 1996). While this design offers a visually rich and interactive environment, research has identified some challenges of learning with hypermedia (see Azevedo, 2005; Jacobson & Archodidou, 2000; Jonassen & Land, 2000). In order to explain these challenges, re-

search has examined the relationship between cognitive load and SRL with hypermedia.

## 1.1. Cognitive load and learning with hypermedia

The challenges faced when learning with hypermedia can be explained, at least in part, by cognitive load imposed on working memory. 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). Extraneous cognitive load, defined as the challenges imposed upon the learner due to the instructional design of the environment (Seufert, Jänen, & Bünken, 2007), is of particular concern during learning with hypermedia (Gerjets & Scheiter, 2003; Kester, Kirschner, & van Merriënboer, 2005). The design of hypermedia offers a substantial amount of information distributed over a variety of representations (i.e. text and diagrams) which requires learners to make decisions about which representation to access and then integrate information from these representations (Seufert et al., 2007). This requirement can result in extraneous cognitive overload and the loss of information due to the process of splitting attention between multiple representations (split attention effect; Seufert et al., 2007). Poorly designed hypermedia environments may enhance the split attention effect. For example, studies have suggested that verbal information presented in both text and diagrams is more difficult to integrate if the design of the hypermedia environment does not provide these two sources of information

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within close proximity (e.g., Chandler & Sweller, 1991, 1992; Mayer & Moreno, 1998; see Ayres & Sweller, 2005 for an overview). This example illustrates the impact of extraneous cognitive load, in which learners' visual subprocessor in their working memory may become overloaded if they are presented with information provided in both text and diagrams. Recently, research has considered how self-regulation may assist learners in meeting these challenges of learning with hypermedia.

### 1.2. Self-regulation and learning with hypermedia

The process of integrating information from multiple sources in hypermedia is one of many challenges faced by learners using hypermedia. The need to integrate information creates cognitive and metacognitive demands and research has found that processes related to *monitoring*, *planning*, and *strategy use* assist learners in meeting these demands (e.g., Azevedo, 2007, in press; Azevedo, Greene, & Moos, 2007; Azevedo & Witherspoon, in press; Greene, Moos, Azevedo, & Winters, 2008; Moos & Azevedo, 2006, 2008a, 2008b). Collectively, these processes are related to self-regulated learning (SRL; Boekaerts, Pintrich, & Zeidner, 2000; Pintrich, 2000; Schunk & Zimmerman, 2008; Zimmerman & Schunk, 2001). While a number of SRL theoretical approaches have emerged, research examining learning with hypermedia has been guided by a SRL model that combines key components of Pintrich (2000) formulation of self-regulation as a four-phase process and Winne (2001) and Winne and Hadwin's (1998) information-processing theory (IPT) of SRL (see Azevedo, Cromley, Winters, Moos, & Greene, 2005). Pintrich's (2000) theoretical perspective offers a comprehensive framework by characterizing SRL as having four different phases and four different areas. The four phases include: *planning*, *monitoring*, *control*, and *reflection*. These phases are intended to reflect common assumptions shared by many SRL models (Zimmerman, 2001). In phase one, the learner plans, sets goals, and activates knowledge about the context, text, and self. Phase two is defined when the learner exhibits metacognitive awareness and monitoring of cognition. In phase three, the learner selects cognitive strategies and regulates different aspects of the context, task, and self. Lastly, in phase four, the learner makes cognitive judgments and reflections on the context, task, and self. (Winne & Hadwin, 1998) theoretical perspective of SRL also proposes four phases, though these phases are conceptually distinct from Pintrich (2000) theoretical approach. Winne and Hadwin (1998) present a SRL model which proposes the following four phases of SRL: (1) understanding the task, (2) goal-setting and planning how to reach the goal(s), (3) enacting strategies, and (4) metacognitively adapting studying. In the first phase, the learner develops a perception of a learning task, which is partly dependent on the retrieval of prior domain knowledge. Prior domain knowledge, drawn from long-term memory into working memory, facilitates the definition of the task and task performance (Winne, 2001). In the second phase, the learner frames multifaceted goals and plans how to reach the goal(s) (Winne & Hadwin, 1998). In phase three, the learner enacts tactics and/or strategies, while phase four includes monitoring activities and cognitive evaluations about discrepancies between goal(s) and current domain knowledge (Winne, 2001; Winne & Hadwin, 1998).

