

Abstract

Title of Dissertation: LEARNING WITH HYPERMEDIA: EXAMINING
COGNITIVE, MOTIVATIONAL, AND CONTEXTUAL
FACTORS

Daniel Charles Moos, Doctor of Philosophy, 2007

Dissertation directed by: Dr. Roger Azevedo
Department of Human Development

Think-aloud, pretest, posttest, and self-efficacy data collected from 85 undergraduates were used to examine factors related to learning with hypermedia. Participants, randomly assigned to either the No Scaffolding (NS) condition or Conceptual Scaffolding (CS) condition, were given 30 minutes to learn about the circulatory system with hypermedia. Participants in the NS condition received an overall learning goal during the hypermedia learning task, while participants in the CS condition received five guiding questions in addition to the same overall learning goal during the hypermedia learning task. There are four findings from this study. First, results from the pretest and posttest indicated that prior domain knowledge significantly predicted both declarative and conceptual knowledge learning outcomes with hypermedia. Second, results from the self-report self-efficacy questionnaire indicated that while self-efficacy significantly fluctuated during learning, the provision of conceptual scaffolds was not related to this fluctuation. Third, results from a think-aloud protocol indicated that self-efficacy significantly predicted monitoring and planning processes, but not strategy use during the hypermedia learning task. Fourth, results from a think-aloud protocol also indicated that self-regulatory processes (particularly processes related to monitoring) significantly predicted conceptual and declarative learning outcomes. Educational and scientific implications are discussed.

LEARNING WITH HYPERMEDIA: EXAMINING COGNITIVE, MOTIVATIONAL,
AND CONTEXTUAL FACTORS

by

Daniel Charles Moos

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2007

Advisory Committee:

Associate Professor Roger Azevedo, Chair/Advisor
Professor William Holliday
Professor Robert Mislevy
Assistant Professor Min Wang
Professor Allan Wigfield

Acknowledgements

I would like to first acknowledge and thank my Ph.D. mentor and advisor, Dr. Roger Azevedo. In addition to providing me with extensive opportunities to be involved in research, Dr. Roger Azevedo has also been the ideal mentor. Passionate about his research, Dr. Azevedo sets high standards for himself, his research, and his graduate students. This passion is coupled with a genuine interest in the development of his graduate students. He is incredibly unselfish with his time and is always willing to provide me with feedback and guidance. I feel extremely fortunate to have had the opportunity to work with Dr. Azevedo over the last five years and am certain that my development as an academic and researcher is a product of his mentoring. It is my hope that, as a future faculty member, I am able to provide the same support to my students.

I would also like to acknowledge and thank the other committee members of this dissertation: Drs. Guthrie, Holliday, Mislevy, Wang, and Wigfield. I have been surrounded by some great scholars while a Ph.D. student at the University of Maryland, College Park. More importantly, however, these scholars have demonstrated a willingness to support graduate students in their development. My experiences with the members from this dissertation committee reflect this support. The thoughtful feedback and questions raised during the proposal defense of this dissertation demonstrated the committee's genuine interest in my development.

Lastly, I would like to acknowledge my wife, Erin, and the rest of my family. They have been incredibly supportive and understanding through this process.

TABLE OF CONTENTS

List of Tables	v
List of Figures	vi
Acknowledgements	ii
CHAPTER I: INTRODUCTION	1
<i>Operational Definitions of Key Terms</i>	8
CHAPTER II: LITERATURE REVIEW	10
<i>Literature Review of Computer-Based Learning Environments</i>	10
<i>Overview of Hypermedia</i>	12
<i>Learning with Hypermedia</i>	13
<i>Literature Review of Self-Regulated Learning</i>	16
<i>Methods Used to Measure SRL</i>	25
<i>SRL and Learning with Hypermedia</i>	29
<i>Conceptual Scaffolds and SRL with Hypermedia</i>	31
<i>Next Steps in Examining Cognitive, Metacognitive, and Motivational Factors</i>	35
<i>Literature Review of Self-Efficacy</i>	37
<i>Self-Efficacy and Learning with Computer-Based Learning Environments</i>	40
<i>Prior Domain Knowledge, SRL, Self-Efficacy, and Conceptual Scaffolds in Learning with Hypermedia: Knowns and Unknowns</i>	47
<i>Research Question and Hypotheses</i>	48
CHAPTER III: METHOD, PROCEDURE, & DATA ANALYSIS (PILOT STUDY) ...	51
<i>Method</i>	52
<i>Participants</i>	52
<i>Research Design</i>	52
<i>Measures</i>	52
<i>Materials</i>	54
<i>Procedure</i>	55
<i>Data Analysis</i>	58
<i>Coding and Scoring</i>	58
<i>Inter-rater agreement</i>	63
<i>Results</i>	63
<i>Summary</i>	69
<i>Changes for Dissertation</i>	71
CHAPTER IV: METHOD, PROCEDURE, & DATA ANALYSIS (DISSERTATION) 73	73
<i>Method</i>	73
<i>Participants</i>	73
<i>Research Design</i>	73
<i>Measures</i>	73
<i>Materials</i>	74
<i>Procedure</i>	75
<i>Data Analysis</i>	76
<i>Coding and Scoring</i>	76
<i>Inter-rater agreement</i>	76
CHAPTER V: RESULTS FOR DISSERTATION	78
<i>Research question #1</i>	79

<i>Research question #2</i>	82
<i>Research question #3</i>	83
<i>Research question #4</i>	87
CHAPTER VI: DISCUSSION	91
<i>Discussion of research question #1</i>	91
<i>Discussion of research question #2</i>	93
<i>Discussion of research question #3</i>	96
<i>Discussion of research question #4</i>	98
Contributions	100
<i>Theoretical Contributions</i>	100
<i>Methodological Contributions</i>	105
Implications	108
<i>Implications for the design of adaptive hypermedia</i>	108
<i>Implications for education</i>	113
Future Directions	115
Limitations	118
Conclusion	119
Appendix A: Pintrich's (2000) 4 x 4 SRL Framework	121
Appendix B: Declarative and conceptual knowledge measures	122
Appendix C: Complete MSLQ	124
Appendix D: Self-efficacy scale used in this study	133
Appendix E: Screen shot of Encarta™	134
Appendix F: Approved IRB and consent form	135
Appendix G: Instructions to participants	138
Appendix H: Sample text from practice think-aloud text	139
Appendix I: Experimental set-up	140
Appendix J: SRL coding scheme	141
Appendix K: Example of coded transcript	144
References	145

List of Tables

1.	Necessary features for each type of mental model.....	59
2.	Predictors of declarative learning outcomes (pilot study).....	64
3.	Means and (standard deviations) of prior declarative and conceptual..... knowledge, declarative and conceptual learning outcomes, and self-efficacy, by condition (pilot study)	65
4.	Predictors of conceptual learning outcomes (pilot study).....	66
5.	Predictors of planning processes (pilot study).....	67
6.	Means and (standard deviations) of SRL processes deployed..... during learning (pilot study)	67
7.	SRL predictors of conceptual learning outcomes (pilot study).....	68
8.	Experimental procedure.....	75
9.	Kurtosis and skewness of data for each variable.....	78
10.	Prior domain knowledge predictors of declarative learning outcomes.....	80
11.	Prior domain knowledge predictors of conceptual learning outcomes.....	81
12.	Means and (standard deviations) of prior declarative and conceptual..... knowledge, and declarative and conceptual learning outcomes, by condition	81
13.	Mean self-reported self-efficacy, by time and condition.....	83
14.	Predictors of planning processes.....	84
15.	Predictors of monitoring processes.....	85
16.	Total raw frequency of individual SRL processes used during..... learning, by condition	86
17.	SRL predictors of declarative learning outcomes.....	88
18.	SRL predictors of conceptual learning outcomes.....	89
19.	Correlations among all of the measures.....	89

List of Figures

1. Fluctuation of self-reported self-efficacy, by condition..... 83

CHAPTER I: INTRODUCTION

While learning with computer-based learning environments (CBLEs) presents many challenges, effectively using these environments to develop knowledge of complex topics can be particularly demanding (e.g., Lajoie & Azevedo, 2006). Learning complex topics, such as the circulatory system, often requires students to develop both declarative and conceptual knowledge, and research has demonstrated that certain processes are related to development of such knowledge when learning with CBLEs (Chi, 2000, 2005; Chi, de Leeuw, Chiu, & LaVancher, 1994). For example, self-regulatory processes such as planning and monitoring have been shown to foster knowledge development of complex topics during learning with CBLEs (e.g., Azevedo, 2005; Azevedo, Cromley, Winters, Moos, & Greene, 2005). Students can face substantial difficulty if they do not use these processes when learning with CBLEs, especially when faced with the task of learning complex topics in which they have little prior domain knowledge (Azevedo, Guthrie, & Seibert, 2004a; Azevedo, Winters, & Moos, 2004b; McNamara, Kintsch, & Songer, 1996; Shapiro, 1999, 2000, 2004; Shapiro & Niederhauser, 2004).

Some types of CBLEs, such as hypermedia, offer students a non-linear learning environment with multiple representations. The relationship between self-regulatory processes and learning is particularly strong within these environments (e.g., Azevedo et al., 2005). It has been suggested that students' use self-regulatory processes when learning with hypermedia is related to different aspects of their motivation (Moos & Azevedo, 2006b, accepted pending revisions). In particular, self-efficacy, a theoretically grounded motivation construct, may affect the use of specific self-regulatory processes when learning with hypermedia. For example, if a student believes he or she is capable of

learning with hypermedia (i.e. has high self-efficacy), then this student may be more apt to use self-regulatory processes during learning. If, on the other hand, the student does not believe that he or she is capable of learning with hypermedia (i.e. has low self-efficacy), then this student may be less likely to use self-regulatory processes during learning. In other words, the extent to which students use self-regulatory processes when learning with hypermedia may be partly dependent on their self-efficacy. Thus, it is necessary to examine both how students learn and why they use self-regulatory processes with hypermedia in order to understand the complexities of learning with this type of CBLE. The goal of this dissertation is to address this issue by examining the relationship between cognitive, motivational, and contextual factors during learning with hypermedia. The cognitive factors examined in this dissertation were *prior domain knowledge* and *self-regulatory processes*, and the motivation factor was *self-efficacy*. The contextual factor, defined as variables in the instructional environment that may affect learning (Winne, 2001; Winne & Hadwin, 1998), was *conceptual scaffolds*. In what follows, I describe why these particular factors were investigated in this dissertation.

Research in the field of educational psychology has examined what skills successful students possess, specifically metacognitive and cognitive factors related to learning (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 cognitive and metacognitive 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; Zimmerman, 1989). 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 in which students are viewed as proactive and strategic learners, as opposed to passive learners in their environment (e.g., Winne, 1995). To explain this proactive, strategic orientation, researchers appealed to social, behavioral, motivational, and cognitive variables in academic achievement. 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, 2006; Zimmerman & Schunk, 2001).

Recently, research has used SRL theory to examine how students learn with CBLEs, such as hypermedia environments (Azevedo, 2005; Graesser, McNamara, & VanLehn, 2005; Lajoie & Azevedo, 2006; Quintana, Zhang, & Krajcik, 2005; White & Fredriksen, 2005; Zimmerman & Tsikalas, 2005). Hypermedia environments, which can contain textual information, static diagrams, and digitized video clips, provide students with a visually rich and interactive environment to learn about complex topics, such as the circulatory system. These non-linear environments, in which students are provided flexible access and high degree of control, offer multiple representations (Jacobson & Reeves, 1996; Williams, 1996). In order to effectively learn in a flexible, non-linear learning environment, students need to use certain self-regulatory processes, such as creating sub-goals and monitoring their emerging understanding (Azevedo et al., 2004a, 2004b). However, the extent to which students use these SRL processes can be influenced by various factors, such as prior domain knowledge. Students who have higher prior domain knowledge are better equipped to monitor their learning (Chen, Fan, &

Macredie, 2006; McNamara & Shapiro, 2005; Shapiro, 2004), and thus are more likely to use self-regulatory processes related to specific monitoring activities, such as evaluating the content and expressing a feeling of knowing (Moos & Azevedo, 2006a). Conversely, students with lower prior domain knowledge do not have a readily accessible knowledge structure that allows them to monitor the relevancy of the content and/or use metacognitive processes when learning with hypermedia (Moos & Azevedo, 2006a). Instead, students with lower prior domain knowledge rely on specific strategies to build an initial knowledge base (Moos & Azevedo, 2006a).

Furthermore, learning with hypermedia can present students with difficulties because these learning environments present both cognitive *and* motivational challenges (Lajoie & Azevedo, 2006; Moos & Azevedo, 2006b; Vuorela & Nummenmaa, 2004; Winne, 2005; Zimmerman & Tskikalas, 2005). When students learn with hypermedia, they are often faced with decisions about which information to access and these decisions can be strongly influenced by their motivation (Debowski, Wood, & Bandura, 2001). In particular, it has been suggested that self-efficacy (i.e. self-perception of capabilities to meet situational demands; Bandura, 1997; Wood & Bandura, 1989) may be a critical factor in learning with hypermedia. As such, it is important to examine both cognitive (e.g., prior domain knowledge and self-regulatory processes) *and* motivational (e.g., self-efficacy) factors in order to best understand how students learn with hypermedia.

In addition to examining cognitive and motivational issues, some researchers have also examined contextual factors in learning with hypermedia. As defined by Winne (2001) and Winne and Hadwin (1998), contextual factors are variables in the instructional environment that may affect learning. Researchers have studied the potential

benefits of providing students with different types of support provided in the context (e.g., scaffolds) during learning with hypermedia. Scaffolds can range from assisting students in learning about how to perform a task with hypermedia (procedural scaffolds), to fostering the use of learning skills with hypermedia (process scaffolding), and to aiding in the development of domain knowledge with hypermedia (conceptual scaffolding; see Hannafin, Land, & Oliver, 1999 for a review). Interestingly, research has produced mixed results in terms of the potential benefit of providing students with different types of scaffolds while learning with hypermedia (Azevedo & Hadwin, 2005). While some research has suggested that specific types of scaffolds assist students in learning with hypermedia, other research has suggested that the provision of scaffolds may actually impede learning with hypermedia for some students.

It is clear that many factors are related to learning with hypermedia. Especially salient issues in these lines of research include understanding (a) the relationship between prior domain knowledge and learning outcomes, (b) how students self-regulate their learning with hypermedia, (c) the relationship between specific constructs of motivation and learning with hypermedia, and (d) the effect of scaffolds on self-regulated learning with hypermedia. Based on these issues, factors related to learning with hypermedia may be best understood by examining research from the following fields: Learning with CBLEs, self-regulated learning, self-efficacy, and scaffolding. As such, this dissertation draws on research from these fields to examine the relationship between cognitive (prior domain knowledge and self-regulatory processes), motivational (self-efficacy), and contextual (scaffolds) factors in learning with hypermedia.

The aims of this dissertation were to (a) provide a literature review on the extensive research that has examined learning with CBLEs, self-regulated learning, self-efficacy, and scaffolding, and (b) describe a study that has the potential to advance the field by addressing some critical issues in these lines of research. Specifically, this study addressed (a) the degree to which prior domain knowledge predicts learning outcomes and self-regulatory processes with hypermedia, (b) the degree to which self-efficacy fluctuates during learning with hypermedia, (c) the degree to which self-efficacy predicts self-regulatory processes with hypermedia, and (d) the degree to which conceptual scaffolds moderate these relationships. The second chapter begins with a review of previous research that has examined learning with CBLEs. This section focuses on hypermedia because this particular type of CBLE was used in both the pilot study and dissertation study. This section provides an overview of factors related to learning with hypermedia, such as prior domain knowledge and SRL. As the second chapter highlights, research has begun to use SRL theory as a guiding lens to examine how students learn with hypermedia (see Azevedo, 2005). In order to provide a comprehensive overview of this line of research, the second chapter presents the theoretical and methodological issues of SRL models. Additionally, this section includes a discussion of research that has examined how scaffolds affect knowledge development and SRL processes during learning with hypermedia. However, as the theoretical and methodological sections in this chapter highlight, research examining SRL in learning with hypermedia has some unanswered questions.

The review presented in the second chapter highlights that incorporating findings from the field of SRL with research from the field of self-efficacy has the potential to

advance our understanding of learning with hypermedia. Thus, the last major section of the second chapter provides a literature review on self-efficacy. The review provided in this section highlights the need for research to more fully examine the relationship between self-efficacy, SRL, and learning outcomes with hypermedia. The second chapter ends with the research questions and hypotheses of this dissertation study. In the spring of 2006, a pilot study was run prior to the dissertation study. The procedure, method, data analyses, and results for this pilot study are presented in chapter three. The methodology of the dissertation study is presented in chapter four, and the results for this study are described in chapter five. Finally, the discussion of these results is presented in chapter six. The potential theoretical and methodological contributions, implications, and future directions of the dissertation study are included in this chapter.

Operational Definitions of Key Terms

Throughout this dissertation, several key constructs are used as foundations for the study. In order to clarify these constructs and how they are related, operational definitions are provided below.

COMPUTER-BASED LEARNING ENVIRONMENTS: Technology used as an educational tool that acts as an intellectual partner to foster student learning (Derry & Lajoie, 1993; Lajoie, 2000; Lajoie & Azevedo, 2006).

CONCEPTUAL KNOWLEDGE: Understanding interrelationships between definitions, properties of concepts, and facts, which include declarative and procedural knowledge (Chi, 2000, 2004; 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.

CONCEPTUAL SCAFFOLDS: Assistance that helps students identify the conceptual organization of the domain more readily (Shapiro, 1999, 2000), and thus assists students when they are learning about conceptually-rich domains (Hannafin et al., 1999).

CONTEXTUAL FACTORS: Variables in the instructional environment that may affect learning. In this study, conceptual scaffolds are considered contextual factors (Winne, 2001; Winne & Hadwin, 1998).

DECLARATIVE KNOWLEDGE: Understanding of definitions, properties of concepts, and facts (Graesser et al., 2005; McCrudden, Schraw, & Kambe, 2005). An example of declarative knowledge in this study includes an understanding that the heart is a pump.

HYPERMEDIA: Computer-based learning environment which includes audio, video, animation, graphics and/or text. This environment is structured in a non-linear format and

is student structured (Jonassen & Reeves, 1996), and is different than hypertext and multimedia environments (Jacobson & Archodidou, 2000).

MOTIVATION: Physiological processes involved in the direction, vigor, and persistence of behavior (Eccles, Wigfield, & Schiefele, 1998; Wigfield & Eccles, 2002)

SCAFFOLDS: Support that assists students with elements of a task that are beyond their capacity, and helps them concentrate on elements of task that are within their range of competence (Wood, Bruner, & Ross, 1976; Wood & Middleton, 1975).

SELF-EFFICACY: Self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of actions needed, and cognitive resources (Bandura, 1997; Wood & Bandura, 1989).

SELF-REGULATED LEARNING: Learning that involves actively constructing an understanding of a topic/domain by using strategies and goals, regulating and monitoring certain aspects of cognition, behavior, and motivation, modifying behavior to achieve a desired goal, and an interaction between performance, contextual factors, and personal characteristics (Pintrich, 2000; Zimmerman, 1998).

CHAPTER II: LITERATURE REVIEW

As noted in the first chapter, this dissertation integrates perspectives from research that has examined learning with CBLEs (with a focus on hypermedia), self-regulated learning, conceptual scaffolding, and self-efficacy. To understand the need for this integration, it is necessary to summarize the major findings and issues from these lines of research. In what follows, the relevant portions of the literature that have examined learning with CBLEs, self-regulated learning, self-efficacy, and conceptual scaffolding are summarized. This literature review highlights current issues in the field and the need for future research to examine cognitive, motivational, and contextual factors in learning with hypermedia. This dissertation addresses these issues through an empirical examination of these factors in learning with hypermedia. The second chapter ends with a presentation of the specific research questions and hypotheses for this dissertation study.

Literature Review of Computer-Based Learning Environments

CBLEs have been used as cognitive tools to help students learn about challenging topics (Derry & Lajoie, 1993; Lajoie & Azevedo, 2006). *Cognitive tools* are defined as tools that are developed with the aim of enhancing the cognitive capabilities of humans during problem solving, thinking, and learning (Derry & Lajoie, 1993; Jonassen & Reeves, 1996; Lajoie, 2000; Lajoie & Azevedo, 2006). The classic model of computers as cognitive tools in education has suggested the “tutor, tool, and tutee” approach (see Taylor, 1980). That is, earlier technologies as cognitive tools were designed to promote knowledge acquisition in well-defined tasks and domains such as geometry (e.g., Anderson, Corbett, & Koedinger, 1995). Thus, traditional uses of technology have

typically relied on the student learning *from* the CBLE. This process involves the CBLE instructing students what they should know and then assessing their learning (Jonassen & Land, 2000). This approach advocates that educational communications transmit standardized interpretations of the world to the student, and that feedback and reinforcement fosters understanding of the accepted views of reality (Jonassen & Reeves, 1996). However, more recent trends in using CBLEs as cognitive tools deviate from this approach by providing an environment in which students can pursue personal goals and solve challenging problems (Jonassen & Reeves, 1996). Thus, the boundaries are not predefined as they were in earlier CBLEs (Lajoie, 2000). While earlier CBLEs instructed students what they should know, more recent CBLEs have assumed that knowledge construction occurs when students are actively participating in the construction of knowledge (Duffy & Jonassen, 1992; Jonassen & Reeves, 1996; Lajoie, 1993, 2000; White & Fredriksen, 2005; Williams, 1996). Some recent CBLEs foster active participation in the acquisition of knowledge by acting as intellectual partners with the learner so that critical thinking and higher order learning can be facilitated (Jonassen & Reeves, 1996; Perez & Solomon, 2005). This approach allows students to learn *with* CBLEs by providing the students with a cognitive tool that supports knowledge construction and exploration (Jonassen, 1990).

Recently, researchers have examined how students learn conceptually-rich domains with CBLEs (CTGV, 1990; Jacobson & Kozma, 2000; Lajoie, 2000). It has been suggested that students need to use metacognitive processes when learning with CBLEs (Azevedo, 2005; Graesser et al., 2005; White & Fredriksen, 2005), and thus several researchers have used models of metacognition (Brown, 1975; Flavell, 1979,

1985; Hacker, 1998; Hacker, Dunlosky, & Graesser, 1998; Schraw & Moshman, 1995; Veenman, Bernadette, Hout-Wolters, & Afflerbach, 2006) to examine the complex processes in learning conceptually-rich domains with CBLEs. The inclusion of metacognition models in this line of research has provided the foundation for researchers to consider CBLEs as metacognitive tools for enhancing learning (see Azevedo, 2005). In addition to the characteristics of cognitive tools, CBLEs used as a metacognitive tool have the capacity to model, prompt, and support specific learning processes, including metacognitive processes (Azevedo, 2005). It should be noted that another defining characteristic of metacognitive tools is that they also support other self-regulatory processes, including motivation (see Zimmerman & Tsikalas, 2005). However, as it is discussed later in this chapter, motivation, especially self-efficacy, in learning with CBLEs has received limited empirical attention (e.g., Lepper & Woolverton, 2004). 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. A primary goal of this dissertation is to empirically examine these processes in learning with hypermedia.