### 1.3. Note-taking and learning with hypermedia

Research guided by Pintrich (2000) and Winne and Hadwin's (1998) theoretical approach to SRL has routinely found that learners of all developmental groups generally rely on a specific subset of processes related to SRL. Learners, particularly those who have lower prior domain knowledge (Moos & Azevedo, 2008a), tend to use *strategies* much more frequently than other SRL processes. Fur-

thermore, note-taking tends to be one of the more dominant (Moos & Azevedo, 2008a). Note-taking is the process of selecting information in the environment and subsequently recording this information (Piolat, Olive, & Kellogg, 2005). This strategy has been identified as a potentially effective means to offload extraneous cognitive load during learning with hypermedia because it places information in a readily available external location as opposed to consuming valuable working memory during learning (Van Meter, Yokoi, & Pressley, 1994). Despite the potential effectiveness of note-taking during learning with hypermedia, some research has found that undergraduates do not effectively use this strategy. For example, Bonner and Holliday (2006) interviewed 23 undergraduates learners over a semester-long science course and found substantial variability in the quality of their notes. While some undergraduates demonstrated the ability to effectively take notes, other undergraduates demonstrated weak self-regulating learning strategies, including inadequate note-taking strategies. Similarly, Peverly, Brobst, Graham, and Shaw (2003) found that undergraduates do not effectively use self-regulated learning processes, including note-taking. These researchers examined the relationship among several variables, including background knowledge, self-regulation, note-taking, and performance, with a sample of 82 undergraduate learners. Findings from these lines of research suggest that while note-taking may be an important process in learning, there is variability in the quality of notes even for older learners such as undergraduates.

Underlying these findings is the issue of why undergraduates take notes, an area that has received limited empirical attention in the context of learning with hypermedia. As suggested by Eccles and Wigfield (2002) and Zimmerman (2008), a fruitful direction for future research is to explore the complex relationship between various theoretically grounded constructs of motivation and SRL processes, such as note-taking. Motivational theories have distinct perspectives, which focus on goals, beliefs, and/or values (Eccles & Wigfield, 2002). Several researchers (see Murphy & Alexander, 2000) have advocated examining theoretically grounded constructs of motivation that capture these distinct perspectives. Based on this assertion, this current study examined the relationship between the following motivation constructs and undergraduates' note-taking during learning with hypermedia: *self-efficacy*, *intrinsic motivation*, *extrinsic motivation*, *task value*, and *control beliefs*.

Self-efficacy is a motivation construct that is grounded in the social cognitive theory. This theory, originated by Bandura (1986), assumes that learners are self-regulating and proactive. Furthermore, this theory suggests that there is dynamic interplay between the environment, learner, and the learner's behavior. Self-efficacy is considered to be a critical component of this interplay and is conceptualized as the self-perception of one's capabilities to meet situational demands based on current states of motivation, course of actions needed, and cognitive resources (Wood & Bandura, 1989). In turn, these self-perceptions are strongly predictive of the learner's performance, task choice, and persistence (Meece, Wigfield, & Eccles, 1990). Similarly, Expectancy-value theories (i.e. Wigfield & Eccles, 2000) also highlight the role of the learner's judgments in performance. However, Expectancy-value theories focus on anticipated outcomes and differentiate expectancy judgments from efficacy judgments. Subjective task value is a critical component to this theoretical approach to motivation and encompasses components related to the learner's interest, the utility, and the importance of the task (Wigfield & Eccles, 2000).

Intrinsic motivation and extrinsic motivation emphasize different components. Intrinsic motivation is defined as an internal desire to engage in a behavior due to pleasure, interest, enjoyment, and/or challenge, while extrinsic motivation refers to the

engagement of behavior due to external incentives, such as money, grades, and praise (Berlyne 1960; Hunt, 1965; White, 1959). Harter (1981) arguably put forth the most famous motivation scale. This scale conceptualized these two motivation constructs as mutually exclusive and has been used in a myriad of studies examining the relationship between extrinsic and intrinsic motivation (e.g., Guay, Boggiano, & Vallerand, 2001; Newman, 1990; Wong, Wiest, & Cusick, 2002). Lastly this study also considered control beliefs, which relate to expectations about the extent to which the learner can influence failure and success in a given outcome (Skinner, Welborn, & Connell, 1990).

#### 1.4. Current study

As highlighted in the preceding sections, a number of factors should be considered when examining learning with hypermedia. First, the issue of *why* undergraduates take notes during learning with hypermedia remains unresolved. As such, this study considered the role of motivational variables in note-taking with hypermedia. Additionally, cognitive and metacognitive factors related to SRL have been demonstrated to be critical during learning with hypermedia. Consequently, this study also examined the possible interaction between note-taking and use of other SRL processes during learning with hypermedia. Lastly, research has found that prior domain knowledge is a particularly important factor to examine when considering the learning process (Shapiro, 1999, 2000, 2004). Based on this line of research, this study also considered the role of prior domain knowledge in note-taking and learning outcomes with hypermedia. This study was guided by the following research questions: (1) to what extent do cognitive and motivational factors predict the content of undergraduates' notes while they learn with hypermedia? (2) To what extent does the content of notes predict learning outcomes with hypermedia, over and beyond that of prior domain knowledge? And (3) to what extent is there an interaction between use of self-regulatory processes and content of notes on learning outcomes with hypermedia?

## 2. Methods

### 2.1. Participants

Participants included 53 ( $N = 53$ ) undergraduate learners, four of which were freshman (8%), six were sophomores (11%), 17 were juniors (32%), and 24 were seniors (45%). Two learners did not report their class standing. The participants' average grade point average was 3.28 ( $SD = .45$ ), and their average age was 21.04 ( $SD = 2.89$ ).

### 2.2. Measures

#### 2.2.1. Prior domain knowledge, learning outcomes, and content of notes

This study examined undergraduates learning of the circulatory system with hypermedia. As such, participants completed a pretest and posttest on the circulatory system. The pretest, which measured the participants' prior domain knowledge of the circulatory system, is identical to the posttest, which measured the participants' learning outcomes. The pretest and posttest are composed of two sections. The first section was designed to measure declarative knowledge of the circulatory system. Declarative knowledge is defined as understanding of definitions, properties of concepts, and facts (Graesser, McNamara, & VanLehn, 2005). An example of declarative knowledge in this study includes an understanding that the heart is a pump. The section measuring declarative knowledge is composed of 13 matching items. Each participant received either a 1 (for a correct match between a concept and its corresponding

definition) or a 0 (for an incorrect match between a concept and definition) for each item on both his or her pretest and posttest (range 0–13). See Appendix A for the section measuring declarative knowledge. The second section was designed to measure conceptual knowledge of the circulatory system. Conceptual knowledge is defined as understanding interrelationships between definitions, properties of concepts, and facts, which include declarative and procedural knowledge (Chi, 2000, 2005; Graesser et al., 2005; Markman & Gentner, 2000). An example of conceptual knowledge in this study includes an understanding of how the different chambers of the heart work together to pump blood throughout the body. The section measuring conceptual knowledge is a mental model essay that asks participants 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 together, and also explain how they contribute to the healthy functioning of the body." In order to code the participants' mental model essay of the circulatory in their pretest and posttest, a coding scheme developed by Azevedo and colleagues was used (see Azevedo et al., 2005; Greene et al., 2008; Moos & Azevedo, 2008a, 2008b). This coding scheme is based on extensive work done by Chi (2000, 2005) and Chi, de Leeuw, Chiu, & LaVancher (1994). The coding scheme consists of 12 mental models, which represent the progression from a low level of understanding to a high level of understanding of the circulatory system.

This coding scheme was also used to measure the content of the participants' notes. As with the mental model essays, each participant received one score for the content of his or her notes with a possible range of this score was 1–12. Higher scores indicated that the participants' notes contained conceptually more information. For example, a participant would receive a score of three if his or her notes contained information indicating that blood circulates around the body and the purpose of this circulation is to provide oxygen and nutrients. On the other hand, another participant would receive a score of five if she or he had this information in addition to notes indicating the heart is a pump, the role of arteries, veins, and lungs in the circulation of blood. A participant would receive a 12 if the content of his/her notes also included structural details of the heart, described the circulation loop throughout the body, and mentioned one of the following: electrical system, transport functions of blood, and/or details of blood cells. See Appendices C and D for example notes from two participants.