Overview of Hypermedia

This dissertation focuses on hypermedia, a specific type of CBLE. Hypermedia has been defined as a non-linear CBLE in which audio, video, animation, and/or graphics are integrated with the text (Jonassen & Reeves, 1996). When learning with hypermedia, students can access these multiple representations of information in a variety of sequences. As such, the non-linear presentation of information in hypermedia environments allows students to determine the sequence of information (Jacobson &

Archodidou, 2000; Jonassen & Reeves, 1996; Nelson, 1980). The ability to navigate freely through hypermedia environments define this environment as learner controlled instruction because this CBLE gives the student some degree of freedom with the respect to the sequencing of information (Williams, 1996). This autonomy in the learning process is consistent with the constructivist approach. Within this framework, active participation in the construction of knowledge, such as afforded by the learner-controlled instruction in hypermedia environments, facilitates learning (Hartley, 1985).

However, learning in these environments is related to a number of factors. In particular, learning with hypermedia places certain cognitive and metacognitive demands on the student. For example, when asked to learn with hypermedia, students need to make a number of decisions, including how much time to spend in different representations and which information to access (Azevedo, 2005; Shapiro, 1999; Williams, 1996).

Furthermore, students need to monitor the relevancy of the content as well as their emerging understanding while making these decisions (Azevedo et al., 2005). In addition to these cognitive and metacognitive demands, learning with hypermedia also offers motivational challenges. Active participation in the learning process is often affected by self-efficacy (Bandura & Schunk, 1986). Thus, students are faced with cognitive, metacognitive, *and* motivational issues when learning with hypermedia. The following section will further describe factors related to learning with hypermedia.

Learning with Hypermedia

Though hypermedia environments should allow students to actively participate in the construction of knowledge (Azevedo, 2005; Azevedo et al., 2004a; Jacobson & Azevedo, in press; Jonassen & Reeves, 1996; Williams, 1996), research has demonstrated

that some students may have difficulty learning in these environments (Lajoie & Azevedo, 2006). In order to clarify why some students have difficulty learning with hypermedia, research has considered how prior domain knowledge is related to learning with hypermedia. The vast majority of this research has focused on the relationship between prior domain knowledge and navigation during learning with hypermedia (e.g., Calisir & Gurel, 2003). As such, the following section will briefly describe findings from previous research which has examined prior domain knowledge and navigation in order to provide an overview of what has been studied in this field. However, while the relationship between prior domain knowledge and navigation certainly warrants research, there is also a need for research that examines prior domain knowledge and learning outcomes with hypermedia (Shapiro, 2004). Though this dissertation study did not focus on navigation, it did examine the extent to which prior domain knowledge predicted learning outcomes with hypermedia. Examining this relationship has the potential to address some current gaps in our understanding of how prior domain knowledge affects learning with hypermedia (Shapiro, 2004).

Because students are able to choose which information to access and how much time to spend in different representations of information when learning with hypermedia (Azevedo, 2005; Shapiro, 1999; Williams, 1996), they need to manage this high degree of control in order to effectively navigate through this environment (Lawless & Brown, 1997). However, some students have difficulty navigating with hypermedia (e.g., Nielson, 2000). As suggested by previous research, prior domain knowledge influences how students navigate with hypermedia, and thus this factor is critical in learning with hypermedia (e.g., Calisir & Gurel, 2003; McDonald & Stevenson, 1998; Shin, Schallert,

& Savenye, 1994). For example, Chen and Ford (1998) found that prior domain knowledge is related to navigational patterns, specifically with the number of navigational moves. Similarly, research has also found that students with higher domain knowledge more readily remembered where they had been in the hypermedia environment and were more likely to identify which information was relevant when learning with hypermedia (Last, O'Donnell, & Kelly, 2001). Chen et al. (2006) suggests that navigation in hypermedia is dependent on an understanding of the conceptual structure of the domain. This understanding guides students in their interaction with the non-linear format of hypermedia. Thus, students who have limited understanding of the conceptual structure of the domain have little to guide their interaction with hypermedia, which explains why they may have difficulty navigating with hypermedia (Shapiro, 2004).

The majority of research examining the relationship between prior domain knowledge and learning with hypermedia has focused on navigation. The relationship between prior domain knowledge and learning outcomes with hypermedia has received much less empirical attention. However, previous research has consistently demonstrated that prior domain knowledge is a powerful determinant in learning with non-hypermedia environments (e.g., Alexander, 2003; Alexander & Murphy, 1998; Dochy & Alexander, 1995; Shapiro, 2004; Shapiro & Neiderhauser, 2004). In order to advance our understanding of factors that are related to learning outcomes with hypermedia, it is necessary to extend previous research and empirically examine the relationship between prior domain knowledge and learning outcomes with hypermedia (Shapiro, 2004). Thus, one goal of this dissertation study was to empirically examine the relationship between

prior domain knowledge and learning outcomes with hypermedia. Another goal of this dissertation study was to examine the relationship between prior domain knowledge and SRL. Thus, the following section will present a literature review on SRL.

Literature Review of Self-Regulated Learning

In order to properly present the underlying theoretical perspectives of SRL, the constructs and assumptions of SRL need to be delineated. At the outset, it is important to note that the field of SRL research consists of many camps and perspectives that sometimes focus on different constructs (Boekaerts et al., 2000; Zimmerman & Schunk, 2001). However, these perspectives share four common assumptions that provide the foundations for all SRL models (Pintrich, 2000). First, an underlying construct of most SRL models is that students are proactive in a constructive process of learning. Students are assumed to actively construct their own strategies, goals, and meaning from information available in their own minds as well as from the external world. Second, most SRL models assume that students can potentially regulate and monitor certain aspects of their cognition, behavior, and motivation. Due to individual differences and developmental constraints, individuals do not constantly monitor and control their cognition, behavior, and adoption of goals in all contexts. Third, most models assume that all human cognitive behavior is goal-directed and that self-regulated students modify their behavior to achieve a desired goal. Individuals set goals for their learning, monitor their progress towards these goals, and then adapt and regulate their behavior, cognition, and motivation to reach those goals. Fourth, most models assume that self-regulatory behavior is a mediator between (a) an individual's performance, (b) contextual factors, and (c) personal characteristics.

These basic assumptions provide the foundation for the SRL model adopted in this dissertation but, as previously mentioned, there are several distinct perspectives that provide detailed accounts of self-regulated learning and provide insight as to how students become self-regulated students. For example, Pintrich (2000) offers a comprehensive framework by characterizing SRL as having four different phases and four different areas (see Appendix A for Pintrich's 4 x 4 SRL framework). 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 student plans, sets goals, and activates knowledge about the context, text, and self. Phase two is defined when the student exhibits metacognitive awareness and monitoring of cognition. In phase three, the student selects cognitive strategies and regulates different aspects of the context, task, and self. Lastly, in phase four, the student makes cognitive judgments and reflections on the context, task, and self.

Pintrich (2000) indicates that there are underlying assumptions associated with the progression of these phases. First and foremost, it is assumed that learning does not necessarily involve all these phases. That is, these phases are not hierarchical in the sense that later phases must always occur after earlier phases. In fact, due to the assumption of most SRL models, phases can occur concurrently and dynamically. For example, a student may continue to adjust and adapt his/her goals based on feedback. Thus, these phases are not necessarily linear nor are they static. Within these individual phases, Pintrich (2000) also proposes four different areas in which self-regulation can occur. Based on different psychological functioning (see Snow, Corno, & Jackson, 1996), the first three areas for regulation are *cognition, motivation/affect, and behavior*. The last

area of context reflects contextual features, such as evaluation features and task characteristics, which can impede or facilitate an individual's attempt to self-regulate their learning. Given the complexity of this 4 x 4 account of SRL, elaborating each area (cognition, motivation, behavior, context) by phase (planning, monitoring, control, and reflection) will provide the necessary detail to adequately explain its utility in examining the richness of SRL.

In the first phase and area, cognitive planning, there are three assumed processes. First, target goals are set that allow students to monitor their learning (Harackiewicz, Barron, & Elliot, 1998). While goal-setting can occur anytime because of the dynamic nature of SRL, it is assumed to occur most often at the onset of a learning task (Pintrich, 2000). During the learning task, the student uses the goal as a criterion to monitor, assess, and guide cognition. Activation of relevant prior knowledge is the second processes of cognitive planning and activation. It has been shown that students who are more self-regulatory when learning actively search their memory for relevant prior knowledge (Pintrich, 2000). Lastly, activation of cognitive strategies and tasks comprise the third aspect of cognitive planning and activation. Activation of these cognitive strategies is the means by which goals are thought to be attainable by the student.

In the next phase of cognition, cognitive monitoring, the student exhibits what is typically viewed as metacognition (Koriat & Goldsmith, 1996). That is, students are involved in a dynamic process of monitoring their cognition. For example, two typical metacognitive monitoring activities are *judgment of learning* (JOLs) and *feeling of knowing* (FOKs). JOLs occur when a student monitors his or her emerging understanding relative to the information provided in the learning environment, while FOKs occur when

a student monitors whether or not he or she has previously learned information provided in the environment.

The third phase of cognition, cognitive control and regulation, is defined when the student selects and uses cognitive strategies for thinking, problem solving, and learning (Guthrie et al., 2004). Strategies including mnemonics, memorizing, and summarizing are behaviors that would be placed in this cell. The last phase of cognition, cognitive reaction and reflection, includes student's reflection on their performance. Studies have demonstrated that students who are self-regulated are differentiated from other students in this area and phase of cognitive regulation because they tend to evaluate their performance (Zimmerman & Schunk, 2001).

In addition to having the capacity to self-regulate their cognition in the four phases of cognition, students can also self-regulate their motivation and affect in all of the phases. In the first phase of planning and activation of motivation and affect, it has been demonstrated that task value beliefs can influence students' effort, persistence, and ultimately their learning and performance (Wigfield, 1994). For example, if a student believes that the task is relevant to near or future goals, they may be more likely to engage in the task and persist in the face of difficulty (Wigfield, 1994). Furthermore, it has been demonstrated that interest can be sparked by contextual and task features (Wigfield, 1994), and that students can try to control and regulate this interest (Sansone, Weir, Harpster, & Morgan, 1992). In addition to the contextual and task features sparking interest, these variables may also produce negative affects such as fear and anxiety which can promote maladaptive strategies (Wigfield & Eccles, 1989; Wolters, 2003).

The second phase of self-regulating motivation, motivational monitoring, has not received the same empirical attention from researchers as motivational planning and activation. It is assumed, however, that monitoring of motivation is a crucial prelude to regulation of motivation (Pintrich, 2000). In order for students to control their efficacy, interest, and anxiety, it is necessary to be first aware of these beliefs and affect. Some research has examined this directionality. For example, Bandura (1997) researched self-efficacy by focusing on the outcomes of individuals who became more aware of their efficacy and then adapted their efficacy levels to make their beliefs more realistic. The third phase of self-regulating motivation, motivational control and regulation, has received more attention from researchers. Researchers such as Boekaerts (1993) and Corno (1993) have examined the numerous strategies individuals can use to control their motivation and affect. For example, strategies include positive self-talk to control self-efficacy (see Bandura, 1997). In addition, self-affirmation strategy has been shown to protect self-worth by decreasing the value of the task (Garcia & Pintrich, 1994). The final phase of self-regulating motivation, motivational reaction, occurs when the student has an emotional reaction to the outcome and then reflects on how the outcome came to be. Emotions such as pride or shame can stem from these reflections. From a self-regulation standpoint, the quality of these emotions has implications for the self-regulation process because intentional strategies used to protect self-worth for future learning tasks may be a product of these emotions (Schutz, & Lanehart, 2002).

The third area of self-regulation, regulation of behavior, occurs when the student intentionally attempts to control his/her behavior. Behavioral forethought, planning, and activation comprise the first phase of this area. Behaviors such as time management or

time and effort planning are placed in this cell. Studies have demonstrated that self-regulated students plan how they will allocate their effort and time (Zimmerman & Martinez-Ponz, 1986). In addition, studies have also demonstrated that self-regulated students use self-observational techniques to modify their own behavior (Zimmerman, 2000). In order for this modification to occur, planning and intention to implement the adaptation must occur. Thus, self-observational techniques also aid with the second phase of behavior regulation. In this phase, behavioral monitoring and awareness, the student monitors their time and effort and/or time management, and then attempts to adapt their effort to meet the learning task. For example, when asked to learn about the circulatory system, a student may decide to spend fifteen minutes memorizing the components of the heart, but later realize that the complexity of the material requires more time. The monitoring of behavior, as exhibited by a self-regulated student, should lead to some modification of effort if the monitoring indicates a discrepancy between the effort and desired goal.

This modification defines the third phase of behavior regulation, behavioral control. Continuing with the previous example, if the student realizes that learning the components of the circulatory system will require more than the initially planned time, the student should modify his/her behavior. An additional strategy that has been demonstrated to be helpful in regulating behavior is help-seeking (Ryan & Pintrich, 1997). Knowing when, how, and from whom to seek help is a defining characteristic of good self-regulators (Karabenick & Sharma, 1994). It should be noted that help-seeking can be either adaptive or maladaptive. Dependent help-seeking, where the student is consistently dependent on this form of support and desires to finish a task quickly, is

generally considered maladaptive. On the other hand, help-seeking where the student seeks help only to overcome specific parts of a problem is generally considered adaptive (Karabenick & Sharma, 1994). Lastly, the fourth phase of behavior regulation, behavioral reaction and reflection, is comprised of an individual's choice of behavior, a result of reaction to past behavior.

Finally, the last area to which self-regulation can be applied is context. For example, in the pilot and dissertation study, context was defined as the totality of surrounding conditions in the experimental session. Thus, context in the pilot and dissertation study included the learning task, the hypermedia environment, and the experimenter-set goals. The first phase of this area is comprised of contextual forethought, planning, and activation. In this phase, individuals focus on contextual regulation and thus cells in this phase include such processes as activation of knowledge pertaining to the context in the form of general knowledge about the classroom and task. It is important to note that perception of classroom norms can affect individual's knowledge about general norms. For example, if a student is presented with a learning task and perceives that he/she does not have much autonomy, then their approach to learning may alter because of this perception (Boekaerts et al., 2000). However, learning tasks are rarely static and contextual conditions are apt to change. Thus, a student needs to not only perceive the classroom norms, but also monitor changing contextual conditions and tasks. Phase two, contextual monitoring, captures this important aspect of self-regulated learning. The monitoring process is closely linked to control and regulation. Contextual regulation and control, as defined in the fourth phase, may be difficult to regulate due to the nature of the context. That is, while cognition, motivation,

and behavior are under the direct control of the individual, contextual control may be under external influence, such as an authority figure. From a SRL perspective, strategies to control the context and optimize learning include shaping or restructuring the learning environment (Zimmerman, 1998). Lastly, in the contextual reaction phase, students reflect about the task and/or classroom environment and these reflections can feed back into the first phase of contextual regulation, contextual forethought, planning, and activation.

The SRL model which was used in this dissertation combines key components of Pintrich's (2000) formulation of self-regulation as a four-phase process and draws from Winne (2001) and Winne and Hadwin's (1998) information processing theory (IPT) of SRL. Winne and Hadwin (1998) present a SRL model which proposes 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 student constructs a perception of the task from two sources: *Cognitive conditions* and *Task Conditions*. *Task conditions* provide information about the task, and include such conditions as experimenter-set learning goals. *Cognitive conditions*, on the other hand, provide information that the student retrieves from long term memory. In other words, a student's perception of a learning task 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 student frames multifaceted *goals* and *plans* how to reach the goal(s) (Butler & Winne, 1995; Winne & Hadwin, 1998). According to IPT, these processes are dynamic as goals can be updated as students proceed through the learning

task. In phase three, the student enacts tactics and/or *strategies* (Winne, 2001; Winne & Hadwin, 1998). Strategy use facilitates the construction of information, which in turn, aides in the progress of the task (Winne 2001). Phase four includes monitoring activities and cognitive evaluations about discrepancies between goal(s) and current domain knowledge (Winne, 2001; Winne & Hadwin, 1998). Monitoring is a self-regulatory process that compares two chunks of information (i.e. learning goal and current domain knowledge; Winne, 2001). Metacognitive monitoring produces information that allows students to determine if there is a discrepancy between any goals and their current level of domain knowledge. Furthermore, monitoring allows students to adapt their planning and/or strategies to more effectively meet the learning goal(s). These monitoring activities can result in the student making adaptations to schemas that structure various self-regulated processes. As such, metacognitive monitoring is the key to self-regulated learning (Butler & Winne, 1995; Winne, 1997).

Though phases may suggest that SRL is linear, an underlying assumption of IPT is that there is a recursive nature to SRL because of a feedback loop. Information processed in one phase can become an input to subsequent information processing. Additionally, it should be highlighted that students may adapt their *planning* and/or *strategies* in order to meet the goal based on discrepancies revealed by *monitoring* activities. Research using Pintrich's (2000) framework of SRL, and Winne (2001) and Winne and Hadwin's (1998) IPT of SRL, have used a think-aloud protocol to examine how students self-regulate their learning (e.g., Azevedo et al., 2005). The following section will provide a review of methods that have been used to measure SRL and will

end with a description of the protocol used to measure SRL in this dissertation, a think-aloud protocol (Ericsson, 2006; Ericsson & Simon, 1994).

Methods Used to Measure SRL

When designing a methodology to examine how students self-regulate their learning, 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*. An aptitude is a relatively enduring trait of an individual which can be used to predict future behavior (Boekaerts et al., 2000). On the other hand, self-regulation as an event suggests that SRL unfolds within particular contexts (Boekaerts et al., 2000). For example, a student may summarize to learn about the circulatory system in one context but, due to various contextual (e.g., goal structure of the task) and/or individual factors (e.g., self-efficacy), choose not to summarize when learning about the immune system. Different methodologies are associated with viewing SRL as either an aptitude or event because these two different views carry distinct assumptions. Thus, it was necessary to first determine whether SRL would be viewed as an event or aptitude when addressing the research questions in this dissertation because this decision determined the protocol used in the methodology. The following section will briefly outline the most frequently used protocols when measuring SRL as either an aptitude or an event and will end with a description of the protocol used in the pilot study and dissertation study.

When SRL is considered an aptitude, it is assumed that a single measurement aggregates a quality of SRL based on multiple events because an aptitude is relatively stable (Winne & Perry, 2000). Based on this assumption, self-perceptions of self-regulation are considered valid measures 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). Relatively easy to administer and score, self-report protocols are an efficient tool in measuring students' self-perception of how they regulate their learning. Several self-report questionnaires are used most frequently, and include such self-report questionnaires as the *Learning and Study Strategies Inventory* (LASSI; Weinstein, 1987). Composed of 77 items, including declarations and conditional relations, this self-report questionnaire was “designed to measure use of learning and study strategies” (Weinstein, 1987, p.2) by undergraduate students. The *Motivated Strategies for Learning Questionnaire* (MSLQ), another frequently used self-report questionnaire, also includes declarations and conditional relations, but was developed to additionally assess “college students' motivational orientations and their use of different learning strategies for a college course” (Pintrich, Smith, Garcia, & McKeachie, 1991; p. 3). Another method, structured interviews, allows for individuals to provide verbal descriptions of their SRL. Lastly, teacher judgments have also been used to measure SRL as an aptitude (Perry, 1998).

While protocols that measure SRL as an aptitude assume that behavior is relatively stable, protocols that measure SRL as an event assume that SRL is a dynamic unfolding event. These protocols are typically based on an IPT 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, 2006b, 2007a, 2007b). Perry, VandeKamp, and Mercer (2002) suggest that self-regulatory processes should be examined in *real* time because SRL is an ongoing process that unfolds within

particular contexts. As such, recent research has advocated that SRL should be considered an event and that SRL data should be collected during learning (Azevedo, 2005; Perry, 1998; Winne, 2005; Winne & Perry, 2000; Winne & Jamieson-Noel, 2003). Several different protocols have been used to measure SRL as an event. For example, *error detection tasks* are designed to measure monitoring and control in a specific context by introducing errors into material (Winne & Perry, 2000). Inducing errors allows the researcher to observe (a) when and whether the student detects the error, and (b) what the student does once the error is detected. SRL processes related to monitoring have been measured by both asking the students to mark the errors (e.g., by underlining) or through eye fixations (Boekaerts et al., 2000). When students underline, it is considered an observable indicator of their cognition and researchers have labeled such indicators as *traces* (Winne, 1982). In these trace methodologies, it is assumed that students mark the text (such as underlining) when they are discriminating between content (Winne et al., 2005). In addition to examining the student and his/her immediate learning task, protocols measuring SRL as an event have begun to account for relationships between the behavior and context. These protocols stress the influence of contextual variables on SRL variables, including evaluation standards and classroom climate (Turner, 1995).

Another protocol that has been used to measure SRL during learning is the think aloud. This protocol is an on-line trace methodology that offers a process methodology to examine SRL *during* learning (Azevedo, 2005). The think aloud has an extensive history in cognitive psychology and cognitive science (see Ericsson, 2006; Ericsson & Simon, 1994; Newell & Simon, 1972 for extensive reviews). Cognitive psychology and cognitive science have used both concurrent and retrospective think aloud protocols as data sources

for cognitive processes (Anderson, 1987). While the think aloud protocol has been most popular in reading comprehension (Dreher & Guthrie, 1993; Pressley & Afflerbach, 1995), it has been shown as an excellent tool to gather verbal accounts of SRL and map out self-regulatory processes during learning (e.g., Azevedo & Cromley, 2004; Boekaerts et al., 2000). This pilot study and dissertation study used a concurrent think aloud protocol, which assumes that thought processes are a sequence of states and that information in a state is relatively stable (Ericsson, 2006; Ericsson & Simon, 1993). Consequently, verbalizing thoughts during learning will not disrupt the learning process. It should be noted, “that subjects verbalizing their thoughts while performing a task do *not* describe or explain what they are doing (Ericsson & Simon, 1993, pg. xiii)” during concurrent think aloud protocols. 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 participants’ performance in these studies.

Furthermore, research has used a concurrent think aloud protocol to examine learning processes with hypermedia. For example, Azevedo, Guthrie, and Seibert (2004a) used a think aloud protocol to examine how SRL related to the development of conceptual understanding while using hypermedia. Other studies have also supported the effectiveness of the think aloud in measuring SRL as an event, including Azevedo, Winters, and Moos (2004a), and Moos and Azevedo (2006c, 2007a, 2007b). In these

lines of research, the think aloud was used to examine how students plan, monitor, use strategies, and handle task difficulties while learning about a science-related topic with hypermedia. In sum, the proven capacity of the think-aloud to measure learning processes in a dynamic learning situation provides support for the use of this protocol (Winne & Perry, 2000). The following section will further describe research which has examined SRL and learning with hypermedia.

SRL and Learning with Hypermedia

Recent research using SRL models (Pintrich, 2000; Winne 2001; Winne & Hadwin, 1998; Zimmerman, 2001) has examined processes related to *cognition*, *metacognition*, and *motivation* in learning with hypermedia. For example, Azevedo et al. (2005) examined the cognitive and metacognitive processes of 111 adolescents while they learned about a conceptually challenging science topic with hypermedia. The participants were randomly assigned to one of three scaffolding conditions (adaptive scaffolding, fixed scaffolding, or no scaffolding). Paper and pencil measures included a pretest and posttest, which measured qualitative changes in the participants' declarative and conceptual knowledge of the circulatory system. Additionally, think-aloud data were collected, which measured the participants' use of specific SRL processes during learning. Findings indicated that the participants in the three scaffolding conditions self-regulated their learning differently, particularly with respect to cognitive and metacognitive processes. For example, participants randomly assigned to the adaptive scaffolding condition self-regulated their learning by activating prior knowledge, monitoring their cognitive activities, and engaging in help-seeking. On the other hand, participants randomly assigned to the fixed scaffolding condition self-regulated their

learning by recycling goals and participants randomly assigned to the no scaffolding condition self-regulated their learning by using strategies such as re-reading, taking notes, and summarizing.

Other lines of research have also considered metacognitive issues in learning with CBLEs. For example, Graesser et al. (2005) addressed the difficulties students have in developing knowledge if they do not deploy metacognitive processes. Metacognitive processes are critical when learning with hypermedia because students need to monitor several aspects of the learning process, including monitoring which information to access, how much time to spend in different representations of information, and their emerging understanding (Azevedo, 2005; McNamara & Shapiro, 2005; Shapiro & Neiderhauser, 2003; Williams, 1996). Graesser and colleagues propose that the use of processes related to metacognition can be facilitated through different approaches to scaffolding, including computer coaches who facilitate answer generation, modeling how to apply metacomprehension strategies, and animated pedagogical agents that scaffold strategies for metacognition.

However, while this research has provided rich and informative data on SRL processes during learning, it has been limited to cognitive and metacognitive processes. Far less research has examined motivational issues in learning with hypermedia. The few studies that have examined motivation and learning with hypermedia have considered constructs such as goal orientation and goal structure. For example, Moos and Azevedo (2006b) collected think-aloud and posttest data from 60 undergraduates to examine the relationship between the goal structure of a hypermedia task and the use of SRL processes. Participants were randomly assigned to a learning task with either a mastery

goal structure, performance-goal structure, or performance-avoidance goal structure.

During the learning task, participants were asked to learn about complex science related topics with Encarta, a commercially-based hypermedia environment. Results indicated that there were significant differences in how participants across conditions self-regulated their learning. Specifically, participants randomly assigned to the performance-avoidance goal structure condition *planned* their learning differently from participants in the other two conditions.

In sum, previous research has identified specific SRL processes that are related to learning with hypermedia. For example, research has demonstrated that SRL processes related to cognition and metacognition foster learning of challenging topics with hypermedia (e.g., Azevedo et al., 2005; Graesser et al., 2005). A smaller body of research has also empirically examined specific SRL processes related to motivation in learning with hypermedia (e.g., Moos & Azevedo, 2006b). However, these lines of research have also found that some students do not use key SRL processes when learning with hypermedia (Azevedo & Cromley, 2004). In order to address the difficulties some students have in learning with hypermedia, research has examined the potential benefit of providing students with scaffolds during learning. The following section will discuss previous research which has examined scaffolding and SRL with hypermedia.

Conceptual Scaffolds and SRL with Hypermedia

Scaffolding was originally conceptualized as support that assists students with elements of a task that are beyond their capacity by helping them concentrate on elements of the task that are within their range of competence (Wood & Middleton, 1975; Wood, Bruner, & Ross, 1976). Various types of scaffolding exist, and can be characterized by

the purposes they serve and the methods in which they are provided (Azevedo & Hadwin, 2005; Hannafin et al., 1999). Scaffolds can serve several purposes, including assisting students in learning how to complete a task embedded in an environment (procedural scaffolds), fostering the learning process by prompting the use of processes such as SRL (process scaffolding), and aiding in the development of domain knowledge by assisting in the identification of the domain's conceptual organization (conceptual scaffolds). There are also a variety of methods in which scaffolds can be provided, ranging from static prompts embedded in the environment (Puntambekar & Hubscher, 2005) to instructors (e.g., human tutor; Azevedo et al., 2005; Hadwin, Wozney, & Pontin, 2005). Because previous research has demonstrated that some students have difficulty developing conceptual knowledge with hypermedia (e.g., Azevedo et al., 2005), this dissertation study focused on conceptual scaffolds.

Research suggests that conceptual scaffolds have the potential to assist students when they are learning about conceptually-rich domains with hypermedia (Hannafin et al., 1999) because they can assist students in understanding the conceptual organization of the domain more readily (Shapiro, 1999, 2000). Furthermore, previous research has demonstrated that some students have difficulty using key SRL processes, and fail to gain deep conceptual knowledge of challenging topics when they are learning with hypermedia in the absence of scaffolds (Azevedo et al., 2004a; Greene & Land, 2000; Hill & Hannafin, 2001; Land & Greene, 2000). Because of these difficulties students face when learning with hypermedia, and the challenges of applying traditional conceptions of scaffolds to recent technological advances, examining conceptual scaffolds in learning

with hypermedia has become a critical issue (Azevedo, 2005; Azevedo & Hadwin, 2005; Pea, 2004; Puntambekar & Hubscher, 2005).

While conceptual scaffolds have the potential to assist students in developing conceptual knowledge with hypermedia, empirical research has produced mixed results. Some research has found that the provision of conceptual scaffolds fosters conceptual knowledge development for students with low prior knowledge of the topic (Shapiro, 1999, 2000). For example, Shapiro (2000) examined the effect of providing students with an interactive overview while learning with hypermedia. In this study, 44 undergraduates with low prior domain knowledge learned about a biology related topic with hypermedia. This interactive overview was designed to facilitate the participants' understanding of the conceptual domain in this study (biology), and thus was considered a conceptual scaffold. Measures of this study included cued-association and card sorting posttests, and results indicated strong effects of the interactive overview. Shapiro (2000) concluded that conceptual scaffolds, in the form of interactive overviews, assisted the participants' in internally representing the structure of the domain. However, Shapiro (2000) also suggested that the potential benefit of providing such conceptual scaffolds may be reduced when students have some background knowledge of the domain. Similarly, McManus (2000) also found that the effect of conceptual scaffolds is dependent on a number of factors. In this study, data were collected from 119 adult students attending an introductory college computer course. The independent variables included the instructional presentation and presence or absence of advanced organizers, while learner achievement was the dependent variables. Results indicated that advance organizers were

effective in highly non-linear hypermedia environments because they helped guide the participants' understanding of the conceptual domain.

On the other hand, research has also found that providing students with conceptual scaffolds while they learn with hypermedia minimally fosters conceptual knowledge development and the use of key SRL processes during learning. For example, Azevedo and colleagues (2005) found that adolescents who received conceptual scaffolding, in the form of 10 domain specific sub-goals designed to guide their learning, demonstrated lower conceptual learning gains from pretest to posttest and used fewer key SRL processes during learning than students who did not receive this type of conceptual scaffold. Similarly, Saye and Brush (2002) suggested that though conceptual scaffolds may be embedded in the hypermedia environment, there are certain limits to these types of scaffolds. In particular, complex conceptual tasks, such as learning about the circulatory system, may require a certain level of adaptive support which cannot currently be provided by embedded conceptual scaffolds (Saye & Brush, 2002).

In sum, research has identified a number of different scaffolds that may assist students when they are learning with hypermedia. In particular, conceptual scaffolds may have the potential to facilitate learning with hypermedia by helping students understand the conceptual organization of the domain more readily. Some research has supported this assertion, while other research has found that the benefit of providing students with conceptual scaffolds during learning with hypermedia is limited. Clearly, more research is needed that clarifies the extent to which conceptual scaffolds affect learning with hypermedia, both in terms of learning outcomes and SRL.

Next Steps in Examining Cognitive, Metacognitive, and Motivational Factors

As highlighted in this chapter, there are several issues in previous research which has examined factors related to learning with hypermedia. First, research examining the relationship between conceptual scaffolds and learning with hypermedia has produced mixed results, and thus there is a need for future research to clarify how conceptual scaffolds affect learning with hypermedia. Furthermore, while this line of research has examined how the provision of conceptual scaffolds is related to the use of SRL processes with hypermedia, it has been primarily cognitive in nature (Moos & Azevedo, 2007a, 2007b). That is, research examining the potential benefit of providing students with conceptual scaffolds has focused on metacognitive and/or cognitive processes (e.g., feeling of knowing and prior knowledge activation), but research examining motivation in learning with hypermedia has been limited. The few studies in this line of research have considered such motivational issues as goal orientation and the goal structure of a hypermedia learning task.

For example, Moos (2004) collected think-aloud and posttest data from 64 undergraduates to examine whether they use a different proportion of SRL processes in two hypermedia learning tasks about related science topics. The goal structure of the two learning tasks was manipulated in order to examine whether the goal structure is related to the use of SRL processes during learning with hypermedia. Participants were randomly assigned to one of three conditions [mastery goal structure, performance-approach goal structure, or performance-avoidance goal structure] and participated in two 20 minute learning tasks in which they learned about the circulatory system and respiratory system. Results indicated that while a mastery goal structure and a performance-approach goal

structure were related to the use of similar SRL processes during learning, a performance-avoidance goal structure was related to the use of different SRL processes, specifically *planning*.

While research that has empirically examined motivation in learning with hypermedia is relatively limited, this area is important to consider because these learning environments present both metacognitive, cognitive *and* motivational challenges (Lepper & Woolverton, 2004; Vuorela & Nummenmaa, 2004). When students learn with hypermedia, they are often faced with decisions about which information to access and these decisions can be strongly influenced by their motivation (Debowski et al., 2001). Furthermore, students' motivation can distinctly affect how they regulate their learning with hypermedia (Lepper & Woolverton, 2004; Zimmerman & Tsikalas, 2005). Though a student may have the capacity to use specific SRL processes, the student's motivation may determine if specific SRL process are actually used while learning with hypermedia (Lepper, Woolverton, Mumme, & Gutner 1993). However, while the relationship between motivation and learning with hypermedia may be intuitively understandable, this relationship needs more empirical attention (see Rheinberg, 1996). Examining constructs of motivation that are theoretically grounded and have been shown to be strongly related to learning in non-hypermedia environments will help direct this research agenda. This dissertation focused on self-efficacy, a theoretically grounded motivation construct that has received considerable attention in non-hypermedia learning environments. In the following section, a literature review on self-efficacy is presented, which highlights the need for research to empirically examine self-efficacy in learning with hypermedia.

Literature Review of Self-Efficacy

Research examining learning in academic domains has considered self-efficacy. The concept of self-efficacy is derived from the social cognitive theory (SCT; Wood & Bandura, 1989) originated by Bandura (1986). The SCT theory accounts for self-regulatory, self-reflective, cognitive, and vicarious processes in human behavioral adaptation. According to this theoretical framework, individuals are self-regulating. Central to this underlying assumption is Bandura's conception of *reciprocal determinism*, which suggests that human functioning is a dynamic interplay between environmental, behavioral, and personal influences. This dynamic interaction helps explain how individuals acquire and maintain certain behavioral patterns. For example, a student's behavior is based on the interaction between personal factors and the learning environment. As the environment presents new experiences, the student may evaluate their current behavior in the new environment and modify or change this behavior to meet the demands of the new learning environment.

Of central importance to the SCT is self-efficacy, originally conceptualized as the self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of actions needed, and cognitive resources (Wood & Bandura, 1989). According to Bandura (1997), self-efficacy can vary along three dimensions: Level, strength, and generality. Individuals may differ in their self-perception of capability for completing tasks of differing difficulty (level). Individuals may also differ in their confidence in attaining a certain level of task performance (strength). Lastly, self-efficacy beliefs associated with a specific activity can be generalized to similar activities (generality).

While Bandura originated the conception of self-efficacy and proposed three dimensions of self-efficacy, past research has made slight modifications in the conceptualization of self-efficacy. For example, Meyer and Gellatly (1988, p. 411) referred to self-efficacy as “a generalized belief concerning one’s task relevant capabilities” and Kanfer (1990, p. 223) suggested that self-efficacy is “complex cognitive judgments about one’s future capabilities to organize and execute activities requisite for goal attainment.” Despite these slight variations, all conceptions of self-efficacy refer to an individual’s perceived capability in what he or she can do in a particular task. Furthermore, regardless of the conceptualization of self-efficacy, it is assumed that this aspect of motivation can influence students’ learning (Mitchell, Hopper, Daniels, George-Falvy, & James, 1994).

One line of research has examined the sources of self-efficacy. It has been suggested that four underlying sources are related to the development of self-efficacy: Mastery experiences, vicarious experiences, social persuasion, and emotional states (Bandura, 1994). While experiences of easy successes may undermine the development of self-efficacy through the expectation of similar results in the future, mastery experiences, in which individuals experience some difficulties in attaining the desired level of performance, allow for the development of more resilient perceptions of capabilities (Bandura, 1994). In addition, vicarious experiences through social modeling develop positive self-efficacy (Bandura, 1994). Individuals that observe other people sustaining effort to achieve a goal allows the observer to believe that he or she also possesses the capabilities to achieve a similar performance level. Verbal persuasion is also critical in developing self-efficacy. Verbal persuasion, in which it is suggested that

an individual has the capability to succeed, has been shown to be an effective means to boost self-efficacy (Bandura, 1994). It has been noted that verbal persuasion is most effective when coupled with learning environments that are structured to bring about success (Bandura, 1994). Lastly, emotional states influence the development of self-efficacy, especially in prolonged activities that require persistence. While fatigue and stress reactions may be perceived as indications of poor performance and thus decrease self-efficacy, positive emotional states may enhance self-efficacy.

Traditionally, research examining self-efficacy has considered this construct to be related to motivation and has primarily focused on student learning in various academic activities. Motivation is defined as physiological processes involved in the choice of task, vigor, and persistence in the task (Eccles et al., 1998; Wigfield & Eccles, 2002). An array of research has demonstrated that self-efficacy is related to key components of motivation. For example, Boufard-Bouchard, Parent, and Larivee (1991) found that high school students with lower self-efficacy did not *persist* as long as students with higher self-efficacy during problem solving. Furthermore, Wigfield and Guthrie (1997) found that efficacy has a significant positive correlation with 4th and 5th graders' breadth of their reading and the time that they took to read outside of school (for an overview of the relationship between motivation, including self-efficacy, and reading, see Guthrie & Wigfield, 1999). In other words, self-efficacy is positively correlated with students' *choice of task*. Additionally, Zimmerman and Bandura (1994) demonstrated that self-efficacy is also related to students' *vigor* towards a task. In this study, self-efficacy for writing was positively correlated with college students' goals for course achievement, among other things.

Additionally, research has also examined the relationship between self-efficacy and student achievement in schools and, not surprisingly, this research suggests that there is positive relationship (e.g., Bandura & Schunk, 1981; Betz & Hackett, 1981; Pajares, 1996; Pajares & Miller, 1994; Pintrich & De Groot, 1990; Schunk, 1982, 1984, 1991; Wigfield, Guthrie, & Tonks, 2004; Zimmerman, Bandura, & Martinez-Pons, 1992). This line of research suggests that students' self-efficacy is strongly related to performance across a variety of subject areas (Multon, 1991). For example, Collins (1982) found that children's mathematical self-efficacy is predictive of their mathematical test scores, while Bouffard-Bouchard (1990) found that children who felt more efficacious for problem solving demonstrated higher performance levels when compared with peers with lower self-efficacy, despite the fact that all of the children had equal ability. Pintrich and De Groot (1990) found that self-efficacy was positively related to other academic domains, such as students' quality of writing.

Self-Efficacy and Learning with Computer-Based Learning Environments

Though self-efficacy in academic learning has been extensively studied in traditional classroom learning environments, this literature review will offer a unique review of self-efficacy in learning with CBLEs. As suggested by Vuorela and Nummenmaa (2004), learning with CBLEs not only requires cognitive and metacognitive processes, but it also presents motivational challenges for students. When students learn with CBLEs, they are often faced with decisions about which information to access and these decisions can be strongly influenced by self-efficacy beliefs (Debowski et al., 2001). Furthermore, it has been argued that learning experiences in traditional environments do not prepare students for learning with CBLEs (Whipp & Chiarelli,

2004). As such, researchers have extended original conceptualizations of self-efficacy to examine how this motivational construct may affect learning with CBLEs (Torkzadeh & Van Dyke, 2002).

The majority of research examining self-efficacy in learning with CBLEs has suggested that two types of factors are related this motivation construct: 1) Psychological factors, and 2) Behavioral factors. In terms of psychological factors, research suggests that students' attitudes towards computers are significantly related to their self-efficacy in learning with CBLEs. It has been suggested that attitudes towards computer includes four interpretable factors: 1) reactions to computer related mechanisms; 2) computer and children education; 3) positive reactions to computers; and 4) negative reactions to computers (Torkzadeh & Van Dyke, 2002). Using data from a sample of 189 undergraduates, Torkzadeh and Van Dyke (2002) found that positive attitudes toward computers were related to higher self-efficacy in learning with CBLEs, while negative attitudes were related to lower self-efficacy in learning with CBLEs. Negative attitudes towards computers included such assumptions as, "I feel that using computers is too time consuming," while positive attitudes towards computers included such assumptions as, "I feel like I have control over what I do when I use a computer" (Torkzadeh & Van Dyke, 2002). Previous findings have also suggested that attitudes towards computers are formed at an early age (Wilder, Mackie, & Cooper, 1985), and that attitudes are relatively stable by the time students reach higher education (Torkzadeh & Van Dyke, 2002). However, Torkzadeh and Koufteros (1993) also found that training programs can modify students' attitudes towards computers and thus indirectly affect self-efficacy in learning with CBLEs.

In addition to these factors, students' curiosity and enjoyment in using CBLEs to learn is related to their self-efficacy in learning with CBLEs. Wang and Newlin (2002), for example, investigated the relationship between college students' personal choices for taking web-based courses and their self-efficacy. They found that students who enrolled because they enjoyed web-based learning environments and/or were curious about web courses had higher self-efficacy towards computers. Studies focusing on psychological factors related to self-efficacy in learning with CBLEs have also examined students' preference for working alone or in collaboration with peers. Gallini and Zhang (1997) examined the relationship among socio-cognitive factors with self-efficacy for 88 fourth and fifth graders. Subjects with a preference to work alone showed significantly higher self-efficacy when learning with a CBLE.

In addition to examining psychological factors, researchers have also examined the relationship between behavioral factors and self-efficacy in learning with CBLEs. The majority of these studies have focused on prior computer use. For example, Houle (1996) examined various characteristics of college students who were enrolled in a computer skills course, including whether they took a computer course in high school, the type of high school computer course, and whether they had taken a prior computer class since high school. Results indicate that previous experiences with computers, including having the experience of taking a spreadsheet and database course in high school and owning a computer, is positively related to self-efficacy. However, findings on the relationship between specific types of computer use and self-efficacy in learning with CBLEs have been somewhat contradictory. For example, while Houle (1996) found a positive relationship between previous use of spreadsheets and database courses with self-efficacy

in learning with CBLEs, Hasan (2003) found that experience with computer programming and graphics applications have a stronger relationship with self-efficacy in learning with CBLEs. While these studies have focused on whether or not students have used computers in the past, others studies have also examined how frequently students use computers. This research suggests that measuring the frequency of usage, above and beyond just assessing whether or not students have previously used computers, is a more appropriate method to analyze the relationship between behavioral factors and self-efficacy in learning with CBLEs (Salanova, Grau, & Cifre, 2000).

The majority of studies in this line of research have examined factors that are associated with students' self-efficacy as it relates to learning with CBLEs. Far fewer studies have explored the relationship between self-efficacy and learning outcomes with CBLEs. Those few studies that have examined this relationship have focused on whether self-efficacy predicts learning outcomes with CBLEs. For example, Thompson, Meriac, and Cope (2002) examined the relationship between self-efficacy and using the Internet for a search task. This study used a data collection technique with Netscape Communicator Internet browser that captured a record of every website used by the participants. Results suggest that self-efficacy significantly predicts the number of correct search results produced. However, while this research suggests that self-efficacy may be a strong predictor of learning outcomes with some types of CBLEs, other research suggests that the predictive power of self-efficacy in learning with CBLEs is not stable. Mitchell et al. (1994), for example, tested 110 undergraduate students using a complex computer task that simulated the job of an air traffic controller. Each participant completed seven trials with a computer simulation, during which their performance was

scored based on the total number of planes landed during each trial (e.g., landing a 747 on a short runway). In addition to performance scores, the researchers also collected data on the participants' expected scores and goals for each trial. Interestingly, the participants' self-efficacy was a better predictor of performance on the early trials than their goals. However, the participants' goals were actually better predictors of performance in later trials than their self-efficacy. Based on these findings, the researchers argue that the predictive power of self-efficacy changes over skill acquisition.

Research has also examined the relationship between different dimensions of self-efficacy and learning outcomes with CBLEs. For example, Shapka and Ferrari (2003) measured proximal and distal self-efficacy of 56 pre-service teachers. This study investigated how computer-related attitudes relate to learning outcomes with a challenging computer task. Proximal self-efficacy referred to the participants' self-reported rating of how successful they thought they would be at the computer task, while distal self-efficacy referred to the participants' self-reported rating of how confident they were in this rating. The results suggest that proximal self-efficacy is significantly associated with the number of searching behaviors and task success, while distal self-efficacy is not related to task success. Other research has also assumed that self-efficacy varies among different dimensions, and that these dimensions can differentially affect learning with computers. For example, Holladay and Quiñones (2003) used a sample of 82 undergraduates to examine self-efficacy generality and intensity as a motivational mechanism in explaining the relationship between practice variability and transfer in a computer naval air defense simulation task. The findings suggest that both self-efficacy

intensity and generality influenced far transfer performance of the participants, although self-efficacy generality served as mediator between practice variability and far transfer.

Due to the nature of some CBLEs, it is also important for research to consider the relationship between students' self-efficacy and how they learn with these environments. In these learning environments, the student determines which information to access and thus there may be individual differences in how students use these learning environments. Studies have suggested that individual differences in self-efficacy may explain why there are individual differences in how students use such CBLEs. For example, MacGregor (1999) videotaped 7th and 11th graders while they used a commercially produced instructional hypermedia system to learn about twelve biomes (e.g., desert, temperate deciduous forest, tundra). The focus of this study was to investigate the relation between students' self-efficacy and their navigation in this hypermedia learning environment. Students' navigation was grouped into three categories: Concept Connector, Sequential Studier, or Video Viewer. The students were characterized as being concept connectors if they demonstrated need for further examples by cross-linking to other related nodes of information. Sequential studiers were described as students who accessed objects on the screen in a linear order, typically from left to right or top to bottom. Lastly, students who were typified as being video viewers demonstrated a primary interest in videos. Results suggest that students with higher levels of self-efficacy tended to structure their navigation in more purposeful manners; that is, these students tended to be characterized as concept connectors because they made non-sequential connections of nodes. On the other hand, students with lower self-efficacy tended to be characterized as sequential studiers due to their linear navigation of the hypermedia environment.

Other studies have also examined how self-efficacy affects students' navigation in CBLEs. For example, Brosnan (1998) used a self-efficacy framework to examine how 50 undergraduates navigate a database. Measures of how the students used the database included the time students chose to take on each of the three tasks and the number of look-tables used during each task. Results indicate that students with higher self-efficacy tended to take advantage of certain aspects of the CBLE; for example, these students used the look-up tables significantly more than students with lower self-efficacy.