#### 2.2.2. Motivation

In order to capture various constructs of motivation, participants completed the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991). The MSLQ is a self-report questionnaire that consists of 81 questions. Of these 81 questions, four questions refer to intrinsic motivation, four questions refer to extrinsic motivation, six questions refer to task value, and four questions refer to control beliefs. All questions were answered on a seven point Likert scale (1 = not at all true of me, 7 = very true of me). The scoring of these questions followed the scoring procedure used for the complete MSLQ (see Pintrich et al., 1991). In this procedure, each participant received one score for each motivation construct. The MSLQ has previously demonstrated both reliability and validity. Previous research using the MSLQ has reported Cronbach's alpha ranging from .52 to .93 for the items. In addition, confirmatory factor analysis in previous research has demonstrated reasonable factor validity for each scale.

#### 2.2.3. Self-regulated learning

A think-aloud protocol (Ericsson, 2006; Ericsson & Simon, 1994) was used to measure participants' SRL during learning. While various methodologies have been used to measure SRL, it has been suggested that *real* time measurements should be used because

SRL is a dynamic process that unfolds within particular contexts (Perry, VandeKamp, & Mercer, 2002). The think-aloud protocol offers a process methodology that measures SRL processes in real time during learning (Azevedo, 2005). The think-aloud has an extensive history in cognitive psychology and cognitive science (see Ericsson, 2006; Ericsson & Simon, 1994; Feltoovich, Ford, & Hoffman, 1997; Newell & Simon, 1972 for an extensive review), and is deeply rooted in the information-processing theory. A guiding assumption of the think-aloud protocol is that thought processes are a sequence of states and that information in a state is relatively stable (Ericsson, 2006; Ericsson & Simon, 1994). This assumption suggests that asking learners to verbalize their thoughts during learning will not disrupt the learning process. However, this protocol also assumes that the learner is *not* asked to also describe or explain what they are doing during the think-aloud (Ericsson & Simon, 1993). If learners are asked to verbalize thoughts, as opposed to additionally engaging in the process of reflection, description, and/or explanation, then the sequence of thoughts will not be disrupted. The think-aloud protocol is an effective measure to capture SRL processes in real time during learning, if administered properly.

The SRL processes captured during the think-aloud were coded using a coding scheme developed by Azevedo, Cromley, & Seibert (2004a), Azevedo, Winters, & Moos (2004b). Their model was based on several recent models of SRL (Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998; Zimmerman, 2001). The modified coding scheme includes 27 SRL processes from the three SRL categories of *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. This phase of data analysis yielded a total of 1,696 coded SRL segments for all participants ( $M_{SRL} = 32$  per participant). Thirty percent of the transcripts ( $N = 17$ ) were used for inter-rater reliability for the coding of the SRL processes, and there was agreement on 496 out of 517 coded SRL segments, yielding a reliability coefficient of .96. Disagreements on the coding of SRL processes were resolved through discussion.

### 2.3. Learning environment

During the learning task, participants used Microsoft Encarta Reference Suite™ (2003) to learn about the circulatory system. This hypermedia environment contains three relevant articles to the circulatory system. These articles (heart, blood, and circulatory system) are comprised of 16,900 words, 35 illustrations, 107 hyperlinks, 18 sections, and one video. It should be noted that the participants' navigation was not constrained to these three articles. They were told that they could freely search all of Encarta while learning about the circulatory system.

### 2.4. Procedure

The author individually tested all participants. Following the collection of consent forms, participants were given 15 min to complete the pretest. The following instructions for the learning task were provided once the participants completed the pretest: "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 min. 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." Following these instructions, participants were told they could take notes during the hypermedia-learning task, if they chose to do so. They were also told that they could use their notes in whatever manner they deemed most appropriate during the hypermedia-learning task, but they could not use them on the posttest. Next, participants were provided a training session of the hypermedia environment, Microsoft Encarta Reference Suite™ (2003). During this training session, the participants practiced using the hyperlinks and search functions in the environment. Next, participants were given 5 min to complete the MSLQ (Pintrich et al., 1991). Following completion of this scale, participants were then given 30 min to learn about the circulatory system with Encarta. During the 30-min learning task, participants were allowed to take notes, but were not required to do so. Additionally, they thought aloud so that their use of SRL processes during learning could be captured. Following the 30-min learning task, participants were given 15 min to complete the posttest.