While this line of research has examined how self-efficacy may potentially affect how students use CBLEs, there are some issues that should be addressed in future research. In particular, the few studies that have examined the relationship between self-efficacy and learning processes have primarily focused on navigation. Advances in this field will be made when research also considers how self-efficacy affects other factors related to learning with hypermedia. As previously highlighted, some students have difficulty learning challenging topics in this instructional context (Azevedo et al., 2004a). In order to help illuminate why some students may have difficulty learning with hypermedia, research has examined contextual and individual factors in learning with hypermedia. Previous research using a theoretical framework of SRL has demonstrated that SRL processes fosters knowledge development when learning with hypermedia (e.g., Azevedo, 2005; Lajoie & Azevedo, 2006). However, research has also found that some students do not use key SRL processes when learning with hypermedia (Azevedo et al., 2004b).

Now that research has begun to examine *how* students self-regulate their learning with hypermedia, the next natural step in this line of research is to consider *why* students

self-regulate their learning with hypermedia. While this research agenda has not received considerable empirical attention, research from the field of self-efficacy provides a rich history which suggests that self-efficacy is a powerful determinant in the process of learning. As such, a promising direction for research examining how students learn with hypermedia is to consider the relationship between self-efficacy, SRL processes, and learning outcomes with hypermedia. Furthermore, given the recent trend in research examining the impact of conceptual scaffolds on SRL processes and learning outcomes with hypermedia (e.g., Azevedo, 2005; Graesser et al., 2005; Shapiro, 1999, 2000), the relationship between self-efficacy, SRL processes, and learning outcomes, should also be considered in learning contexts that provide conceptual scaffolds.

Prior Domain Knowledge, SRL, Self-Efficacy, and Conceptual Scaffolds in Learning with Hypermedia: Knowns and Unknowns

The preceding sections suggest that while previous research has empirically examined various factors in learning with hypermedia, there are some current issues which should be addressed in future research. In terms of cognitive factors, research has examined *prior domain knowledge* in learning with hypermedia. However, the vast majority of this research has focused on the relationship between prior domain knowledge and navigation during learning with hypermedia (e.g., Calisir & Gurel, 2003). While the effect of prior domain knowledge on navigation certainly warrants research, there is also a need for research that examines prior domain knowledge and learning outcomes with hypermedia (Shapiro, 2004). In addition to examining prior domain knowledge, previous research has also explored *self-regulatory processes* in learning with hypermedia. This line of research has provided rich data on the relationship between

specific self-regulatory processes and learning outcomes with hypermedia (e.g., Azevedo et al., 2004a). However, the relationship between motivation and use of SRL processes in learning with hypermedia has received very little empirical attention (Lepper & Woolverton, 2004; Moos & Azevedo, 2006b). Thus, future research is needed that examines the relationship between theoretical driven constructs of motivation, such as *self-efficacy*, and SRL processes.

Lastly, while research has also considered contextual factors, such as *conceptual scaffolds*, in learning with hypermedia, the results have been slightly mixed. Research is needed that clarifies the relationship between conceptual scaffolds and learning with hypermedia. To the best of my knowledge, a study has not been conducted that addresses all of these issues pertaining to cognitive, motivational, and contextual factors in learning with hypermedia. This dissertation addresses these issues.

Research Question and Hypotheses

In summary, the findings presented in the literature review of learning with hypermedia, SRL, self-efficacy, and scaffolding are the theoretical and empirical foundations for the research questions and hypotheses of this dissertation. The four specific research questions of this dissertation are:

- 1) *To what degree does prior domain knowledge predict declarative and conceptual learning outcomes, and does the provision of conceptual scaffolds moderate these relationships?*
- 2) *To what degree does self-efficacy fluctuate during learning with hypermedia, and does the provision of conceptual scaffolds moderate this relationship?*

- 3) *To what degree do prior domain knowledge and self-efficacy predict self-regulatory processes, and does the provision of conceptual scaffolds moderate these relationships?*
- 4) *To what degree do self-regulatory processes predict declarative and conceptual learning outcomes, and does the provision of conceptual scaffolds moderate these relationships?*

Based on previous research, the following hypotheses were proposed:

- 1) Though relatively limited empirical research has considered the relationship between prior domain knowledge and learning outcomes with hypermedia, extensive research in non-hypermedia environment has demonstrated that prior domain knowledge is a strong determinant in learning (Alexander & Jetton, 2003; Moos & Azevedo, in press). As such, it is predicted that prior domain knowledge will predict declarative and conceptual knowledge, and conceptual scaffolds will moderate this relationship.
- 2) Some research has indicated that self-efficacy changes over knowledge acquisition when learning with CBLEs (e.g., Mitchell et al., 1994). Based on this research, it is hypothesized that self-efficacy will significantly fluctuate during learning for participants in both conditions.
- 3) Previous research has indicated that self-efficacy is predictive of learning processes in some types of CBLEs, including simulations (e.g., Holladay & Quiñones, 2003; Thompson et al., 2002), and thus it is hypothesized that self-efficacy will predict SRL processes during learning with hypermedia. Furthermore, previous research with non-hypermedia environments indicates

that prior domain knowledge is a powerful determinant in learning (e.g., Alexander, 2003; Alexander & Murphy, 1998; Dochy & Alexander, 1995; Shapiro, 2004; Shapiro & Neiderhauser, 2004). Based on this research, it is hypothesized that prior domain knowledge, regardless of the condition, will predict SRL processes.

- 4) Previous research has suggested that SRL processes may be related to conceptual, but not declarative, learning outcomes (e.g., Azevedo et al., 2004a, 2005; Greene & Azevedo, in press). Thus, it is hypothesized that SRL processes will predict conceptual, but not declarative learning outcomes.

CHAPTER III: METHOD, PROCEDURE, & DATA ANALYSIS (PILOT STUDY)

The author ran a pilot study in the spring of 2006, which examined slightly different research questions from those outlined above. Several issues were raised in the proposal defense, particularly with measuring self-efficacy at different points during the hypermedia learning task. In order to address the issues raised in the proposal defense, several modifications were made to the dissertation study. The research questions for the dissertation study reflect these modifications, and thus are slightly different from the research questions for the pilot study. The following three research questions were used for the pilot study:

- 1) *To what degree do cognitive (prior domain knowledge), motivational (self-efficacy), and contextual (conceptual scaffolds) factors predict declarative and conceptual knowledge learning outcomes?*
- 2) *To what degree do cognitive (prior domain knowledge), motivational (self-efficacy), and contextual (conceptual scaffolds) factors predict self-regulatory processes?*
- 3) *To what degree do self-regulatory processes predict declarative and conceptual knowledge learning outcomes?*

Based on previous research, the following hypotheses were proposed:

- 1) Self-efficacy and prior domain knowledge will predict declarative and conceptual knowledge learning outcomes. The provision of conceptual scaffolds will predict conceptual learning outcomes, but not declarative learning outcomes.

- 2) Self-efficacy and prior domain knowledge will predict monitoring and strategy use, while self-efficacy and conceptual scaffolds will predict planning.
- 3) SRL processes will predict conceptual knowledge learning outcomes, but not declarative knowledge learning outcomes.

Method

Participants

Participants for the pilot study included 38 undergraduate education majors from the University of Maryland, College Park. Their average age was 20.97 ($SD = 1.80$); there were 27 females (70%) and 11 male (30%), and their average GPA was 3.11 ($SD = .42$). The sample consisted of six sophomores (16%), 15 juniors (40%), and 17 seniors (44%). The author individually tested all participants in Dr. Roger Azevedo's Cognition and Technology lab, located in the Benjamin Building at the University of Maryland.

Research Design

A pretest-posttest control group design was used with a think-aloud protocol methodology (Ericsson, 2006; Ericsson & Simon, 1993). A 2 x 2 mixed factorial design was used, with condition (No Scaffolding or Conceptual Scaffolding) as the between subjects factor and time (pretest to posttest) as the within subjects factor. The participants were randomly assigned to one of two conditions: No Scaffolding (NS; $n = 19$) or Conceptual Scaffolding (CS; $n = 19$).

Measures

Conceptual and declarative knowledge measures. Participants completed a pretest and posttest on the circulatory system. The pretest and posttest are identical and are

comprised of two parts: (a) a sheet which asks participants to match 13 words with their corresponding definitions (matching task measuring declarative knowledge of the circulatory system), and (b) a sheet which 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”* (mental model essay measuring conceptual knowledge of the circulatory system; see Appendix B for declarative and conceptual knowledge measures). These measures have been used in previous studies examining how students learn about the circulatory system with hypermedia (see Azevedo et al., 2005; Moos & Azevedo, 2006a, 2006c).

Motivation. The Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991) was used in this pilot study. The MSLQ is a self-report questionnaire which consists of 81 items answered on a seven point Likert scale (1 = not at all true of me, 7 = very true of me), and these 81 items fall into nine scales (see Appendix C for complete MSLQ). This pilot study focused on self-efficacy, and thus participants completed the self-efficacy scale from the MSLQ. Participants completed the eight questions from the self-efficacy scale immediately before the hypermedia learning task (see Appendix D for the self-efficacy scale used in this study). 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 (e.g., Rao & Sachs, 1999). In addition to statistical tests that have been used to confirm the validity of this scale, the wording of the questions is also

consistent with the theory of self-efficacy. Self-efficacy refers to self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of actions needed, and cognitive resources (Bandura, 1997; Wood & Bandura, 1989). Based on this operational definition, valid measures of self-efficacy should include questions that are context and task specific. Thus, the wording for the self-efficacy questions used in this pilot study were modified from the original MSLQ to ensure that the questions were more appropriate for this task and context (e.g., "I expect to do well in this class" was changed to "I expect to do well learning about the circulatory system with this computer program"). The Cronbach's alpha of the self-efficacy questions for the sample in the pilot study was .91, which suggests reliability and is consistent with previous research that has used this scale from the MSLQ (e.g., Pintrich et al., 1991).

Materials

Hypermedia Environment. During the learning task, participants used Microsoft Encarta Reference Suite™ (2003) on a laptop to learn about the circulatory system. This environment has been used in previous research examining learning with hypermedia (e.g., Moos & Azevedo, 2006a, 2006b, 2006c, accepted pending revisions). This hypermedia environment contains three articles and an animation that are all related to the circulatory system, and these articles are comprised of 16,900 words, 35 illustrations, 107 hyperlinks, and 18 sections. The Flesch Kincaid Grade Level of the text in these three articles is 12.0. Participants were able to freely search all of Encarta while learning about the circulatory system (see Appendix E for a screen shot of Encarta), but they were not allowed to go on-line and search while learning about the circulatory system.

Conceptual Scaffolds. Participants randomly assigned to the Conceptual Scaffolding (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 questions are conceptual scaffolds because they were designed to foster the development of conceptual knowledge throughout the 30-minute hypermedia learning task. They were designed in consultation with a veteran science teacher who is familiar with the content provided in the hypermedia environment.

Procedure

Each participant was individually tested by the author. First, the participant was given as much time as needed to complete the consent form (see Appendix F), and then was given 15 minutes to complete the pretest on the circulatory system. After completing the pretest, participants were given a five minute training session and walkthrough of the hypermedia environment, in which the most relevant articles for the topic of the learning task were identified. During this walkthrough, they also practiced navigating and accessing multiple representations (text, static diagrams, and digitized video clip). Following this walkthrough of the hypermedia environment, instructions for the learning task were provided. The instructions for the NS condition 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 encyclopedias. 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.” This overall learning goal has been previously used in empirical research examining how students learn about the circulatory system, and has demonstrated treatment fidelity of scaffolding conditions (see Azevedo et al., in press; Moos & Azevedo, 2006c). Additionally, it should be noted that the wording of this overall learning goal was purposefully designed to create a learning task in which the participants would need to self-regulate their learning in order to meet the goal. The instructions for the CS condition were identical to the above instructions, with one exception. The instructions for the CS condition also included a statement indicating that five guiding questions would be provided during the 30 minute learning task (see Appendix G for instructions provided to participants, by condition). After receiving the instructions, participants completed the self-efficacy scale from the MSLQ (Pintrich et al., 1991). On average, participants completed the eight questions in this self-efficacy scale in 60 seconds or less.

Next, participants were asked to think-aloud in a 5-minute think-aloud practice task in which they learned about a topic unrelated to the circulatory system with hypermedia (the causes of the American Civil War). The Flesch Kincaid Grade Level of the text in this article is 12.0 (see Appendix H for sample text from this article). After this practice task, participants were given 30 minutes to learn about the circulatory system with the hypermedia environment. During the 30-minute learning task, the five guiding questions were presented sequentially to participants in the CS condition. These participants were able to proceed through the questions at their own pace during the 30-minute hypermedia learning task, and were given the option to return to a previously answered question at any point during the 30-minute hypermedia learning task. These questions were placed to the right of the computer on a small copy stand and were always visible to the participants throughout the 30-minute learning task (see Appendix I for experimental set-up). Participants in the NS condition did not have access to these questions. However, participants in both the NS and CS condition had access to the overall learning goal during the 30-minute learning hypermedia learning task. During the 30 minute learning task, the participants' verbalizations were recorded and later used to analyze their self-regulated learning. 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.

Data Analysis

Coding and Scoring

In this section, the coding and scoring of the participants' answers to the matching task and mental model essay are described. In addition, the scheme that was used to analyze the participants' self-regulatory processes during learning is provided. Finally, the method in which inter-rater agreement was calculated is discussed.

Matching task. For the matching task, 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). Each participant received two matching task scores, one for their pretest and one for their posttest. The participants' pretest matching task score served as an indicator of their prior declarative knowledge of the circulatory system, while their posttest matching task score served as an indicator of their declarative learning outcome.

Mental models. The second part of the pretest and posttest was the mental model essay, which was designed to measure the participants' conceptual knowledge of the circulatory system. The participants' mental model of the circulatory system was examined using Azevedo and colleagues' method (Azevedo & Cromley, 2004; Azevedo, et al., 2004a, 2004b, 2005, in press), which is based on Chi and colleagues' research (Chi, 2000, 2004; Chi et al., 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 (see Table 1). Conceptual knowledge inherently involves declarative knowledge, especially for the lower mental models. As such, this coding scheme captures both declarative and conceptual knowledge. Each participant

received two mental model scores, one for his or her pretest and one for his or her posttest. The participants' pretest mental model served as an indicator of their prior conceptual knowledge of the circulatory system, while their posttest mental model served as an indicator of their conceptual learning outcome.

Table 1. Necessary features for each type of mental model (from Azevedo & Cromley, 2004)

<p>1. No understanding</p>	<p>7. Single Loop with Lungs</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • mentions lungs as a “stop” along the way describe “purpose” – oxygen/nutrient transport
<p>2. Basic Global Concepts</p> <ul style="list-style-type: none"> • blood circulates 	<p>8. Single Loop with Lungs - Advanced</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • mentions Lungs as a "stop" along the way • describe “purpose” – oxygen/nutrient transport • mentions one of the following: electrical system, transport functions of blood, details of blood cells
<p>3. Global Concepts with Purpose</p> <ul style="list-style-type: none"> • blood circulates • describes “purpose” - oxygen/nutrient transport 	<p>9. Double Loop Concept</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describes “purpose” - oxygen/nutrient transport • mentions separate pulmonary and systemic systems • mentions importance of lungs
<p>4. Single Loop – Basic</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport 	<p>10. Double Loop – Basic</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describe “purpose” - oxygen/nutrient transport • describes loop: heart - body - heart - lungs – heart

Table 1, continued

<p>5. Single Loop with Purpose</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describe “purpose” - oxygen/nutrient transport 	<p>11. Double Loop – Detailed</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describe “purpose” - oxygen/nutrient transport • describes loop: heart - body - heart - lungs – heart • structural details described: names vessels, describes flow through valves
<p>6. Single Loop - Advanced</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describe “purpose” – oxygen/nutrient transport • mentions one of the following: electrical system, transport functions of blood, details of blood cells 	<p>12. Double Loop - Advanced</p> <ul style="list-style-type: none"> • blood circulates • heart as pump • vessels (arteries/veins) transport • describe “purpose” - oxygen/nutrient transport • describes loop: heart - body - heart - lungs - heart • structural details described: names vessels, describes flow through valves • mentions one of the following: electrical system, transport functions of blood, details of blood cells

Self-Regulatory Processes. A think-aloud protocol methodology (Ericsson, 2006; Ericsson & Simon, 1993) was used to capture participants’ SRL processes during learning. Modified codes developed by Azevedo, Cromley, and Seibert (2004c) were used to code the participants’ verbalizations. Their model was based on several recent models of SRL (Butler & Winne, 1995; Corno & Mandinach, 2004; Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998; Winne & Perry, 2000; Zimmerman, 2000, 2001).

This model includes key components of Pintrich’s (2000) formulation of self-regulation as a four-phase process and extends these key components to capture the major phases of self-regulation. The modified coding scheme in this pilot study included 27 SRL processes from the three SRL categories of *planning*, *monitoring*, and *strategy use* (see Appendix J for list of SRL codes). The *planning* category consisted of goal setting,

planning, prior knowledge activation, and recycling goals into working memory. The *monitoring* category consisted 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 plus and minus categories were added to the coding scheme to differentiate between qualitatively distinct self-regulatory processes used during learning with hypermedia. For example, feeling of knowing (plus) is when the student is aware of having read or learned something in the past, while feeling of knowing (minus) is when the student is aware of *not* having read or learned something in the past. Though both of these processes represent monitoring activities, the qualitative nature of these activities is distinct and represents the positive and negative feedback loops during monitoring. Thus, the modified coding scheme attempts to capture these differences by including pluses and minuses for the monitoring activities. The *strategy use* category consisted of several effective and less effective learning strategies, including controlling video, coordinating informational sources, drawing, knowledge elaboration, making an inference, memorizing, reading notes, re-reading, summarizing, searching, and taking notes. Codes related to the category of *Handling Task Difficulties and Demands* were not coded in this study.

The raw SRL data collected from this pilot study came from 1,140 minutes (19 hours) of audio recordings from 38 participants who gave extensive verbalizations while learning about the circulatory system. During the first phase of data analysis, the audio tapes were transcribed and a text file was created for each student. This phase of the data

analysis yielded a total of 437 double-spaced pages ($M = 11.5$ pages per participant). All of the transcriptions were then coded by assigning one of the SRL variables to each segment. It should be noted that the SRL coding scheme was not designed to segment and code all of the participants' verbalizations. If a verbalization was not codeable (i.e. the content of the verbalization was not related to any of the SRL codes in the coding scheme or was inaudible), then the segment was not assigned a SRL code. For example, the segments in which a participant was reading from the hypermedia environment were not coded because reading is not related to any of the SRL codes in the coding scheme. The coding phase of data analysis yielded a total of 1,290 coded SRL segments for all participants ($M_{\text{SRL}} = 33.9$ per participant). After coding each transcription, the individual SRL codes were then collapsed into one of the three corresponding SRL categories (*planning*, *monitoring*, or *strategy use*). For example, if a participant had a total of three prior knowledge activation codes (*planning*), two recycle goals codes (*planning*), ten summarization codes (*strategy use*), four coordinating informational source codes (*strategy use*), two monitoring progress towards goals codes (*monitoring*), and one time monitoring code (*monitoring*) then this participant would have a total of five *planning* codes, 14 *strategy use* codes, and three *monitoring* codes. Each participant's totals for the three SRL categories (*planning*, *strategy use*, and *monitoring*) were used in the data analyses for research questions two and three.

Motivation. The self-efficacy scale from the MSLQ 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 these items followed the scoring procedure used for the complete MSLQ (see Pintrich et al., 1991). In this procedure, each participant received one self-efficacy

score. The score was calculated by dividing the sum of the participant's answers to all of the questions (possible range = 8 to 56) by eight (the total number of questions in the self-efficacy scale). Thus, each participant's self-efficacy score had a possible range from 1 to 7. Higher self-efficacy scores indicated that the participant was more efficacious.

Inter-rater agreement

The author, who has been trained to use an adapted version of Azevedo and colleagues' coding scheme and has coded hundreds of transcriptions from think-aloud protocols (Azevedo et al., 2005; Moos & Azevedo, 2006a, 2006b, 2006c), first coded all of the transcriptions. A fellow graduate student and former research assistant who aided in the development of the coding scheme and has been trained to use this scheme independently recoded thirty-two percent of the transcriptions ($n = 12$). There was agreement on 399 out of 403 coded SRL segments, yielding a reliability coefficient of .99. Inter-rater reliability was also obtained for the mental model essays. After the author scored all mental model essays, the same graduate student, who was also trained to use the mental scoring scheme, independently scored thirty-two percent of the pretest and posttest mental model essays ($n = 24$). The graduate student was blind to condition. There was agreement on the scoring of 21 out of 24 mental model essays, yielding a reliability coefficient of .88.

Results

Research Question #1: To what degree do cognitive factors (prior domain knowledge), motivational (self-efficacy), and contextual (conceptual scaffolds) factors predict declarative and conceptual knowledge learning outcomes? In order to address the first research question, two separate regressions were run. In the first regression analysis,

the factors of prior declarative knowledge, self-efficacy, and condition were used to predict declarative knowledge learning outcomes (as measured by the participants' score on the matching task of the posttest). Because there was missing data from the self-efficacy scale for one participant, $N = 37$ for each of the regressions.

Declarative Knowledge. The regression analysis revealed that the model including prior declarative knowledge, self-efficacy, and condition was a significant predictor of declarative knowledge learning outcomes, $F(3, 36) = 23.500, p < .001$. This model predicted 68.1% of the variance in the participants' matching posttest score. Analysis of the main effects indicated that prior declarative knowledge ($\beta = .695, p < .001$; see Table 2) and self-efficacy were significant predictors ($\beta = .248, p = .027$; see Table 2) of declarative learning outcomes, while the main effect for condition was not significant ($p > .05$; see Table 2). The means of prior declarative and conceptual knowledge, declarative and conceptual learning outcome, and self-efficacy are presented in Table 3.

Table 2. Predictors of declarative learning outcomes ($N = 37$)

Predictors		β
Main Effects	Prior Declarative Knowledge	.695**
	Self-efficacy	.248*
	Condition	-.197

* $p < .05$; ** $p < .01$

Table 3. Means and (standard deviations) of prior declarative and conceptual knowledge, declarative and conceptual learning outcomes, and self-efficacy, by condition

Variable	NS condition (<i>n</i> = 19)	CS condition (<i>n</i> = 19)	Overall (<i>n</i> = 38)
Prior Domain Knowledge (Declarative) ¹	7.26 (3.60)	8.00 (3.87)	7.63 (3.71)
Prior Domain Knowledge (Conceptual) ²	4.58 (3.55)	4.74 (2.96)	4.66 (3.05)
Learning Outcome (Declarative) ¹	10.42 (2.77)	9.79 (3.08)	10.11 (2.91)
Learning Outcome (Conceptual) ²	8.00 (3.48)	9.37 (2.75)	8.68 (3.17)
Self-efficacy ^{3,4}	4.70 (0.95)	4.64 (1.12)	4.67 (1.02)

1 = Range for declarative knowledge measures is 0 to 13.

2 = Range for conceptual knowledge measures is 0 to 12.

3 = Range for self-efficacy measure is 1 to 8.

4 = *N* = 37.

In the second regression analysis for this research question, prior conceptual knowledge, self-efficacy, and condition were used to predict conceptual knowledge learning outcomes (as measured by the participants' score on the mental model section of the posttest).