## 3. Results

### 3.1. Question 1

To what extent do cognitive and motivational factors predict the content of undergraduates' notes while they learn with hypermedia? Twenty-eight of the 53 participants decided to take notes during learning. Thus, the analyses for all three research questions are based on the notes from these 28 participants. In order to examine research question one, a stepwise regression was run in which the variables of prior knowledge (declarative and conceptual) and motivation (intrinsic, extrinsic, task value, control beliefs, and self-efficacy) were used to predict the content of notes. See (Table 1) for descriptive statistics for these variables. This analysis revealed that a model including extrinsic motivation and intrinsic motivation was a significant predictor of the content of undergraduate notes,  $F(2, 27) = 40.459, p = .004$ . This model predicted 30.9% of the variance in the content of the participants' notes. Analysis of the main effects indicated that extrinsic motivation was a significant positive predictor ( $\beta = .420, p = .015$ ), while intrinsic motivation was a significant negative predictor ( $\beta = -.444, p = .010$ ).

**Table 1**  
Mean (and standard deviation) for prior knowledge and motivation.

Variable	Mean (standard deviation)
Prior declarative knowledge <sup>a</sup>	7.98 (3.13)
Prior conceptual knowledge <sup>b</sup>	5.45 (3.10)
Intrinsic motivation <sup>c</sup>	4.83 (1.02)
Extrinsic motivation <sup>c</sup>	4.47 (0.90)
Control beliefs <sup>c</sup>	4.80 (1.02)
Task value <sup>c</sup>	4.42 (1.13)
Self-efficacy <sup>c</sup>	5.08 (0.98)

<sup>a</sup> Range = 0–13.

<sup>b</sup> Range = 1–12.

<sup>c</sup> Range = 1–7.

### 3.2. Question 2

To what extent does the content of notes predict learning outcomes with hypermedia, over and beyond that of prior domain knowledge? In order to examine this research question, two separate hierarchical regressions were run. In the first hierarchical regression, prior declarative knowledge (entered in the first step) and the score for the content of the participants' notes (entered into the second step) were used to predict declarative learning outcomes. See (Table 2) for descriptive statistics for learning outcomes and score for the content of the participants' notes. This analysis revealed that the overall model was a significant predictor,  $F(2, 27) = 29.403$ ,  $p = .001$ . This model predicted 42.9% of the variance in the participants' posttest score for the matching task. However, analysis of the main effects indicated that while prior declarative knowledge was a significant positive predictor ( $\beta = .592$ ,  $p = .001$ ) of declarative learning outcomes, the content of notes was not a significant predictor over and beyond that of prior declarative knowledge ( $p > .05$ ).

In the second hierarchical regression, prior conceptual knowledge (entered in the first step) and the score for the content of the participants' notes (entered into the second step) were used to predict conceptual learning outcomes. See (Table 2) for descriptive statistics for learning outcomes and score for the content of the participants' notes. This analysis revealed that the overall model was a significant predictor,  $F(2, 27) = 69.368$ ,  $p = .001$ . This model predicted 44.7% of the variance in the participants' posttest score for the mental model essay. However, analysis of the main effects indicated that while prior conceptual knowledge was a significant positive predictor ( $\beta = .648$ ,  $p = .001$ ) of conceptual learning outcomes, the content of notes was not a significant predictor over and beyond that of prior conceptual knowledge ( $p > .05$ ).

### 3.3. Question 3

To what extent is there an interaction between use of self-regulatory processes and content of notes on learning outcomes with hypermedia? In order to examine this research question, two separate hierarchical regressions were run. In the first hierarchical regression, prior declarative knowledge (entered in the first step), the score for the content of the participants' notes (entered into the second step), and the interaction between the score for the content of the participants' notes and use of SRL processes (entered in the third step) were used to predict declarative learning outcomes. For the purposes of this research question, the total frequency of all SRL processes was used. See (Table 3) for descriptive statistics of SRL processes. Analyses for this regression indicate that there was a not a significant interaction between use of SRL processes and content on notes for declarative learning outcomes.

In the second hierarchical regression, prior conceptual knowledge (entered in the first step), the score for the content of the participants' notes (entered into the second step), and the interaction

**Table 2**

Mean (and standard deviation) for learning outcomes and notes.