Conceptual Knowledge. The regression analysis revealed that the model including prior conceptual knowledge, self-efficacy, and condition was a significant predictor of conceptual knowledge learning outcomes, $F(3, 36) = 5.972, p = .002$. This model predicted 35.2% of the variance in the participants' conceptual knowledge learning outcome. Analysis of the main effects indicated that prior conceptual knowledge was a

significant predictor ($\beta = .532, p = .001$; see Table 4), while the main effect of self-efficacy and condition were not significant ($p > .05$; see Table 4).

Table 4. Predictors of conceptual learning outcomes ($N = 37$)

Predictors		β
Main Effects	Prior Conceptual Knowledge	.532**
	Self-efficacy	.154
	Condition	.120

* $p < .05$; ** $p < .01$

Research Question #2: To what degree do cognitive factors (prior domain knowledge), motivational (self-efficacy), and contextual (conceptual scaffolds) factors predict self-regulatory processes? In order to address the second research question, three separate regressions were run. Because there was missing self-efficacy data one participant, $N = 37$ for each of the regressions. In the first regression analysis, the factors of prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition were used to predict *planning* processes. The regression analysis revealed that the model including prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition was a significant predictor of planning processes, $F(4, 36) = 5.800, p = .001$. This model predicted 42.0% of the variance in the planning processes during learning with hypermedia. Analysis of the main effects indicated that condition was a significant predictor ($\beta = .533, p < .001$; see Table 5), while the main effects for prior declarative knowledge, prior conceptual knowledge, and self-efficacy were not significant ($p > .05$; see Table 5).

Table 5. Predictors of planning processes ($N = 37$)

Predictors		β
Main Effects	Prior Declarative Knowledge	.139
	Prior Conceptual Knowledge	.083
	Self-efficacy	.207
	Condition	.533**

* $p < .05$; ** $p < .01$

In the second regression analysis, the factors of prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition were used to predict *monitoring* processes. In the third regression analysis, the factors of prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition were used to predict *strategy use*. These two regressions analyses were not significant ($p > .05$). The mean frequency of each SRL category, by condition, is presented in Table 6.

Table 6. Means and (standard deviations) of SRL processes used during learning, by condition

SRL Category	NS condition ($n = 19$)	CS condition ($n = 19$)
Planning	2.00 (1.80)	6.74 (4.55)
Monitoring	6.32 (7.69)	10.47 (5.99)
Strategy Use	18.16 (9.35)	24.21 (11.53)

Research Question #3: What is the relation between self-regulatory processes and declarative and conceptual knowledge learning outcomes? In order to address the third research question, two separate regressions were run. There was no missing data for this research question, so $N = 38$ for both regressions. In the first regression analysis, the factors of planning, monitoring, and strategy use were used to predict declarative knowledge learning outcomes. The regression analysis revealed that the model including these factors was not a significant predictor of declarative learning outcomes ($p > .05$).

In the second regression analysis, the factors of planning, monitoring, and strategy use were used to predict conceptual knowledge learning outcomes. This analysis revealed that the model including these factors was a significant predictor of conceptual knowledge learning outcomes $F(3, 37) = 4.376, p = .010$. This model predicted 27.9% of the variance in conceptual knowledge learning outcomes. Analysis of the main effects indicated that monitoring was a significant predictor ($\beta = .388, p = .019$; see Table 7), while the main effects of planning and strategy were not significant predictors of conceptual learning outcomes ($p > .05$; see Table 7).

Table 7. SRL predictors of conceptual learning outcomes

Predictors		β
Main Effects	Planning	-.051
	Monitoring	.388*
	Strategy Use	.309

* $p < .05$; ** $p < .01$

Summary

This pilot study examined relationships between various factors and learning outcomes with hypermedia. In terms of the first research question, analysis of the main effects indicated that prior domain knowledge predicted both declarative and conceptual knowledge learning outcomes. This finding is consistent with previous research (e.g., Alexander & Jetton, 2003). Analysis of the main effects for this research question also indicated that self-efficacy predicted declarative, but not conceptual learning outcomes. This result partially supported the hypotheses for this pilot study. In particular, the hypothesis that self-efficacy would also predict conceptual learning outcomes was not supported by the results from this pilot study. One possible explanation for this somewhat surprising finding is that a source of self-efficacy may stem from the most interpretable indicator of performance. In the case of this pilot study, performance on the matching section may have been easier to interpret than performance on the essay section of the knowledge measures. As such, the participants' responses to the self-efficacy questions may have reflected an interpretation of their performance on the matching section.

In terms of research question two, condition was the only factor that predicted self-regulatory processes, specifically *planning* processes. On one hand, this finding is consistent with some previous research that has found students, particularly undergraduates, regulate their learning differently when provided conceptual scaffolds. For example, Moos and Azevedo (2006c) found that students who received conceptual scaffolds when learning about the circulatory system with hypermedia used more planning processes than students who did not receive these scaffolds. However, the non-significant main effects of prior declarative knowledge and prior conceptual knowledge

were slightly contradictory with previous research. Some research suggests that prior domain knowledge is related to how students self-regulate their learning (Chen et al., 2006). In particular, this line of research indicates that students with lower prior domain knowledge tend to use more strategies while students with higher prior domain knowledge tend to use more monitoring processes when learning with hypermedia (Moos & Azevedo, 2006a). Given the limited sample size of this pilot study, more participants were needed to adequately address the relationship between prior domain knowledge and SRL processes.

The results for the third research question indicated that SRL processes did not predict declarative learning outcomes with hypermedia. This finding is consistent with previous research that has differentiated between declarative and conceptual learning outcomes. For example, Azevedo and colleagues (Azevedo & Cromley, 2004; Azevedo et al., 2004a, 2004c, 2005) have routinely found significant differences in how undergraduates self-regulate their learning with hypermedia, especially when comparing undergraduates in different scaffolding conditions. However, these results also indicated that most undergraduates demonstrate declarative learning gains when learning with hypermedia, even in the absence of scaffolds and when they use different SRL processes. Results from this pilot study indicated that most undergraduates are able to develop conceptual knowledge when learning with hypermedia even though there was variability in how they self-regulated their learning, which is consistent with previous research. Results from this pilot study also indicated that SRL processes related to monitoring predicted conceptual learning outcomes. However, given the small sample size of this

pilot study, the conclusions that can be drawn are limited and a much larger sample size was needed.

Changes for Dissertation

Though the pilot study presented some interesting findings on the relationship between prior domain knowledge, self-efficacy, SRL, and conceptual scaffolding, several changes were made to the dissertation. First, a power analysis was run to determine the minimum sample size for the dissertation. This power analysis indicated that a sample of 84 undergraduates was needed. Thus, one goal of the dissertation was to run this study with a larger sample. Second, the issue of measuring self-efficacy at several points during the learning task, as opposed to measuring it once before the participants began the learning task, was raised in the proposal defense. This methodological approach allows for an examination of how self-efficacy fluctuates during learning with hypermedia. In order to address this issue, the dissertation measured self-efficacy at additional points during the 30-minute hypermedia learning task. While the pilot study measured self-efficacy at one point during the experimental session (immediately before the participants began the hypermedia learning task), the dissertation measured self-efficacy at three time points during the experimental session (immediately before the hypermedia learning task, 10 minutes into the hypermedia learning task, and 20 minutes into the hypermedia learning task). The modification of measuring self-efficacy at different points during the learning task is reflected in the altered research questions for the dissertation study. Additionally, slight changes were made to the self-efficacy questions in the dissertation. The changes were made to ensure that the self-efficacy questions were specific to the particular context and learning task in the dissertation study. Except for these

modifications, the method and procedure for the dissertation study was identical to the pilot study.

CHAPTER IV: METHOD, PROCEDURE, & DATA ANALYSIS (DISSERTATION)

Method

Participants

A power analysis, performed following the pilot study, indicated that a sample of 84 was necessary for a power of .80 and α set at .05 (Cohen, 1992). In order to obtain a minimum sample of 84 participants, undergraduate students were recruited from nine different education classes at the University of Maryland, College Park, to participate in this dissertation study during the fall 2007 semester. Participants received extra credit in their classes (as determined by their individual professor) for participation in this study. Ninety-two undergraduates participated in this study. However, seven participants had missing data and/or poor audio quality in the think-aloud. Thus, the final sample for this dissertation study included data from 85 participants. The participants' average age was 20.92 ($SD = 2.51$); there were 63 women (74%) and 22 men (26%). Of the 85 participants, 4 (5%) were freshmen, 15 (18%) were sophomores, 27 (32%) were juniors, and 36 (42%) were seniors. Three participants (3%) did not report their class standing. The participants' average GPA was 3.26 ($SD = .46$).

Research Design

The research design in the dissertation study was identical to the one used in the pilot study. The participants were randomly assigned to one of two conditions: No Scaffolding (NS; $n = 43$) or Conceptual Scaffolding (CS; $n = 42$).

Measures

Conceptual and declarative knowledge measures. Participants completed the identical pretest and posttest that was used in the pilot study. The matching task on the

pretest measured prior declarative knowledge, while the matching task on the posttest measured declarative learning outcomes. The mental model essay on the pretest measured prior conceptual knowledge, while the mental model on the posttest measured conceptual learning outcomes.

Motivation. Participants completed the self-efficacy scale from the MSLQ (Pintrich et al., 1991) at three points during the experimental session: Immediately prior to the hypermedia learning task, 10 minutes into the hypermedia learning task, and 20 minutes into the hypermedia learning task. This approach allowed for the measurement of the fluctuation of self-efficacy during the experimental session.

The self-efficacy scale from the MSLQ includes eight questions. The wording of these eight questions was slightly modified in this dissertation 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.” The Cronbach’s alpha for the self-efficacy scale used in this study was as follows: $\alpha = .91$ (self-efficacy scale administered immediately 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), which is consistent with previous research that has used this scale from the MSLQ.

Materials

Hypermedia Environment and Conceptual Scaffolds. The materials used in this dissertation study were identical to those used in the pilot study. During the learning task, participants from both conditions used the same hypermedia environment from the pilot

study (Microsoft Encarta Reference Suite™, 2003). Additionally, participants randomly assigned to the CS condition received five guiding questions during the hypermedia learning task. These guiding questions were identical to those used in the pilot study.

Procedure

All participants were individually tested by the author. The procedure for the dissertation study was identical to the pilot study, except that participants from both conditions completed the self-efficacy scale from the MSLQ at two time points during the hypermedia learning task (10 minutes into the learning task and 20 minutes into the learning task)¹. The procedure is presented in Table 8.

Table 8. Experimental procedure

Procedure							
Condition	15 Minutes	5 Minutes	5 Minutes	5 Minutes	5 Minutes	30 Minutes	15 Minutes
No Scaffolding	Pretest	Walkthrough of Hypermedia Environment	Instructions for 30- minute Learning Task	Self- efficacy scale from MSLQ	Practice think- aloud task	Learning Task With Hypermedia ^{1,2}	Posttest
Conceptual Scaffolding Condition	Pretest	Walkthrough of Hypermedia Environment	Instructions for 30- minute Learning Task	Self- efficacy scale from MSLQ	Practice think- aloud task	Learning Task With Hypermedia ^{1,2, 3}	Posttest

1 = Participants provide think-aloud during learning

2 = Participants complete the self-efficacy questionnaire 10 minutes and 20 minutes into the learning task

3 = Participants in Conceptual Scaffolding condition receive five guiding questions during learning

¹ Self-efficacy data was collected at 10 minute intervals (immediately prior to the learning task, 10 minutes into the learning task, and 20 minutes into the learning task). These intervals were deemed to be most appropriate because it has been suggested that self-efficacy fluctuates when students gain knowledge (Bandura, 1994). Time intervals shorter than the ones used in this study (e.g., five minutes) may not have been a sufficient amount of time for the participants to develop knowledge of the circulatory system.

Data Analysis

Coding and Scoring

The coding and scoring for the matching task, mental model essay, MSLQ score, and SRL processes were computed identically to the way they were computed in the pilot study.

The raw SRL data collected from this dissertation study came from 2,550 minutes (42.5 hours) of audio recordings from 85 participants who gave extensive verbalizations while learning about the circulatory system. During the first phase of data analysis, the audio tapes were transcribed and a text file was created for each student. This phase of the data analysis yielded a total of 910 double-spaced pages ($M = 10.7$ pages per participant). All of the transcriptions were then coded by assigning one of the SRL variables to each segment (see Appendix K for an example of a page coded by the author). The coding phase of data analysis yielded a total of 3,103 coded SRL segments for all participants ($M_{\text{SRL}} = 36.5$ per participant). After coding each transcription, the individual SRL codes were then collapsed into one of the three corresponding SRL categories (*planning, monitoring, or strategy use*).

Inter-rater agreement

The author, who has been trained to use an adapted version of Azevedo and colleagues' coding scheme and has coded hundreds of transcriptions from think-aloud protocols (Azevedo et al., 2004, 2005, in press; Moos & Azevedo, 2006a, 2007a, in press), first coded all of the transcriptions. Then, the same graduate student who helped with the inter-rater reliability for the pilot study completed the inter-rater reliability for the dissertation study by independently recoding thirty-one percent of the transcriptions

($n = 26$). There was agreement on 908 out of 918 coded SRL segments, yielding a reliability coefficient of .98.

Inter-rater reliability was also established for the coding of the participants' mental model essays on the pretest and posttest. The author scored all of the participants' pretest and posttest mental model essays. The same graduate student who helped with inter-rater reliability for the pilot study completed the inter-rater reliability by independently recoding 31% of the participants' pretest ($n = 26$) and posttest ($n = 26$) mental model essays. She was blind to condition during the recoding of the mental model essays. There was agreement on 45 out of 52 scored essays, yielding an inter-rater reliability of .87. Disagreements on the mental model scoring and coding of SRL processes were resolved through discussion.

CHAPTER V: RESULTS FOR DISSERTATION

Before the data could be analyzed for each of the research questions, normality of the distribution was examined because the analyses for this dissertation are based on the assumption of normal distribution. Examination of the normality is particularly important in the field of education and psychology as normal distributions tend to be rare (Micceri, 1989). In order to test for the normality of data in this dissertation, the descriptive statistics of kurtosis and skewness and visual examination of the histogram for the distribution of each variable were observed (see Table 9).

Table 9. Kurtosis and skewness of data for each variable.

Variable	Kurtosis	Skewness
Prior Declarative Knowledge	-.815	.076
Prior Conceptual Knowledge	-.744	.193
Declarative Learning Outcome ¹	.835	-1.104
Conceptual Learning Outcome	-.33	-.865
Self-efficacy (Time 1)	-.571	-.217
Self-efficacy (Time 2)	-.439	-.253
Self-efficacy (Time 3)	-.797	-.247
Planning ¹	2.785	1.557
Monitoring ¹	2.357	1.492
Strategy Use	.636	.622

¹ = Kurtosis and/or skewness indicate non-normal distribution of data for that variable

The examination of the kurtosis and skewness suggest that the following variables did not have a normal distribution of data: Declarative learning outcomes, planning, and monitoring. In order to address this violation of the normal distribution assumption, a square-root transformation, a commonly used transformation in the field (Hartwig & Dearing, 1979), was conducted on these three variables. The square root transformation involves taking the square root of each data point for each variable and then using the transformed data points in the analyses. This transformation was done using the ‘transform’ function in SPSS. The square root transformation often results in homogeneous variances of the variables (Micceri, 1989). These transformed variables were used in the following analyses.

Research question #1: To what degree does prior domain knowledge predict declarative and conceptual learning outcomes, and do conceptual scaffolds moderate these relationships?

In order to address the first research question, two separate regressions were run. In the first regression analysis, the factors of prior declarative knowledge, prior conceptual knowledge, and condition (as the moderator variable) were used to predict declarative knowledge learning outcomes (as measured by the square-root transformation of the participants’ score on the matching task of the posttest).

Declarative Knowledge. The regression analysis revealed that the model including prior declarative knowledge and prior conceptual knowledge was a significant predictor of declarative knowledge learning outcomes, $F(2, 84) = 38.500, p < .001$. This model predicted 48.4% of the variance in the participants’ matching posttest score. Analysis of the main effects indicated that prior declarative knowledge was a significant predictor (β

= .597, $p < .001$; see Table 10), while the main effect for prior conceptual knowledge was not significant ($p > .05$; see Table 10). It should be noted that the final model for this regression did not include the moderating variable of condition as this variable was not significant ($p > .05$). Thus, the provision of conceptual scaffolds did not moderate the relationship between prior domain knowledge and declarative learning outcomes.

Table 10. Prior domain knowledge predictors of declarative learning outcomes ($N = 85$)

Predictors		β
Main Effects	Prior Declarative Knowledge	.597**
	Prior Conceptual Knowledge	.162

* $p < .05$; ** $p < .01$

In the second regression analysis, the factors of prior declarative knowledge, prior conceptual knowledge, and condition (as the moderator variable) were used to predict conceptual knowledge learning outcomes (as measured by participants' score on the mental model essay of the posttest).

Conceptual Knowledge. The model including prior conceptual knowledge and prior declarative knowledge was a significant predictor of conceptual knowledge learning outcomes, $F(2, 84) = 19.453, p < .001$. This model predicted 32.2% of the variance in the participants' conceptual knowledge learning outcome. Analysis of the main effects indicated that prior conceptual knowledge was a significant predictor ($\beta = .326, p = .003$; see Table 11) and prior declarative knowledge was a significant predictor ($\beta = .323, p = .003$; see Table 11). It should be noted that the final model for this regression did not include the moderating variable of condition as this variable was not significant ($p > .05$).

Means of prior declarative and conceptual knowledge, and declarative and conceptual learning outcomes, are presented in Table 12.

Table 11. Prior domain knowledge predictors of conceptual learning outcomes ($N = 85$)

Predictors		β
Main Effects	Prior Declarative Knowledge	.323**
	Prior Conceptual Knowledge	.326**

* $p < .05$; ** $p < .01$

Table 12. Means and (standard deviations) of prior declarative and conceptual knowledge, and declarative and conceptual learning outcomes, by condition²

Variable	NS condition ($n = 43$)	CS condition ($n = 42$)	Overall ($n = 85$)
Prior Declarative Knowledge ¹	7.81 (3.35)	7.93 (3.41)	7.87 (3.36)
Prior Conceptual Knowledge ²	5.44 (3.17)	5.36 (2.85)	5.40 (3.00)
Declarative Learning Outcome ¹	10.70 (2.50)	10.50 (2.96)	10.60 (2.72)
Conceptual Learning Outcome ²	7.77 (3.27)	9.17 (2.99)	8.46 (3.19)

¹ = Possible range was 0 to 13

² = Possible range was 1 to 12

² This dissertation focused on learning with hypermedia. As such, two paired sample t-tests were run in order to determine if the participants were in fact learning with hypermedia. Results from the first paired sample t-test indicated that the participants' matching task score on the posttest was significantly higher than their matching task score on the pretest, $t(84) = -10.31, p < .001$. Results from the second paired sample t-test indicated that the participants' mental model on the posttest was significantly higher than their mental model on the pretest, $t(84) = -9.07, p < .001$.

Research question #2: To what extent does self-efficacy fluctuate during learning, and is the provision of conceptual scaffolds related to this fluctuation?

The participants' responses to the questions from the self-efficacy scale of the MSLQ at three 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 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, $F(1.723, 143.016) = 4.636, p = .015, \eta^2 = .053$, the main effect of condition was not significant, and the interaction between time on self-efficacy and condition was not significant. A pairwise comparison of self-efficacy at different points indicated that participants in both conditions reported, on average, significantly higher levels of self-efficacy before the hypermedia learning task when compared to their reported self-efficacy 10 minutes ($p = .010$) and 20 minutes ($p = .024$) into the hypermedia learning task. However, participants' self-efficacy 10 minutes into the learning task was not significantly different, on average, than their self-efficacy 20 minutes into the learning task ($p > .05$). See Figure 1 for the fluctuations of self-efficacy and Table 13 for participants' mean self-reported self-efficacy, by time and condition. In sum, these results indicated that participants in both conditions reported significantly higher levels of self-efficacy, on average, immediately before the hypermedia learning task when compared to their reported self-efficacy during the hypermedia learning task.

Figure 1. Fluctuations in self-reported self-efficacy, by condition

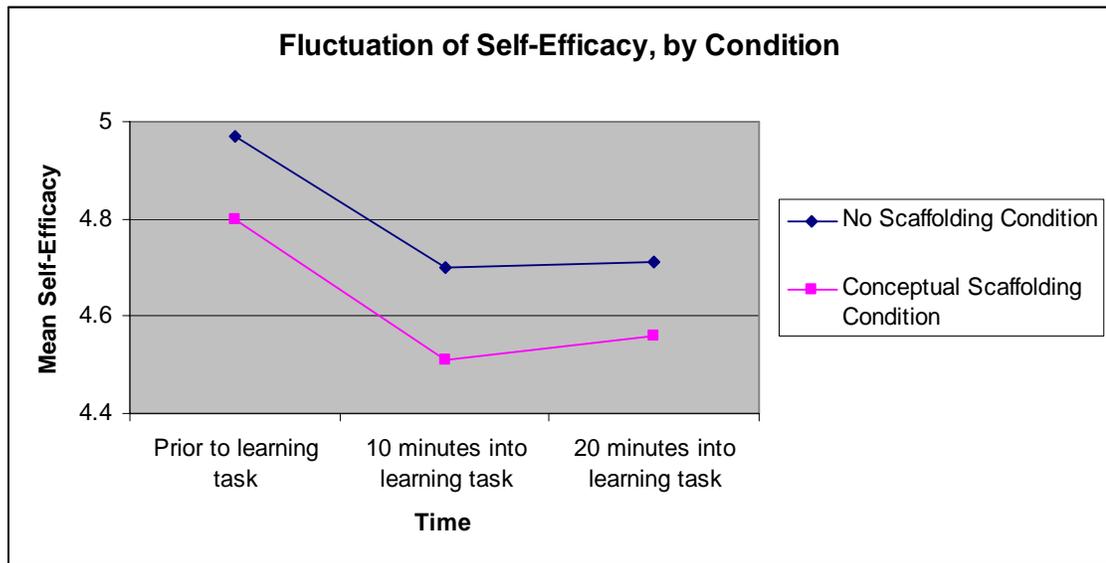


Table 13. Mean self-reported self-efficacy, by time and condition

Variable	NS condition (<i>n</i> = 43)	CS condition (<i>n</i> = 42)
Self-efficacy prior to learning task	4.95 (0.89)	4.79 (1.07)
Self-efficacy 10 minutes into learning task	4.71 (1.06)	4.50 (1.22)
Self-efficacy 20 minutes into learning task	4.73 (0.98)	4.56 (1.14)

Research question #3: To what degree does prior domain knowledge and self-efficacy predict self-regulatory processes during learning, and do conceptual scaffolds moderate these relationships?

In order to address this research question, three separate regressions were run. In the first regression analysis, the factors of prior declarative knowledge, prior conceptual

knowledge, self-efficacy, and condition (as the moderator variable) were used to predict planning processes during learning. Participants' responses to the self-efficacy scale completed prior to learning with the hypermedia environment (Time 1) were used in the regression analyses for this research question.

Planning. The regression analysis revealed that the model including prior declarative knowledge, prior conceptual knowledge, and self-efficacy was a significant predictor of planning processes during learning, $F(3, 84) = 3.281, p = .025$. This model predicted 10.8% of the variance in planning processes during learning. Analysis of the main effects indicated that self-efficacy was a significant predictor ($\beta = .287, p = .013$; see Table 14) of planning processes, while prior declarative knowledge and prior conceptual knowledge were not significant predictors ($p > .05$; see Table 14). It should be noted that the final model for this regression did not include the moderating variable of condition as this variable was not significant ($p > .05$). Thus, the provision of conceptual scaffolds did not moderate the relationship between prior domain knowledge and self-efficacy with planning processes during learning with hypermedia.

Table 14. Predictors of planning processes ($N = 85$)

Predictors		β
Main Effects	Self-efficacy	.271*
	Prior Declarative Knowledge	.037
	Prior Conceptual Knowledge	.045

* $p < .05$; ** $p < .01$

In the second regression analysis for this research question, the factors of prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition (as the moderator variable) were used to predict monitoring processes during learning.

Monitoring. The regression analysis revealed that the model including prior declarative knowledge, prior conceptual knowledge, and self-efficacy was a significant predictor of monitoring processes during learning, $F(3, 84) = 4.784, p = .004$. This model predicted 15.1% of the variance in the monitoring processes during learning. Analysis of the main effects indicated that self-efficacy was a significant predictor ($\beta = .360, p = .002$; see Table 15) of monitoring processes, while prior declarative knowledge and prior conceptual knowledge were not significant predictors ($p > .05$; see Table 15). It should be noted that the final model for this regression did not include the moderating variable of condition as this variable was not significant ($p > .05$). Thus, the provision of conceptual scaffolds did not moderate the relationship between prior domain knowledge and self-efficacy with monitoring processes during learning with hypermedia.

Table 15. Predictors of monitoring processes ($N = 85$)

Predictors		β
Main Effects	Self-efficacy	.360**
	Prior Declarative Knowledge	.129
	Prior Conceptual Knowledge	-.124

* $p < .05$; ** $p < .01$

In the third regression analysis for this research question, the factors of prior declarative knowledge, prior conceptual knowledge, self-efficacy, and condition (as the moderator variable) were used to predict strategies during learning.

Strategies. The overall model was not a significant predictor of strategies during learning ($p > .05$). The mean frequency of planning processes, monitoring processes, and strategies, by condition, is presented in Table 16.

In sum, the results for research question three indicated that self-efficacy predicted planning and monitoring processes during the hypermedia learning task, but prior domain knowledge did not predict these processes. Additionally, the results also indicated that conceptual scaffolds did not moderate the relationship between self-efficacy and SRL processes during the hypermedia learning task. Lastly, the results indicated that neither self-efficacy nor prior domain knowledge predicted strategies during the hypermedia learning task.

Table 16. Total raw frequency of individual SRL processes used during learning, by condition

SRL Processes	No Scaffolding Condition (n = 43)	Conceptual Scaffolding Condition (n = 42)
<i>Planning</i>		
Planning	1	1
Prior Domain Knowledge Activation	43	86
Recycle Goal in Working Memory	17	113
Sub-Goals	45	50
TOTAL	106	250
<i>Monitoring</i>		
Content Evaluation (+)	21	45
Content Evaluation (-)	66	54
Expecting Adequacy (+)	18	22
Expecting Adequacy (-)	16	21
Feeling of Knowing (+)	121	78
Feeling of Knowing (-)	67	44
Judgment of Learning (+)	30	21
Judgment of Learning (-)	29	28
Monitoring Progress Toward Goals	14	49

Table 16, continued

Monitor Use of Strategies	9	4
Time Monitoring	18	10
TOTAL	409	376
<i>Strategy Use</i>		
Coordinating Informational Sources	29	16
Control of Video	48	36
Draw	12	8
Goal-Directed Search	15	31
Inferences	12	24
Knowledge Elaboration	22	34
Memorization	5	9
Read Notes	26	39
Re-Reading	142	168
Self-Test	0	4
Summarization	208	275
Taking Notes	304	304
TOTAL	823	948

Research question #4: To what degree do self-regulatory processes predict declarative and conceptual learning outcomes, and do conceptual scaffolds moderate these relationships?

In order to address this research question, two separate regressions were run. In the first regression analysis, the factors of planning, monitoring, strategies, and condition (as the moderator variable) were used to predict declarative learning outcomes.

Declarative knowledge. The regression analysis revealed that the model including planning, monitoring, and strategies was a significant predictor of declarative knowledge learning outcomes, $F(3, 84) = 3.026, p = .034$. This model predicted 10.1% of the variance in the conceptual learning outcomes. Analysis of the main effects indicated that monitoring was a significant predictor ($\beta = .343, p = .007$; see Table 17), but planning and strategy use were not significant predictors of declarative learning outcomes ($p > .05$). Additionally, results indicated that condition did not moderate the relationship between SRL and declarative learning outcomes.

Table 17. SRL predictors of declarative learning outcomes ($N = 85$)

Predictors		β
Main Effects	Planning	-.044
	Monitoring	.343**
	Strategy Use	-.023

* $p < .05$; ** $p < .01$

In the second regression analysis, the factors of planning, monitoring, strategies, and condition (as the moderator variable) were used to predict conceptual learning outcomes.

Conceptual knowledge. The regression analysis revealed that the model including planning, monitoring, and strategies was a significant predictor of conceptual knowledge learning outcomes, $F(3, 84) = 9.270, p < .001$. This model predicted 25.6% of the variance in the conceptual learning outcomes. Analysis of the main effects indicated that monitoring was a significant predictor ($\beta = .337, p = .003$; see Table 18), but planning and strategy use were not significant predictors of conceptual learning outcomes ($p > .05$; see Table 18). Additionally, the results indicated that condition did not moderate the relationship between SRL and conceptual learning outcomes. Bivariate correlations among all of the measures are shown in Table 19.

Table 18. SRL predictors of conceptual learning outcomes ($N = 85$)

Predictors		β
Main Effects	Planning	.222
	Monitoring	.337**
	Strategy Use	.037

* $p < .05$; ** $p < .01$

Table 19. Correlations among all of the measures

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.PDK	-										
2.PCK	.528**	-									
3.DLO	.696**	.491**	-								
4.CLO	.495**	.497**	.535**	-							
5.SE(1)	.342**	.290**	.436**	.269*	-						
6.SE(2)	.346**	.408**	.400**	.341*	.762**	-					
7.SE(3)	.380**	.392**	.373**	.285**	.707*	.873**	-				
8.Plan	.139	.187	.175	.357**	.313**	.301*	.333**	-			
9.Mon	.144	.032	.288**	.346**	.372**	.335**	.251*	.380**	-		
10.Strat	.105	.117	.099	.250*	.217*	.083	.030	.492**	.322**	-	
11.Cond	.017	-.014	-.037	.220*	-.086	-.087	-.056	.424**	-.039	.159	-

* $p < .05$; ** $p < .01$

PDK = prior domain knowledge; PCK = prior conceptual knowledge; DLO = declarative learning outcomes; CLO = conceptual learning outcomes; SE(1) = self-efficacy at time 1; SE(2) = self-efficacy at time 2; SE(3) = self-efficacy at time 3; Plan = planning; Mon = monitoring; Strat = strategy; Cond = condition

Overall, the results from these research questions present four findings. First, prior domain knowledge predicted both declarative and conceptual knowledge learning outcomes. Second, self-efficacy fluctuated during the 30 minute hypermedia learning task. Specifically, participants from both conditions reported higher self-efficacy, on average, immediately before the hypermedia learning task when compared to their reported self-efficacy at 10 and 20 minutes into the hypermedia learning task. Third, self-efficacy predicted monitoring and planning processes, but not strategy use during learning. Fourth, self-regulatory processes (particularly processes related to monitoring) predicted conceptual and declarative learning outcomes. Fourth, results indicated that the provision of conceptual scaffolds did not moderate any of these relationships.

CHAPTER VI: DISCUSSION

In this study, think-aloud, pretest, and posttest data from 85 undergraduates were collected to examine the relationship between various factors and learning with hypermedia. In particular, the relationships between *prior domain knowledge*, *self-efficacy*, *scaffolding* and *learning outcomes* with hypermedia were examined. There were four major findings in this dissertation. First, prior domain knowledge predicted both declarative and conceptual knowledge learning outcomes. Second, self-efficacy fluctuated during learning and the provision of conceptual scaffolds was not related to this fluctuation. Third, self-efficacy predicted monitoring and planning processes, but not strategy use during learning. Fourth, self-regulatory processes (particularly processes related to monitoring) predicted conceptual and declarative learning outcomes. Results indicated that the provision of conceptual scaffolds did not moderate these relationships.

The following discussion further examines these results by individually discussing each of the four research questions. Following this section of the discussion, the potential theoretical and methodological contributions of these findings are presented. Next, implications for education and for the design of hypermedia is examined, followed by a discussion of a promising agenda for future research. Lastly, this chapter concludes with potential limitations of this dissertation study.

Discussion of research question #1: To what degree does prior domain knowledge predict declarative and conceptual learning outcomes, and does the provision of conceptual scaffolds moderate these relationships?

The first research question addressed the extent to which prior domain knowledge predicts declarative and conceptual learning outcomes, and whether conceptual scaffolds

moderate these relationships. Results indicated that the prior domain knowledge of the circulatory system significantly predicted both declarative and conceptual learning outcomes. These results support the hypothesis for this research question. More specifically, though, these results are consistent with previous research that has examined prior domain knowledge and learning with non-linear CBLEs.

For example, Müller-Kalthoss and Möller (2003) examined the influence of individual variables, including prior domain knowledge, on learning outcomes. In this study, 82 students learned about the psychology of memory with a hypermedia environment. This study included structural and factual knowledge measures, and data from these two measures indicated that domain-specific prior domain knowledge was a significant predictor of learning outcomes. Shapiro (2004) also demonstrated that prior domain knowledge is a powerful predictor of learning outcomes with hypermedia. Shapiro (2004) argued that prior domain knowledge has a marked effect on learning outcomes and thus should be included in analyses. Data from this dissertation is consistent with these findings from previous research.

The interaction between prior domain knowledge and the non-linear format of hypermedia explains the results of this dissertation study and previous research. The non-linear nature of hypermedia requires students to make certain instructional decisions, such as determining which information to access, deciding which information to attend to, and determining how long to spend in different representations. Prior domain knowledge may be particularly important in the process of making these instructional decisions as prior domain knowledge provides existing knowledge structures that assist in determining which information to attend to, which information to ignore, and which

information to place in memory (Shapiro, 1999, 2000). Without prior domain knowledge, students may have difficulty making these instructional decisions. The effect of prior domain knowledge on learning with hypermedia may be particularly strong during a learning task in which students are asked to learn about a complex topic within a relatively short time, as was the case with this dissertation study. In the case of this dissertation study, participants were asked to learn about the circulatory system in 30 minutes. Thus, participants who had limited understanding of the circulatory system before this experimental learning task may have lacked the necessary knowledge structure to determine which information to attend to during the 30 minute learning task. On the other hand, participants who came into the learning task with higher prior domain knowledge of the circulatory system had an existing knowledge structures to guide their learning with the non-linear environment (Shapiro, 2004). This relationship explains the results of this dissertation study and is consistent with previous research which has also found the prior domain knowledge is a significant predictor of learning outcomes with non-linear CBLEs (e.g., Müller-Kalthoss & Möller, 2003).

Discussion of research question #2: To what degree does self-efficacy fluctuate during learning with hypermedia, and does the provision of conceptual scaffolds moderate this relationship?

The second research question addressed the degree to which self-efficacy fluctuates during learning 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. These results support the hypothesis for research question two and are consistent with the small body of previous research which has examined the fluctuation of self-efficacy during learning with CBLEs. For example, Mitchell et al. (1994) tested 110 undergraduate students using a complex computer task that simulated the job of an air traffic controller. Each participant completed seven trials with a computer simulation, during which their performance was scored based on the total number of planes landed during each trial, minus any error points accumulated (e.g., landing a 747 on a short runway). In addition to learning outcomes, the researchers also collected data on the participants' self-efficacy and goals in each trial. Interestingly, the participants' self-efficacy was more highly correlated with learning outcomes ($r = .27$ on Trial 1) than their goals ($r = .09$ on Trial 1) on the early trials. However, the participants' goals were actually more highly correlated with learning outcomes ($r = .85$ on Trial 7) than their self-efficacy ($r = .58$ on Trial 7) in later trials. Based on these results, the researchers argued that self-efficacy changes over knowledge and skill acquisition, which is consistent with the findings for research question two of this dissertation study.

Bandura (1997) provides a possible explanation of why participants from both conditions in this dissertation study reported, on average, higher self-efficacy immediately before the 30-minute learning task than during this learning task. As suggested by Bandura (1997), judgment of 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 imbedded in seemingly easy tasks (Bandura & Schunk, 1981). In this case, reports of self-efficacy may reflect the seemingly easy nature of the task, and not the complex cognitive processes required to complete the task (Cervone, 1989). In the case of this dissertation study, participants were asked to learn about the circulatory system with a hypermedia environment. As it has been highlighted throughout this dissertation, numerous studies have demonstrated that learning with hypermedia requires complex cognitive and metacognitive processes. However, students may not understand what processes are needed to successfully learn with hypermedia until they are actually involved in the learning task. In other words, when participants were asked to report their self-efficacy before beginning the hypermedia learning task, they may have selectively attended to the overall learning goal (a relatively manageable task) without understanding the complex cognitive and metacognitive processes needed to meet this learning goal. However, once the participants began the learning task with the hypermedia environment, the processes necessary to meet the learning goal may have become more apparent. This explanation addresses 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. However, it should also be noted that while participants' self-efficacy significantly fluctuated during the experimental session, the correlations between their reported self-efficacy at different times were significant (see Table 19 page 88). These results suggest that though self-efficacy may fluctuate during learning, there is a certain level of stability over time. That

is, the rank order of the participants' self-efficacy over time remained relatively stable through the learning task, which explains the significant correlations.

Discussion of research question #3: To what degree do prior domain knowledge and self-efficacy predict self-regulatory processes, and does the provision of conceptual scaffolds moderate these relationships?

The third research question addressed the extent to which prior domain knowledge and self-efficacy predict self-regulatory processes, and whether the provision of conceptual scaffolds moderates this relationship. Results indicated that while the overall model including self-efficacy, prior declarative knowledge, and prior conceptual knowledge predicted planning processes, self-efficacy was the only factor that had a significant main effect. Similarly, results indicated that while the overall model predicted monitoring processes, self-efficacy was the only factor that had a significant main effect.

Some previous research has found that prior domain knowledge is related to SRL with hypermedia (Moos & Azevedo, in press). The results of this study indicated that participants with higher prior domain knowledge tended to use processes related to monitoring, while participants with lower prior domain knowledge tended to use strategies during learning with hypermedia. While the results of this dissertation did not find these relationships between prior domain knowledge and SRL, there is a possible explanation. In this previous research, prior domain knowledge was measured, but motivation constructs, such as self-efficacy, were not measured. As suggested by previous research, prior domain knowledge does not guarantee that students will deploy processes necessary to improve comprehension (Lenski & Nierstheimer, 2002). On the other hand, research examining self-efficacy has routinely found that this motivation

construct is positively related to students' persistence and choice of behavior (e.g., Bandura, 1997; Eccles, Wigfield, & Schiefele, 1998; Wigfield & Eccles, 2002). These two assertions suggest that self-efficacy may be a stronger predictor of SRL processes, which would explain why prior domain knowledge did not have significant main effect over and beyond that of self-efficacy for research question three.

The significant main of self-efficacy is supported by previous research. Specifically, self-efficacy predicted planning and monitoring processes, regardless of experimental condition. Based on the rich body of literature in motivation, these results are not surprising. Motivation has been operationally defined as physiological processes involved in the direction, vigor, and choice of behavior (Bergin et al., 1993). Research has identified a number of fundamental constructs related to motivation (see Alexander, Schallert, & Hare, 1991; Greene & Ackerman, 1995; Murphy & Alexander, 2000 for extensive reviews), including self-efficacy. Results from this dissertation support the assumption that self-efficacy, as a motivational construct, is related to choice of behavior. Specifically, participants with higher self-efficacy tended to use more planning and monitoring processes during the 30-minute hypermedia learning task. Previous research has found similar results in non-hypermedia learning environments (see Wigfield & Eccles, 2002). For example, Boufard-Bouchard, Parent, and Larivee (1991) demonstrated that self-efficacy is significantly positively correlated to high school students' monitoring and persistence during problem solving in a non-hypermedia learning environment.

One explanation for the relationship between self-efficacy and self-regulatory processes is the cost-benefit metaphor (Pintrich & Zusho, 2002). According to the information processing model, there is a certain cognitive cost in using self-regulatory

processes (such as planning and monitoring), because the use of these processes during learning is effortful and consumes working memory capacity. As such, the “cost” of using these effortful processes is high. Self-efficacy may determine if the “benefit” of using these effortful processes outweighs the high cost. For example, if a student perceives that he or she is capable of meeting the objectives of the learning task, the benefit of using these effortful SRL processes may be quite high. In this case, the benefit outweighs the cost. If, on the other hand, the student lacks confidence in meeting the objectives of the learning task, then the benefit of using these effortful SRL processes may be quite low. In this case, the cost of using SRL processes outweighs the benefit. This cost-benefit metaphor may explain the results for research question two, which found that self-efficacy is positively related to the use of planning and monitoring processes.

Discussion of research question #4: To what degree do self-regulatory processes predict declarative and conceptual learning outcomes, and does the provision of conceptual scaffolds moderate these relationships?

The fourth research question addressed the extent to which self-regulatory processes predict declarative and conceptual learning outcomes with hypermedia. Results indicated that the model including planning, monitoring, and strategy use significantly predicted learning outcomes with hypermedia. These results are consistent with previous research and demonstrate that complex cognitive and metacognitive processes are critical when learning about a challenging topic with a hypermedia environment. This relationship may be particularly strong when the learning task involves a general learning goal. In this dissertation study, participants were provided a general learning goal (i.e.

Your task is to learn all you can about the circulatory system in 30 minutes) for a hypermedia learning task. The generality of the learning goal required the participants to self-regulate their learning. That is, SRL processes related to *planning* their learning by examining this goal, and then *monitoring* their learning and adapting *strategies* to meet this overall goal facilitates learning (Winne, 2001; Winne & Hadwin, 1998). Furthermore, developing knowledge in a non-linear environment with a general learning goal required the participants to make a number of instructional decisions. Effectively making these decisions facilitates knowledge development; however, in order to make these decisions, participants needed to self-regulate certain aspects of the learning process.

However, it should be noted that conceptual scaffolds did not moderate the relationship between SRL and learning outcomes. This finding is consistent with some previous research which has examined conceptual scaffolds and SRL with hypermedia. For example, Azevedo and colleagues (2005) examined how conceptual scaffolding, in the form of 10 domain specific sub-goals designed to foster conceptual knowledge of the circulatory system, was related to SRL with hypermedia. Results from this study indicated that participants who received this type of conceptual scaffolding used fewer key SRL processes during learning and demonstrated lower conceptual learning gains from pretest to posttest than participants who did not receive this type of conceptual scaffold.

There are two possible explanations for why conceptual scaffolds were either detrimental to learning, or had minimal impact on learning processes, in these studies. First, as highlighted by Azevedo (2005), there are substantial cognitive and

metacognitive demands when learning with hypermedia. These demands are related to the defining characteristics of this learning environment (i.e. nonlinear and multiple representations). Thus, though conceptual scaffolds may have the potential to assist students in understanding the conceptual organization of the domain more readily (Shapiro, 1999, 2000), the cognitive and metacognitive demands still exist even when students are provided conceptual scaffolds. In other words, students need to self-regulate their learning with hypermedia, regardless of whether or not they are provided conceptual scaffolds during learning. This explanation addresses why results of this dissertation indicated that conceptual scaffolds did not moderate the relationship between SRL processes and learning outcomes with hypermedia. Secondly, as suggested by Saye and Brush (2002), there are certain limits to these types of scaffolds. In particular, complex conceptual tasks, such as learning about the circulatory system, may require a certain level of adaptive support which cannot currently be provided by embedded conceptual scaffolds (Saye & Brush, 2002).

Contributions

Theoretical Contributions

Self-regulated learning involves actively constructing an understanding of a topic/domain by using strategies and goals, regulating and monitoring certain aspects of cognition, behavior, and motivation, and modifying behavior to achieve a desired goal (Pintrich, 2000). Though this definition of SRL is commonly used, the field of self-regulated learning (SRL) consists of various theoretical perspectives that sometimes focus on different constructs (Boekaerts et al., 2000; Zimmerman & Schunk, 2001). This study draws from Winne (2001) and Winne and Hadwin's (1998) information processing

theory (IPT) of SRL. This IPT theory suggests a 4-phase model of SRL, and provides a conceptual framework for describing the relationship between the macromechanisms (i.e. SRL categories such as planning) in SRL. Specifically, the IPT of SRL provides a conceptual framework that describes the interrelationship between *planning*, *monitoring*, and *strategy use*. However, the micromechanisms (i.e. specific SRL processes) underlying these broader categories of SRL have not received as much attention. For example, while phase four in Winne's (2001) IPT model of SRL entails monitoring, there is limited empirical research that has examined specific types of monitoring processes (i.e. feeling of knowing) during learning with hypermedia. Though this dissertation did not measure phases of SRL, as outlined by IPT (Winne 2001; Winne & Hadwin, 1998), it did provide empirical evidence of specific processes related to these phases. As such, data from this dissertation study extends Winne (2001) and Winne and Hadwin's (1998) SRL theoretical framework by providing empirical evidence on the extent to which students use specific self-regulatory processes while learning with hypermedia.

The following section elaborates Winne's SRL model by relating the data from the dissertation study to the four phases outlined in the IPT of SRL. According to this theory, the first phase of SRL entails the student constructing a perception of the task. These perceptions are drawn from two sources, including prior domain knowledge residing in long term memory (Winne, 2001). Data from this dissertation study indicated that participants from both conditions activated *prior domain knowledge* during the 30-minute learning task, though to varying degrees. Examining the frequency data of individual SRL processes (see Table 16 on page 85) indicates that participants in the CS condition activated their prior domain knowledge more frequently, on average, than

participants in the NS condition. This difference in this frequency may be explained by the second source of information that contributes to the construction of the task definition. According to Winne's (2001) IPT model, the second source of information about the task comes from such sources as experimenter-set learning goals. In the case of this dissertation study, participants in the CS condition received experimental-set learning goals in the form of the five guiding questions during the hypermedia learning task. These guiding 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. As such, according to the IPT theory, participants in the CS condition had an additional source of information which, in turn, explains why they activated prior domain knowledge more frequently. Furthermore, asking participants in the CS condition to answer a series of higher-ordered questions allowed them to anchor newly acquired knowledge in prior knowledge (Martin & Pressley, 1991).

In phase two, students frame multifaceted goals and plan how to reach the goal(s) (Butler & Winne, 1995; Winne & Hadwin, 1998). An underlying assumption of this phase is that goals can be updated as students proceed through the learning task. Process data from this dissertation study provides empirical evidence that participants from both conditions rarely, if ever, set a goal or coordinated multiple goals (see Table 16 on page 85). These data suggest that the participants were not active in this particular cyclical phase of the SRL process; that is, they were not updating goals as they progressed through the learning task. As highlighted by IPT, students are active agents who can choose whether or not to self-regulate their learning in various phases (Winne, 2001).