Variable	Mean (standard deviation)
Declarative learning outcome <sup>a</sup>	10.89 (2.45)
Conceptual learning outcome <sup>b</sup>	8.26 (3.25)
Content of notes <sup>c</sup>	4.53 (4.79)

<sup>a</sup> Range = 0–13.

<sup>b</sup> Range = 1–12.

<sup>c</sup> Range = 1–12.

**Table 3**

Mean use of individual SRL processes during hypermedia-learning task.

SRL processes	Mean
<i>Planning</i>	
Planning	0.02
Prior domain knowledge activation	1.66
Recycle goal in working memory	1.08
Sub-goals	1.04
<i>Monitoring</i>	
Content evaluation (+)	0.83
Content evaluation (–)	1.55
Feeling of knowing (+)	2.64
Feeling of knowing (–)	1.30
Judgment of learning (+)	0.79
Judgment of learning (–)	0.43
Monitoring progress toward goals	0.86
Monitor use of strategies	0.15
Time management	0.47
<i>Strategy use</i>	
Control video	0.96
Coordinating informational sources	0.79
Draw	0.22
Goal-directed search	0.38
Inferences	0.41
Knowledge elaboration	0.79
Memorization	0.17
Read notes	0.43
Re-reading	3.53
Summarization	5.91
Taking notes	5.08

between the score for the content of the participants' notes and use of SRL processes (entered in the third step) were used to predict conceptual learning outcomes. For the purposes of this research question, the total frequency of all SRL processes was used. See (Table 3) for descriptive statistics for SRL processes. This analysis revealed that the overall model was a significant predictor,  $F(3, 27) = 13.465$ ,  $p < .001$ . This model predicted 58.1% of the variance in the participants' conceptual learning outcomes. Analysis of the main effects indicated that there was a significant interaction between use of SRL processes and content on participants' notes on conceptual learning outcomes ( $\beta = .483$ ,  $p = .002$ ).

## 4. Discussion

While previous research has examined note-taking, relatively little research has used process data to examine cognitive and motivational factors related to note-taking with hypermedia. Results from research question one begin to address why undergraduates take notes by examining the role of motivation in the use of this strategy. Results from this research question found that intrinsic motivation was a significant negative predictor while extrinsic motivation was a significant positive predictor. These findings suggest that learners who are intrinsically motivated may actually have less conceptual content in their notes than learners who are extrinsically motivated. While the significant relationship between these specific motivation constructs and the learning process has been long documented (see Murphy & Alexander, 2000 for a review of motivation), the relationship between extrinsic motivation and the content of the participants' notes in this study is somewhat surprising. This finding may be explained, at least in part, by nature of the formal educational system in the United States of America. Note-taking has become an integral part of formal schooling, particularly at the undergraduate level. It is often assumed that undergraduates should take notes during lectures. This cultural norm may lead learners to develop a perception that there is a strong association between taking notes and performance. Consequently, learners who are extrin-

sically motivated, and thus have an underlying motivation to perform well on a formal assessment, may frequently engage in the strategy of note-taking. The reliance on this particular strategy may be particularly strong when learning in environments such as hypermedia. As highlighted in the introduction, hypermedia environments may create extraneous cognitive load, particularly if the environment requires integration of information from multiple sources (Seufert et al., 2007). Note-taking may be an effective strategy to offload information that is presented in a number of informational sources within a hypermedia environment. As a result, participants who are extrinsically motivated may use this strategy in an attempt to cognitively manage substantial information from a number of information sources within hypermedia. This explanation is a hypothesis and further examination is needed, an issue addressed in the future directions section.

While extrinsic and intrinsic motivation predicted content of notes, prior domain knowledge was not a significant predictor. In the broadest sense, this finding is not consistent with some previous research that has examined the relationship between prior domain knowledge and learning with hypermedia. For example, Moos and Azevedo (2008a) found a significant relationship between prior domain knowledge and use of SRL processes during learning with hypermedia. Specifically, this study found that undergraduates who had high prior domain knowledge tended to rely on monitoring processes during learning with hypermedia, while undergraduates who had lower prior domain knowledge tended to rely on strategies. However, this study examined the frequency in which the undergraduates used SRL processes, such as note-taking, and not the quality of these processes. Examining both the frequency and quality may provide a more comprehensive explanation of the factors related to note-taking with hypermedia.