These data provide empirical evidence that students may be less active with some of the micomechanisms underlying the different phases of SRL, at least in the context of learning with hypermedia in a relatively short time period (30 minutes). These data are consistent with previous research that has found undergraduates rarely use SRL processes related to *planning* during a 30 or 40 minute learning task with hypermedia (Moos & Azevedo, 2006c, 2007b).

In phase three, students enact strategies (Winne, 2001; Winne & Hadwin, 1998). As can be seen in Table 16 (page 85), most of the participants in both conditions used strategies to learn with the hypermedia environment. For participants in the NS condition, 62% of the total coded SRL processes ($n = 823$) were related to strategies, while 60% of the total coded SRL processes ($n = 948$) were related to strategies for participants in the CS condition. *Taking notes* ($n_{ns} = 304$; $n_{cs} = 304$), *summarization* ($n_{ns} = 208$; $n_{cs} = 275$), and *re-reading* ($n_{ns} = 142$; $n_{cs} = 168$) were the most prevalent strategies for participants in both conditions. As indicated by Winne 2001, strategies are meant to construct information to make progress on the task, and data from this dissertation indicated that the participants frequently used a small subset of specific strategies while learning with hypermedia.

However, monitoring the use of these strategies and making cognitive evaluations about discrepancies between the task goals and current profile of work on a task is a critical component of SRL (Winne, 2001; Winne & Hadwin, 1998). Monitoring is a self-regulatory process that compares two chunks of information (i.e. learning goal and current domain knowledge; Winne, 2001). Metacognitive monitoring produces information that allows students to determine if there is a discrepancy between any goals

and their current level of domain knowledge. Furthermore, monitoring allows students to adapt their planning and/or strategies to more effectively meet the learning goal(s). These monitoring activities occur in phase four when the student may make adaptations to schemas that structure various self-regulated processes (Butler & Winne, 1995; Winne, 1997). Data from this dissertation study indicate that participants from both conditions monitored various aspects of the learning process (see Table 16 on page 85). Monitoring processes accounted for 31% of the total SRL codes ($n = 409$) for participants in the NS condition, while they accounted for 24% of the total SRL codes ($n = 376$) for participants in the CS condition. As highlighted by IPT, monitoring includes both information of matches and mismatches between the standards of the task and current knowledge states. The modified coding scheme used in this dissertation study allowed for the examination of such monitoring activities. In particular, the coding scheme revealed that participants monitored when there was a match (i.e. feeling of knowing (+)), as well as when there was a mismatch (i.e. feeling of knowing (-)). Furthermore, the empirical evidence from this dissertation indicated that, to some degree, participants from both conditions monitored their knowledge development (i.e. judgment of learning (+) and judgment of learning (-)).

However, an underlying assumption of IPT is that there is a recursive nature to SRL because of a feedback loop. That is, information processed in one phase can become an input to subsequent information processing, and thus students may adapt their *planning* and/or *strategies* in order to meet the goal based on discrepancies revealed by *monitoring* activities. While this dissertation study provides empirical evidence of the extent to which undergraduates use specific processes in various phases of SRL during

learning with hypermedia, the data analyses did not provide empirical evidence which examined the dynamic nature of SRL. For example, did the participants adapt their strategies after a monitoring activity (i.e. judgment of learning) revealed a discrepancy? The dissertation data did not empirically examine the dynamic nature of the phases in SRL, and thus could not address this question. Rather, the data from this dissertation study provide evidence of the degree to which the participants used micromechanisms (i.e. specific SRL processes) related to the phases outlined in this SRL model. In order for this SRL model to be further advanced, research should consider measuring both micromechanisms and macromechanisms related to SRL. This issue is addressed in the *future directions* section.

Methodological Contributions

In addition to potential theoretical contributions, there are also potential methodological contributions. In particular, this dissertation used a relatively unique methodological paradigm by combining a think-aloud protocol (Ericsson, 2006; Ericsson & Simon, 1993) with a self-report questionnaire (MSLQ; Pintrich et al., 1991) to measure cognitive, metacognitive and motivational factors during learning. The use of this paradigm potentially offers two methodological contributions to the field.

First, previous research has used several different methods to measure motivation during learning. For example, Ainley, Corrigan, and Richardson (2005) asked young adolescents to read a science text. After having read one-fourth of the text, the participants were asked to select one emotion icon (e.g., sad, interested, bored). Another line of research has extended the think-aloud protocol to the “think and feel aloud protocol” (TFA). In the TFA protocol, participants are asked to verbalize both what they

are *thinking* and what they are *feeling* during the learning task. For example, Eva-Wood (2004) used the TFA to examine how undergraduate students analyzed poems. The TFA protocol captured participants' feelings towards the task, including "happy", "funny", and "positive."

However, using the TFA protocol to measure other constructs of motivation, such as self-efficacy, during learning with hypermedia poses several issues. First, as evidenced by Eva-Wood (2004), the TFA may elicit verbalizations of how participants feel towards the task, but there is no guarantee that it will elicit verbalizations that are directly related to self-efficacy. Furthermore, if this measure of motivation is being used in conjunction with a think-aloud protocol (as was the case for this dissertation), the directions for these two measurements should be consistent. The directions for the think-aloud protocol do not explicitly ask students to verbalize specific processes (i.e. strategy use). As such, the directions for a TFA should be consistent and thus should not direct participants to verbalize a specific aspect of how they are feeling towards the learning task (i.e. self-efficacy). Consequently, using the TFA in conjunction with a think-aloud protocol may not be an appropriate method to measure motivation during learning because previous research has not demonstrated that TFA is an effective protocol in eliciting feelings of self-efficacy during learning.

Another option is to measure self-efficacy with a self-report questionnaire at specific time points during the learning task. Previous research has used this methodology, including Järvenoja and Järvelä (2005). Additionally, the author has used this approach to measure interest and perceived task difficulty before and during a hypermedia learning task (Moos & Azevedo, 2006c, accepted pending revisions). During

this study, participants completed a short self-report questionnaire about their interest and perceived task difficulty immediately before a hypermedia learning task, and then at three regular intervals during the learning task. There are two benefits of measuring motivation with self-report questionnaires at specific points during the learning task. First, the data points are consistent across all participants. Second, the researcher can control what is being measured through the design of the self-report questionnaire, as opposed to the TFA which does not guarantee that participants will verbalize their self-efficacy during the learning task. This dissertation study adopted this methodological approach of measuring motivation with self-report questionnaires at different points during the learning session. This approach potentially contributes to the field by demonstrating a reliable and valid methodological approach which allows for the examination of the fluctuation of motivation.

Furthermore, the methodology of this dissertation study extends previous research that has used concurrent think aloud protocols to examine learning processes with hypermedia (see Azevedo, 2005). For example, Azevedo et al. (2004a) used the concurrent think aloud methodology to examine SRL with hypermedia. This line of research has drawn primarily from the IPT of SRL (Winne, 1998; Winne & Hadwin, 1998). Thus, the coding scheme used to analyze the SRL processes verbalized during the think-aloud was developed to reflect the four phases of SRL. For example, key monitoring processes (such as *judgment of learning* and *feeling of knowing*) were included in the coding scheme. However, as previously highlighted, monitoring processes include comparing chunks of information to determine both a match *and* mismatch between goal(s) and current knowledge state. In order to more accurately measure

monitoring processes, this dissertation study used a modified SRL coding scheme. In particular, plus and minus categories were used for the following monitoring processes: Content evaluation, expect adequacy, feeling of knowing, and judgment of learning. The plus and minus categories were added to differentiate between qualitatively distinct self-regulatory processes used during learning with hypermedia. For example, feeling of knowing (plus) is when the student is aware of having read or learned something in the past, while feeling of knowing (minus) is when the student is aware of *not* having read or learned something in the past. Though both of these processes represent monitoring activities, the qualitative nature of these activities is distinct and represents the positive and negative feedback loops during monitoring. As such, this coding scheme is more consistent with the conceptualization of monitoring processes in the IPT of SRL (Winne, 2001; Winne & Hadwin, 1998), and thus represents a potential methodological contribution to the field.

Implications

Implications for the design of adaptive hypermedia

In addition to the potential methodological and theoretical contributions to the fields of SRL, motivation, and learning with CBLEs, this study also has implications for the design of hypermedia. In particular, data from this dissertation study potentially addresses the following three questions: 1) Should adaptive hypermedia assess prior domain knowledge? 2) Should adaptive hypermedia provide conceptual scaffolds during learning? and 3) Which specific SRL processes should be traced and fostered during learning with adaptive hypermedia?

Results from this dissertation study indicated that learning with hypermedia may be most effective when students have some prior domain knowledge. Thus, adaptive hypermedia environments should include an assessment of prior domain knowledge. If this assessment reveals that the student has limited prior domain knowledge, the adaptive hypermedia environment could provide a short domain-specific tutorial. This tutorial, which provides the necessary background knowledge for the domain, would allow the student to enter the learning task with some prior domain knowledge, thus maximizing the effectiveness of the adaptive hypermedia environment.

In terms of conceptual scaffolds, the results indicated that conceptual scaffolds did not moderate any relationship between cognitive and metacognitive factors with learning outcomes. In other words, the relationship between SRL processes and learning outcomes existed whether or not the participant was provided conceptual scaffolds during the hypermedia learning task. Thus, adaptive hypermedia environments should foster key SRL processes, regardless of whether or not conceptual scaffolds are provided during learning. However, the more critical question concerns whether or not adaptive hypermedia environments should provide conceptual scaffolds during learning. Examining the raw frequencies of the individual SRL processes, by condition, potentially addresses this question (see Table 16 on page 85). Examining the raw frequencies reveals that participants who received conceptual scaffolds activated their prior domain knowledge more frequently, on average, than those who did not receive conceptual scaffolds during learning. Furthermore, participants who received conceptual scaffolds also recycled goals in working memory almost seven times more, on average, than participants who did not receive conceptual scaffolds. The nature of the conceptual

scaffolds in this study may explain these findings. The conceptual scaffolds were five guiding questions that the participants were asked to answer during learning, 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, students needed to recall what they had learned for the previous question. Consistent with the literature from elaborative interrogation (e.g., Martin & Pressley, 1991), effective higher-ordered questions allow students to anchor newly acquired knowledge in prior knowledge.

Furthermore, students may need external guidance when using hypermedia to learn about a challenging topic in which they have little prior knowledge. The questions provided in the CS condition offered the participants with external guides, and the frequency in which participants from this condition recycled goals in working memory (i.e. re-read the guiding question) suggests that they were often relying on the questions to guide their interaction with hypermedia. These data indicated that participants who received conceptual scaffolds during learning used SRL processes from the *planning* category (i.e. prior knowledge activation and recycle goals) more frequently during the learning task than participants who did not receive conceptual scaffolds. Based on these data, it is concluded that the process of learning with adaptive hypermedia environments may be facilitated with the provision of conceptual scaffolds. However, as highlighted by Holliday, Whittaker, and Loose (1984), the format of conceptual scaffolds should be carefully considered. This research found that verbatim guiding questions during learning of science topics can actually impede meaningful learning. Rather, guiding questions are most effective when they become increasingly complex, and require students to recall

what they had learned for previous questions in order to answer the current question. This format allows students to anchor newly acquired knowledge in prior knowledge (Martin & Pressley, 1991), and thus increases the potential that students will use specific SRL processes such as prior knowledge activation.

In terms of the third implication for the design of adaptive hypermedia, this study potentially offers specific design principles by identifying key SRL processes that should be traced and fostered. For participants in the NS condition, 62% of the total SRL codes were related to strategies, while 31% were related to monitoring processes, and 7% were related to planning processes. Similarly, 60% of the total SRL codes were related to strategies, while 24% were related to monitoring processes, and 16% were related to planning processes for participants in the CS condition. Clearly, students from both conditions most frequently used strategies during learning. However, the vast majority of the strategies students used during the hypermedia learning task are considered “low-level” because they have been shown to be related to surface-level processing (Alexander et al., 1995). In particular, 79% of the 823 coded strategies were re-reading, summarization, or note-taking for participants in the NS condition. Similarly, 78% of the 948 coded strategies were re-reading, summarization, or note-taking for participants in the CS condition. While students heavily relied on these strategies, other “higher-order” strategies were used much less frequently. For example, coordinating informational sources, a strategy that has been shown to be related to learning with hypermedia (Azevedo et al., 2005), accounted for only 4% of the strategy codes for the NS condition and only 2% of the strategy codes for the CS condition. Similarly, research has empirically demonstrated that 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 strategy codes for the NS condition and only 3% of the strategy codes for the CS condition. These data suggest that students would benefit from embedded prompts which facilitate the use of *inferences* and *coordinating informational sources* during learning. For example, when a student links to a location in the environment in which multiple representations provide complementary information (Ainsworth & Loizou, 2003; Hmelo-Silver & Pfeffer, 2004), the environment could display a prompt asking the student to, “Please connect what you read in the following text with the corresponding diagram.”

In addition to fostering inferences and coordinating informational sources, adaptive hypermedia environments should foster specific monitoring and planning processes. While students frequently relied on strategies during the hypermedia learning task, they used much fewer monitoring and planning processes. For participants in the NS condition, 31% were related to monitoring processes, and only 7% were related to planning processes. Similarly, 24% were related to monitoring processes, while only 16% were related to planning processes for participants in the CS condition. Particularly interesting is the rarity in which participants from both conditions used some of the monitoring processes. For example, participants from both conditions, on average, rarely *monitored their time*. Additionally, participants infrequently, on average, made *judgments of their learning*. However, as highlighted by the IPT of SRL, monitoring activities are key SRL processes in learning. As such, these monitoring processes should be fostered during learning with adaptive hypermedia, especially because these data indicate that the participants rarely monitored certain aspects of their learning. Embedding Likert-style

prompts that periodically ask students to indicate the degree to which they understand the material may facilitate monitoring processes such as *judgment of learning*. Additionally, verbal time prompts from the adaptive hypermedia environment may facilitate *time monitoring*.

Implications for education

As hypermedia environments become an increasingly popular educational tool, it is important for empirical research to provide data that informs educators on how to most effectively use these environments. One pressing issue concerns when educators should use these environments in the curriculum. Educators are faced with several choices, including whether they should: 1) Use these environments to introduce a topic, or 2) Use these environments to complement what their students have already learned. Data from this dissertation suggest that hypermedia may be most effective when students already have some prior domain knowledge. Because the data indicated that prior domain knowledge was a predictor of learning outcomes, it is suggested that educators use hypermedia as a complementary tool as opposed to using this environment to introduce a topic.

This educational implication is supported from a theoretical standpoint. As suggested by IPT, students have a limited working memory capacity and thus are able to process a limited number of chunks of information. When students are faced with academic tasks in which they have very little prior domain knowledge, they may not be able to simultaneously process information and apply self-regulatory processes (Winne, 2001). In order to process relatively novel information, a substantial portion of working memory may be consumed, leaving little or insufficient working memory capacity for

self-regulatory processes. If, however, students with lower prior domain knowledge attempt to use a variety of self-regulatory processes, they then may have insufficient working memory capacity to process information (Kanfer & Ackerman, 1989). As such, students with low prior domain knowledge may be caught in a catch-22. If they focus on self-regulating their learning, they may not be able to process information. If, however, they decide to focus primarily on processing information, they may not be able to simultaneously self-regulate their learning. Thus, environments such as hypermedia may not be effective learning environments for students who have low prior domain knowledge because they necessitate the use of SRL processes.

However, educators can address this potentially problematic issue. When students are learning with hypermedia, educators can facilitate the use of several strategies that may help maximize the availability of working memory capacity for processing information. For example, off-loading, in which information is stored outside the mind, is an example of a strategy that allows students to maximize working memory for processing information. Off-loading includes such strategies as taking notes so that relevant information is externally recorded and thus does not clutter working memory. Educators should explicitly promote the strategy of taking notes during complicated tasks with hypermedia because this may allow students to free up cognitive resources for processing information.

Additionally, educators should externally support specific SRL processes that have been shown to be related to learning with hypermedia, especially when students are learning about a domain in which they have little prior domain knowledge. For example, while metacognitive monitoring processes (such as judgment of learning and feeling of

knowing) are critical SRL processes when learning with hypermedia, students with minimal prior domain knowledge may have little working memory capacity to allocate to processing information if they use these SRL processes. Thus, educators should structure the environment so that there are limited demands on students' working memory in terms of metacognitive monitoring. Educators can externally monitor their students' emerging understanding. For example, educators' detailed feedback, as a by-product of external monitoring, may alleviate students' need to monitor their own progress when learning with hypermedia and thus working memory space is freed up to process information.

Future Directions

While this dissertation potentially contributes to our understanding of the relationship between various factors and learning with hypermedia, future research could extend this research agenda by addressing the following four issues. First, our theoretical understanding of how students learn with CBLEs needs attention, particularly in the area of motivation (Wigfield & Eccles, 2002; Zimmerman & Tsikalas, 2005). Though researchers have empirically examined a vast array of motivational constructs, the lexicon within some lines of motivation research can greatly vary (Murphy & Alexander, 2000). Other motivational constructs, however, are much more theoretically grounded. As suggested by Murphy and Alexander (2000), self-efficacy is an example of such a motivational construct. Additionally, self-efficacy is thought to be a powerful determinant in learning (e.g., Bandura & Schunk, 1981; Betz & Hackett, 1981; Pajares, 1996; Pajares & Miller, 1994; Pintrich & De Groot, 1990; Schunk, 1982, 1984, 1991; Wigfield et al., 2004; Zimmerman, Bandura, & Martinez-Pons, 1992), especially when students are learning with CBLEs that allow them to make decisions about which

information to access (Debowski, Wood, & Bandura, 2001). As such, this dissertation study focused on the motivational construct of self-efficacy. As previously highlighted, the self-report questionnaire used in this dissertation study asked participants to make judgments of self-efficacy in terms of the overall learning task. However, judgments of self-efficacy for the cognitive and metacognitive activities required to meet the goal for this learning task were not measured, which may explain why participants from both conditions reported higher levels of self-efficacy immediately before the learning task when compared to their self-efficacy during the learning task. In order to further explain the relationship between self-efficacy and learning with hypermedia, future research should consider including measurements that tap into judgments of self-efficacy for cognitive activities (Cervone, 1989). Secondly, there are other motivation variables related to students' choice of achievement tasks, persistence on those tasks, and vigor in carrying out those tasks (Eccles et al., 1998). In order to provide a more comprehensive theoretical understanding of how motivational constructs are related to learning with hypermedia, future research should extend this research agenda by considering other motivational constructs.

Third, future research could extend the IPT model of SRL by providing a more comprehensive examination of the various SRL processes in learning. In particular, Winne (2001) and Winne and Hadwin's (1998) IPT of SRL is a phase model, and more empirical evidence of when SRL processes occur during learning is needed. There is currently limited empirical research that has examined both the broader phases of SRL (i.e. monitoring) and specific SRL processes related to these phases (i.e. judgment of learning). In order for the IPT of SRL to be further advanced, future research should

empirically examine both macromechanisms (i.e. broader phases of SRL) and micromechanisms (i.e. specific processes related to the phases of SRL). This research agenda will allow for a more comprehensive examination of the particular phases outlined in Winne (2001) and Winne and Hadwin's (1998) model of SRL.

Fourth, one of the criticisms of the IPT of SRL is that this theoretical approach does not account for individual differences. Though the IPT describes self-monitoring processes in terms of a feedback loop, it does not currently explain individual reactions to negative feedback during learning (Bandura, 1991). For example, while some students adapt their strategies and modify their plans once monitoring reveals that they have not met their goal(s), other students simply lower their standards and/or do not alter their strategies. A few studies have begun to explore the dynamic nature of such SRL processes during learning. For example, Witherspoon, Azevedo, Greene, Moos, and Baker (2007) examined the temporal nature of SRL processes during learning and this line of research begins to provide a more comprehensive examination of the dynamic nature of SRL. Future research should continue to examine individual differences in reaction to positive and negative feedback.

Lastly, it should be noted that it is currently unclear whether the results found in this dissertation are unique to learning with hypermedia. As suggested by previous research, learning with hypermedia places certain cognitive and metacognitive demands on students (Azevedo, 2005). These demands may be unique to this type of CBLE, particularly when compared to other CBLEs such as multimedia and hypertext. Though multimedia offers multiple representations during learning, it is not considered a nonlinear environment (Jacobson & Archodidou, 2000). Similarly, hypertext is also

distinct in that it does not contain multiple representations (Jacobson & Archodidou, 2000). Thus, these two CBLEs may not place similar cognitive and metacognitive demands during learning. If these demands are not present, or exist to a lesser degree, when learning with these two environments, the relationships between cognitive and metacognitive processes and learning may not be as strong. Though this dissertation did not focus on examining the relationships cognitive and metacognitive processes with various types of CBLEs, future research should consider addressing this issue.

Limitations

While this study potentially offers theoretical and methodological contributions to the fields of SRL, CBLEs, and motivation, there are three limitations that need to be addressed. First, the results may be constrained by the particular sample and/or task in this study. The relationship between cognitive, metacognitive, and motivational processes measured in this dissertation may be moderated by various variables, including this particular sample (undergraduates), and the context and task (learning about the circulatory system with hypermedia). In order to tease apart any moderating influences of these variables, this line of research would benefit from future research which examines the relationship of these processes with different samples learning various domains in similar open-ended CBLEs.

Second, as previously mentioned, the dissertation does not offer a comprehensive examination of the relationship between motivation and other processes involved in learning with hypermedia. Though self-efficacy is a valid motivational construct to examine in this line of research, there are certainly other motivational variables that are related to learning with hypermedia (e.g., goal orientation). As such, the limited approach

of this dissertation could be addressed in future research that considers other motivation constructs. Third, the limitations of the research design should be addressed. Specifically, there was a potential fatigue effect in the experimental paradigm. A fatigue effect may have been present because participants were asked to complete a mental model essay after they already completed a pretest and a challenging 30-minute learning task. While this experimental paradigm has been used in a number of previous studies (Azevedo et al., 2005; Greene & Azevedo, 2006; Moos & Azevedo, accepted pending revisions) and is based on extensive work by Chi et al. (1994, 2000, 2005), a fatigue effect may have occurred due to the length of the experimental session. As such, limiting the length of the pretest and posttest may address this concern. For example, asking participants to draw how blood flows through the circulatory system may be a more economical measure of their conceptual knowledge, as opposed to having them write a pretest and posttest mental model essay.

Conclusion

While there are some limitations to this dissertation, it provides empirically-based and theoretically-driven analyses that build on existing models of SRL in learning with hypermedia by examining the relationship between cognitive, metacognitive, and motivational processes. In addition, this study also adds to the field of motivation by examining the relationship between self-efficacy and how students learn with hypermedia. Providing rich data that extend previous research on self-efficacy in non-hypermedia learning environments, this study used a think-aloud methodology to capture the dynamic interaction between self-efficacy, SRL processes, and learning outcomes. In addition to providing empirically-based and theoretically-driven analyses, this

dissertation also provides the foundation for future research. Lastly, these findings also offer data that have implications for the design of hypermedia environments and the education community.