The second and third research questions examined the extent to which the content of notes predicted learning outcomes, over and beyond that of prior domain knowledge, and whether there was an interaction with the use of SRL processes. Results from these research questions yielded two interesting findings. First, the content of notes did not significantly predict learning outcomes, over and beyond that of prior domain knowledge. This finding is consistent with some recent research. For example, Gil, Vidal-Abarca, and Martínez (2008) assigned college-aged learners to two experimental groups (“no-notes” and “notes”) to determine the relationship between note-taking and performance with electronic text. This line of research found that undergraduates in the “no-notes” group scored significantly higher than undergraduates who were allowed to take notes while learning with electronic text. The data from this study suggested that undergraduates who were allowed to take notes explored less frequently while learning with electronic text. Non-linear and open-ended environments, such as hypermedia, may require exploration in order for learners to locate relevant information. As such, extensive note-taking may detract from learners’ exploration in the environments and, as a result, limit their exposure to relevant information. This limited exposure may explain why participants in the “notes” condition performed significantly worse than participants assigned to the “no-notes” condition (Gil et al., 2008). Additionally, process data from this study also found that participants in the “notes” condition often paraphrased when they engaged in the process of note-taking. This action of paraphrasing may not allow for high level integration during the learning process, which also may explain why these participants performed significantly worse than participants who did not take notes.

Findings from Gil et al.’s (2008) study are consistent with results from research questions two and three, which indicated that the content of notes did not significantly predict learning outcomes with hypermedia. An additional explanation of this finding

may be related to the role of note-taking during learning with hypermedia. Meaningful learning may be limited during note-taking because relevant information is simply being moved from one external source (the hypermedia environment) to another external source (the learner’s notes). Other processes are needed to ensure that this information is, at some point, moved into long-term memory. As such, note-taking will not lead to any meaningful learning, in the absence of other SRL processes. This explanation is consistent with the results from the third research question. Findings from this research question suggest that there is an interaction between the content of notes and use of SRL processes with learning outcomes. This finding has specific implications for the design of hypermedia environments, an issue addressed in the following section.

#### 4.1. Future directions

Future research should consider empirically examining how undergraduates learn with hypermedia environments that include an embedded note-taking template in the presence and absence of support. While research suggests that undergraduates have the capacity to take notes, and frequently do so when learning with hypermedia (Moos & Azevedo, 2006, 2008a, 2008b), it should not be assumed that they have the capacity to effectively use this strategy. As highlighted by Bonner and Holliday (2006), undergraduate learners may need some additional scaffolding in order to effectively take notes. In fact, undergraduates could benefit from note-taking support during learning with hypermedia, which could be delivered in various formats including short tutorials and/or embedded scaffolds. Additionally, results from this study also indicate that note-taking is insufficient if used in the isolation of other SRL processes. As such, future research should also consider examining the effect of scaffolding other processes related to SRL, in addition to scaffolding the use of note-taking during learning with hypermedia.

#### 4.2. Limitations

The following three limitations of the study need to be identified. First, it should be noted that this study treated extrinsic and intrinsic motivation as mutually exclusive motivation constructs. However, as suggested by some researchers (see Murphy & Alexander, 2000), this characterization of extrinsic and intrinsic motivation is open to discussion. Students may in fact engage in behavior because it both interests them (intrinsic motivation) and because it will better enable them to earn a high grade (extrinsic motivation). Future research would be well served to use methodology that accounts for this conceptualization of extrinsic and intrinsic motivation. Second, this study focused on the content area of the circulatory system, which is consistent with a line of research examining the role of SRL processes in learning with hypermedia (Azevedo, 2007, in press; Azevedo and Witherspoon, in press, 2007; Greene et al., 2008; Moos & Azevedo, 2006, 2008a, 2008b). However, the complex relationship between note-taking and learning with hypermedia may not be fully understood until this research agenda is extended to various content areas, including both ill-defined and well-defined domains. Third, research has also demonstrated developmental differences in a number of the constructs examined in this study, including motivation and use of learning strategies (see Pintrich & Zusho, 2002). Thus, the relationships found in this study may be constrained to the particular developmental group of undergraduates. Future research should examine potential developmental constraints on the relationship between various learning strategies during learning with hypermedia.

**Appendix A. Matching section measuring declarative knowledge**

Match as many components of the heart as you can.

1. Valve	A muscular pump that circulates blood throughout the body
2. Ventricle	The fluid that circulates through the heart and blood vessels
3. Vein	Pattern of blood flow through the lungs
4. Heart	The main organ that supplies the blood with oxygen
5. Lung	A muscular chamber that pumps blood out of the heart
6. Pulmonary circulation	A structure which keeps blood from flowing backwards within the circulatory system
7. Aorta	The impulse-generating tissue located in the right atrium. The normal heartbeat starts here
8. Atrium	Thin-walled vessel that carries blood back toward the heart
9. Artery	Smallest blood vessel in the body
10. Capillary	Largest artery in the body; carries blood from the left ventricle of the heart to the thorax and abdomen
11. Blood	Thick-walled, elastic vessel that carries blood away from the heart to the arterioles
12. Pacemaker	Flow of blood from left ventricle through all organs except the lungs
13. Systemic circulation	Chamber of the heart that receives blood from veins and pumps it to the ventricle on the same side of the heart

**Appendix B**

Mental model coding scheme (from Azevedo et al., 2004a) used to score participants' notes and their pretest/posttest essay (range = 1–12).

1. No understanding	7. Single loop with lungs <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• mentions lungs as a “stop” along the way</li> <li>• describe “purpose” – oxygen/nutrient transport</li> </ul>
2. Basic global concepts <ul style="list-style-type: none"> <li>• blood circulates</li> </ul>	8. Single loop with lungs – Advanced <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• mentions Lungs as a “stop” along the way</li> <li>• describe “purpose” – oxygen/nutrient transport</li> <li>• mentions one of the following: electrical system, transport functions of blood, details of blood cells</li> </ul>
3. Global concepts with purpose <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• describes “purpose” - oxygen/nutrient transport</li> </ul>	9. Double loop concept <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describes “purpose” - oxygen/nutrient transport</li> <li>• mentions separate pulmonary and systemic systems</li> <li>• mentions importance of lungs</li> </ul>
4. Single loop – Basic <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> </ul>	10. Double loop – Basic <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describe “purpose” - oxygen/nutrient transport</li> <li>• describes loop: heart-body-heart-lungs-heart</li> </ul>
5. Single loop with purpose <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describe “purpose” - oxygen/nutrient transport</li> </ul>	11. Double loop – Detailed <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describe “purpose” - oxygen/nutrient transport</li> <li>• describes loop: heart-body-heart-lungs- heart</li> <li>• structural details described: names vessels, describes flow through valves</li> </ul>
6. Single loop – Advanced <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describe “purpose” – oxygen/nutrient transport</li> <li>• mentions one of the following: electrical system, transport functions of blood, details of blood cells</li> </ul>	12. Double loop – Advanced <ul style="list-style-type: none"> <li>• blood circulates</li> <li>• heart as pump</li> <li>• vessels (arteries/veins) transport</li> <li>• describe “purpose” - oxygen/nutrient transport</li> <li>• describes loop: heart-body-heart-lungs-heart</li> <li>• structural details described: names vessels, describes flow through valves</li> <li>• mentions one of the following: electrical system, transport functions of blood, details of blood cell</li> </ul>

**Appendix C**

Example from participant who received a mental model score of 11 for her notes.

main heart, blood, blood vessels

vital function: increase flow of blood  
meet energy demand  
regulate body temp

Sends clotting cells

atria = auricles  
& receive

ventricles = pump blood  
veins = back to the heart

arteries = away from the heart

aorta = largest artery in the body

Right side pumps oxygen poor blood to the lungs  
left side pumps oxygen rich blood to the body

poor blood SVC & IVC → right side → pulmonary artery → lungs → fresh blood → pulmonary vein → left side → aorta → body

pericardium  
superior vena cava  
aorta  
pulmonary artery  
Right Atrium  
tricuspid valve  
Ventricle  
myocardium  
inferior vena cava  
pulmonary vein  
left Atrium  
mitral valve  
Ventricle

**Appendix D**

Example from participant who received a mental model score of 5 for her notes.

heart - hollow muscle organ pumps blood to body

heart, blood, blood vessels make up circ. syst.

Responsible for distribut. oxygen & nutrients to body & carry away carbon dioxide & other waste products.

circulatory system's power supply is heart.

Heart made primarily of muscle tissue

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