Appendix A: Pintrich's (2000) 4 x 4 SRL Framework

AREAS PHASES	Cognition	Motivation	Behavior	Context
Planning, Activation, Forethought	<ul style="list-style-type: none"> • Target goal Setting • Prior knowledge activation • Metacognitive knowledge activation 	<ul style="list-style-type: none"> • Goal orientation adoption • Efficacy judgments • Ease of learning judgments • Task value activation • Interest activation 	<ul style="list-style-type: none"> • Time and effort planning • Planning for self-observation and behavior 	<ul style="list-style-type: none"> • Perception of task • Perception of context
Monitoring	<ul style="list-style-type: none"> • Metacognitive awareness and monitoring of cognition (FOKs, JOLs) 	<ul style="list-style-type: none"> • Awareness and monitoring of motivation and effect 	<ul style="list-style-type: none"> • Awareness and monitoring of effort, time use, need for help • Self-observation of behavior 	<ul style="list-style-type: none"> • Monitoring changing task and context conditions
Control	<ul style="list-style-type: none"> • Selection and adaptation of cognitive strategies for learning, thinking 	<ul style="list-style-type: none"> • Selection and adaptation of strategies for managing motivation and affect 	<ul style="list-style-type: none"> • Increase/decrease effort • Persist, give-up • Help-seeking behavior 	<ul style="list-style-type: none"> • Change of renegotiate task • Change or leave context
Reflection	<ul style="list-style-type: none"> • Cognitive judgments • Attributions 	<ul style="list-style-type: none"> • Affective reactions • Attributions 	<ul style="list-style-type: none"> • Choice behavior 	<ul style="list-style-type: none"> • Evaluation of task/context

Appendix B: Declarative and conceptual knowledge measures (from Azevedo et al., 2005)

Declarative Knowledge Measure

**MATCH AS MANY COMPONENTS OF THE HEART AS YOU CAN
(13 points)**

- | | | |
|--------------------------|-----|---|
| 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 C: Complete MSLQ (from Pintrich et al., 1991)

(1 = *not at all true of me*; 7 = *very true of me*)

REHEARSAL

When I study for this class, I practice saying the material to myself over and over.

1 2 3 4 5 6 7

When studying for this class, I read my class notes and the course readings over and over.

1 2 3 4 5 6 7

I memorize key words to remind me of important concepts in this class.

1 2 3 4 5 6 7

I make lists of important terms for this course and memorize the lists.

1 2 3 4 5 6 7

ELABORATION

When I study for this class, I pull together information for different sources, such as lectures, readings, and discussions.

1 2 3 4 5 6 7

I try to relate ideas in this participant to those in other courses whenever possible

1 2 3 4 5 6 7

When reading for this class, I try to relate the material to what I already know.

1 2 3 4 5 6 7

When I study for this course, I write brief summaries of the main ideas from readings and the concepts from the lectures.

1 2 3 4 5 6 7

I try to understand the material in this class by making connections between readings and the concepts from the lectures.

1 2 3 4 5 6 7

I try to apply ideas from course readings in other class activities such as lectures and discussions.

1 2 3 4 5 6 7

ORGANIZATION

When I study the readings for this course, I outline the material to help me organize my thoughts.

1 2 3 4 5 6 7

When I study for this course, I go through the readings and my class notes and try to find the most important ideas.

1 2 3 4 5 6 7

I make simple charts, diagrams, or tables to help me organize course material.

1 2 3 4 5 6 7

When I study for this course, I go over my class notes and make an outline of important concepts.

1 2 3 4 5 6 7

CRITICAL THINKING

I often find myself questioning things I hear or read in this course to decide if I find them convincing.

1 2 3 4 5 6 7

When a theory, interpretation, or conclusion is presented in class or in readings, I try to decide if there is good supporting evidence.

1 2 3 4 5 6 7

I treat the course material as a starting point and try to develop my own ideas about it.

1 2 3 4 5 6 7

I try to play around with ideas of my own related to what I am learning in this course.

1 2 3 4 5 6 7

Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.

1 2 3 4 5 6 7

METACOGNITION

During class time I often miss important points because I'm thinking of other things.

1 2 3 4 5 6 7

When reading for this course, I make up questions to help focus my reading.

1 2 3 4 5 6 7

When I become confused about something I'm reading for this class, I go back and try to figure it out.

1 2 3 4 5 6 7

If course materials are difficult to understand, I change the way I read the material.

1 2 3 4 5 6 7

Before I study new course material thoroughly, I often skim it to see how it is organized.

1 2 3 4 5 6 7

I ask myself questions to make sure I understand the material I have been studying in class.

1 2 3 4 5 6 7

I try to change the way I study in order to fit the course requirement and instructor's teaching style.

1 2 3 4 5 6 7

I often find that I have been reading for class but don't know what it was all about.

1 2 3 4 5 6 7

I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.

1 2 3 4 5 6 7

When studying for this course, I try to determine which concepts I don't understand well.

1 2 3 4 5 6 7

When I study for this class, I set goals for myself in order to direct my activities in each study period.

1 2 3 4 5 6 7

If I get confused taking notes in class, I make sure I sort it out afterward.

1 2 3 4 5 6 7

INTRINSIC MOTIVATION

In a class like this, I prefer course material that really challenges me so I can learn new things.

1 2 3 4 5 6 7

In a class like this, I prefer course material that arouses my curiosity, even if it difficult to learn.

1 2 3 4 5 6 7

The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.

1 2 3 4 5 6 7

When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.

1 2 3 4 5 6 7

EXTRINSIC MOTIVATION

Getting a good grade in this class is the most satisfying thing for me right now.

1 2 3 4 5 6 7

The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.

1 2 3 4 5 6 7

If I can, I want to get better grades in this class than most of the other students.

1 2 3 4 5 6 7

I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.

1 2 3 4 5 6 7

TASK VALUE

I think I will be able to use what I learn in this course in other courses.

1 2 3 4 5 6 7

It is important for me to learn the material in this class.

1 2 3 4 5 6 7

I am very interested in the content areas of this course.

1 2 3 4 5 6 7

I think the material in this class is useful for me to learn.

1 2 3 4 5 6 7

I like the participant matter of this course.

1 2 3 4 5 6 7

Understanding the participant matter of this course material is very important to me.

1 2 3 4 5 6 7

CONTROL BELIEFS

If I study in appropriate ways, then I will be to learn the material in this course.

1 2 3 4 5 6 7

It is my own fault if I don't learn the material in this course.

1 2 3 4 5 6 7

If I try hard enough, then I will understand the course material.

1 2 3 4 5 6 7

If I don't understand the course material, it is because I didn't try hard enough.

1 2 3 4 5 6 7

SELF-EFFICACY

I believe I will receive an excellent grade in this course.

1 2 3 4 5 6 7

I'm certain I can understand the most difficult material presented in the readings for this course.

1 2 3 4 5 6 7

I'm confident I can understand the basic concepts taught in this course.

1 2 3 4 5 6 7

I'm confident I can understand the most complex material presented by the instructor in this course.

1 2 3 4 5 6 7

I'm confident I can do an excellent job on the assignments and tests in this course.

1 2 3 4 5 6 7

I expect to do well in this class.

1 2 3 4 5 6 7

I'm certain I can master the skills being taught in this class.

1 2 3 4 5 6 7

Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

1 2 3 4 5 6 7

TEST ANXIETY

When I take a test I think about how poorly I am doing compared with other students.

1 2 3 4 5 6 7

When I take a test I think about items on other parts of the test I can't answer.

1 2 3 4 5 6 7

When I take I think of the consequences of failing.

1 2 3 4 5 6 7

I have an uneasy, upset feeling when I take an exam.

1 2 3 4 5 6 7

I feel my heart beating fast when I take an exam.

1 2 3 4 5 6 7

TIME AND STUDY ENVIRONMENT

I usually study in a place where I can concentrate on my course work.

1 2 3 4 5 6 7

I make good use of my study time for this course.

1 2 3 4 5 6 7

I find it hard to stick to a study schedule.

1 2 3 4 5 6 7

I have a regular place set aside for studying.

1 2 3 4 5 6 7

I make sure I keep up with the weekly readings and assignments for this course.

1 2 3 4 5 6 7

I attend class regularly.

1 2 3 4 5 6 7

I often find that I don't spend very much time on this course because of other activities.

1 2 3 4 5 6 7

I rarely find time to review my notes or readings before an exam.

1 2 3 4 5 6 7

EFFORT REGULATION

I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.

1 2 3 4 5 6 7

I work hard to do well in this class even if I don't like what we are doing.

1 2 3 4 5 6 7

When the course work is difficult, I give up or only study the easy parts.

1 2 3 4 5 6 7

Even when course materials are dull and uninteresting, I manage to keep working until I finish.

1 2 3 4 5 6 7

PEER LEARNING

When studying for this course, I often try to explain the material to a classmate or a friend.

1 2 3 4 5 6 7

I try to work with other students from this class to complete the course assignments.

1 2 3 4 5 6 7

When studying for this course, I often set aside time to discuss the course material with a group of students from the class.

1 2 3 4 5 6 7

HELP-SEEKING

Even if I have trouble learning the material in this class, I try to do work on my own, without help from anyone.

1 2 3 4 5 6 7

I ask the instructor to clarify concepts I don't understand well.

1 2 3 4 5 6 7

When I can't understand the material in this course, I ask another student in this class for help.

1 2 3 4 5 6 7

I try to identify students in this class whom I can ask for help if necessary.

1 2 3 4 5 6 7

Appendix D: Self-efficacy scale used in this 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 is 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

Appendix E: Screen shot of Encarta™ (2003)

Microsoft Encarta Reference Library 2003

File Edit View Favorites Favorites Tools Help

Find circulatory system

Article Outline Related Articles Contents Page

Heart

article

I. INTRODUCTION

I INTRODUCTION

Heart, in anatomy, hollow muscular organ that pumps blood through the body. The heart, blood, and blood vessels make up the circulatory system, which is responsible for distributing oxygen and nutrients to the body and carrying away carbon dioxide and other waste products. The heart is the circulatory system's power supply. It must beat ceaselessly because the body's tissues—especially the brain and the heart itself—depend on a constant supply of oxygen and nutrients delivered by the flowing blood. If the heart stops pumping blood for more than a few minutes, death will result.

web center

Find the best online information about Heart.

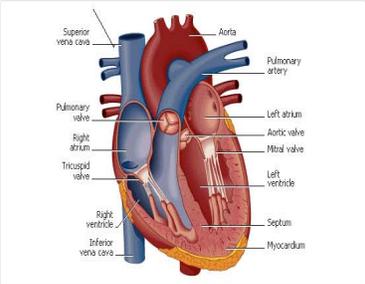
Encarta Editors' Picks

How Your Heart Works

The Heart: An Online

Human Heart

The human heart is a hollow, pear-shaped organ about the size of a fist. The heart is made of muscle that rhythmically contracts, or beats, pumping blood throughout the body. Oxygen-poor blood from the body enters the heart from two large blood vessels, the inferior vena cava and the superior vena cava, and collects in the right atrium. When the atrium fills, it contracts, and blood passes through the tricuspid valve into the right ventricle. When the ventricle becomes full, it starts to contract, and the tricuspid valve closes to prevent blood from moving



Superior vena cava, Aorta, Pulmonary artery, Pulmonary valve, Left atrium, Aortic valve, Mitral valve, Left ventricle, Right atrium, Tricuspid valve, Right ventricle, Inferior vena cava, Septum, Myocardium

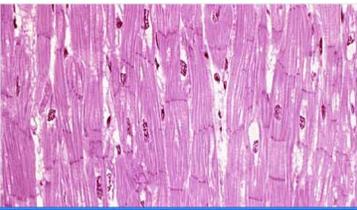
The human heart is shaped like an upside-down pear and is located slightly to the left of center inside the chest cavity. About the size of a closed fist, the heart is made primarily of muscle tissue that contracts rhythmically to propel blood to all parts of the body. This rhythmic contraction begins in the developing embryo about three weeks after conception and continues throughout an individual's life. The muscle rests only for a fraction of a second between beats. Over a typical life span of 76 years, the heart will beat nearly 2.8 billion times and move 169 million liters (179 million quarts) of blood.

Since prehistoric times people have had a sense of the heart's vital importance. Cave paintings from 20,000 years ago depict a stylized heart inside the outline of hunted animals such as bison and elephant. The ancient Greeks believed the heart was the seat of intelligence. Others believed the heart to be the source of the soul or of the emotions—an idea that persists in popular culture and various verbal expressions, such as "heartbreak," to the present day.

II STRUCTURE OF THE HEART

Cardiac Muscle

Cardiac muscle is a unique muscle tissue found only in the heart. Unlike most forms of muscle, which are stimulated to contract by nerves or hormones, certain cardiac muscle cells can contract spontaneously. Without a constant supply of oxygen, cardiac muscle will die, and heart attacks occur from the damage caused by insufficient blood supply to cardiac muscle.



G.W. Willis/Tony Stone Images

The human heart has four chambers. The upper two chambers, the right and left atria, are receiving chambers for blood. The atria are sometimes known as auricles. They collect blood that pours in from veins, blood vessels that return blood to the heart. The heart's lower two chambers, the right and left ventricles, are the powerful pumping chambers. The ventricles propel blood into arteries, blood vessels that carry blood away from the heart.

Appendix F: Approved IRB and consent form


**UNIVERSITY OF
MARYLAND**

INSTITUTIONAL REVIEW BOARD

 2100 Blair Lee Building
 College Park, Maryland 20742-5121
 301.405.4212 TEL 301.314.1475 FAX
 irb@deans.umd.edu
 www.umresearch.umd.edu/IRB

August 21, 2006

MEMORANDUM*Addendum Approval Notification*

To: Dr. Roger Azevedo
Mr. Dan Moos
Department of Human Development

From: *for* Roslyn Edson, M.S., CIP, *Rosanne C. Friedman*
IRB Manager
University of Maryland, College Park

Re: **IRB Application Number:** 06-0011
Project Title: "The Role of Motivation in Self-Regulated Learning with Hypermedia within College Students"

Approval Date Of Addendum: August 17, 2006

Expiration Date of IRB Project Approval: January 18, 2007

Application Type: *Addendum/Modification; Approval of request, submitted to the IRB Office on 25 July 2006, to use revised motivation questionnaire.*

Type of Review of Addendum: Expedited

Type of Research: Non-exempt

The University of Maryland, College Park Institutional Review Board (IRB) Office approved your IRB application. The research was approved in accordance with the University's IRB policies and procedures and 45 CFR 46, the Federal Policy for the Protection of Human Subjects. Please reference the above-cited IRB application number in any future communications with our office regarding this research.

Recruitment/Consent: For research requiring written informed consent, the IRB-approved and stamped informed consent document is enclosed. The IRB approval expiration date has been stamped on the informed consent document. Please keep copies of the consent forms used for this research for three years after the completion of the research

Continuing Review: If you want to continue to collect data from human subjects or to analyze private, identifiable data collected from human subjects, after the expiration date for this approval (indicated above), you must submit a renewal application to the IRB Office at least 30 days before the approval expiration date.

(Continued)

Participant ID: _____

STUDENT INFORMED CONSENT FORM

Page 1 of 2

<i>Identification of Project</i>	The role of motivation in self-regulated learning with hypermedia in college students.
<i>Statement of Age of Participant</i>	You are over 18 years of age and wish to participate in a research study being conducted by Daniel Moos and Dr. Roger Azevedo in the Department of Human Development at the University of Maryland, College Park.
<i>Purpose</i>	The purpose of this research is to examine students' motivational and cognitive processes when using an electronic encyclopedia to learn about a complex biological system.
<i>Procedures</i>	The experimental procedure will involve one session and will last approximately 90 minutes. During the session, you will be asked to use an electronic encyclopedia environment to learn about the circulatory system. After filling out the participant questionnaire, you will be asked to engage in the following: (1) Complete a pretest on the circulatory system, (2) complete a short motivation questionnaire, (3) verbalize your thinking during the learning task, and (4) complete a posttest on the circulatory system. The session will be audio and video recorded. You are free to refuse to answer any questions at any point during this session. Questions that you may be asked include, "Name and label different parts of the heart" and "Indicate how interested you are in learning about a biological system." The data will be stored in a locked cabinet in the EDHD graduate student office, located in room 3304 of the Benjamin Building, University of Maryland, College Park. This data will be stored in this location throughout the duration of the data collection and analysis. In addition, this data will eventually be destroyed, following the guidelines of American Psychological Association.
<i>Confidentiality</i>	All information collected in the study is confidential to the extent permitted by law. Data that you provide will be grouped with data others provide for reporting and presentation and your name will not be used.
<i>Risks</i>	There are no known risks associated with participation in this research.

STUDENT INFORMED CONSENT FORM, continued
Page 2 of 2

*Benefits: Freedom to
Withdraw and Ask
Questions*

The experiment is not designed to help you personally, but the investigator hopes to learn more about students' cognitive and motivational processes when using electronic encyclopedia to learn about complex systems. Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not lose any benefits to which you otherwise qualify.

*Contact Information of
Investigator*

Dr. Roger Azevedo, Department of Human Development
3304 Benjamin Building, 3304E, razevedo@umd.edu

*Contact Information of
Institutional Review Board*

If you have any questions about your rights as a research subject and/or wish to report a research-related injury, please contact:
**Institutional Review Board Office, University of Maryland,
College Park, Maryland, 20742; irb@deans.umd.edu;
301-405-0678.**

Printed Name of Participant

Signature of Participant

Date

Appendix G: Instructions to participants

Conceptual Scaffolding (experimental condition):

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. To guide your learning, we are giving you 5 questions which you will answer verbally during those 30 minutes.

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.

Conceptual Scaffolding (control condition):

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.

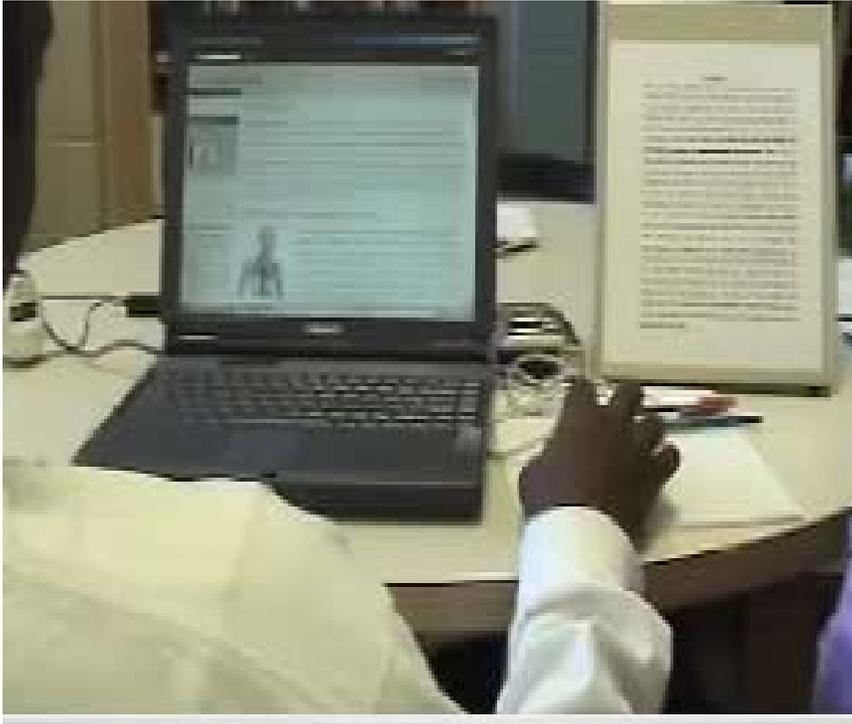
Appendix H: Sample text from practice think-aloud text (Encarta™, 2003)

Before the Civil War, the federal government's chief source of revenue was the tariff. There were few other sources of revenue, for example, neither personal nor corporate income taxes existed. The tariff paid for most improvements made by the federal government, such as roads, turnpikes, and canals. To keep tariffs low, the South preferred to do without these improvements.

The expanding Northwest Territory, which was made up of the present-day states of Ohio, Indiana, Illinois, Michigan, Wisconsin, and part of Minnesota, was far from the markets for its grain and cattle. It needed such internal improvements for survival, and so supported the Northeast's demands for high tariffs. In return, the Northeast supported most federally financed improvements in the Northwest Territory.

As a result, although both the South and the West were agricultural, the West allied itself with the Northern, rather than the Southern, point of view. Economic needs sharpened sectional differences, adding to the interregional hostility.

Appendix I: Experimental set-up



Appendix J: SRL coding scheme

Classes, Descriptions and Examples of the Variables Used to Code Students' Regulatory Behavior (modified version from Azevedo et al., 2005)

Variable	Description ³	Student Example
Planning		
Planning	Stating two or more learning goals	"First, I'll look around to see the structure of environment and then I'll go to specific sections of the circulatory system."
Prior Knowledge Activation	Searching memory for relevant prior knowledge either before beginning performance of a task or during task performance	" <i>Their primary function is to carry oxygen from the lungs to every cell in the body.</i> Umm, red blood cells are red because the oxygen reacts with iron in the blood and um, which makes it rust, turn red."
Recycle Goal in Working Memory	Restating the goal (e.g., question or parts of a question) in working memory	"...what does blood do when it leaves the right side of the heart?"
Sub-Goal	Articulating a specific sub-goal that is relevant to the experiment-provided overall goal	"I want to learn more about plasma. I'm going to click on that."
Monitoring		
Content Evaluation (Plus)	Stating that just-seen text, diagram, or video is relevant	[Learner reads about red blood cells] "This is just what I was looking for."
Content Evaluation (Minus)	Stating that just-seen text, diagram, or video is irrelevant	"I'm reading through the info but it's not specific enough for what I'm looking for."
Expectation of Adequacy of Content (Plus)	Expecting that a certain content (e.g., section of text, diagram, video) will be adequate given the current goal	"...the video will probably give me the info I need to answer this question."
Expectation of Adequacy of Content (Minus)	Expecting that a certain content (e.g., section of text, diagram, video) will not be adequate given the current goal	"Mmm, circulatory system disorders..I don't think that will answer my question."

³ All codes refer to what was recorded with the think-aloud protocol

Feeling of Knowing (Plus)	Stating that there is an awareness of having read or learned something in the past and having some understanding of it	"Oh, I already read that."
Feeling of Knowing (Minus)	Stating that there is an awareness of not having read or learned something in the past	"I didn't know that."
Judgment of Learning (Plus)	Indicating that there is an understanding of what was just read/seen	"Okay, this makes sense."
Judgment of Learning (Minus)	Indicating that there is not an understanding of what was just read/seen	"Wait, this isn't making any sense."
Monitor Progress Toward Goals	Assessing whether previously-set goal has been met	"Those were our goals, we accomplished them."
Monitor Use of Strategies	Commenting on usefulness of strategy	"Yeah, drawing it really helped me understand how blood flow throughout the heart."
Time Monitoring	Referring to the number of minutes remaining	"I'm skipping over that section since 40 minutes is too short to get into all the details."

Strategy Use

Control Video	Using pause, start, rewind, or other controls in the digital animation	<i>Then the heart relaxes, the aortic and pulmonary valves close, and diastole starts again.....[Learner pauses video]</i>
Coordinating Informational Sources	Coordinating multiple representations (e.g., drawing and notes)	"I'm going to put that [text] with the diagram."
Draw	Making a drawing or diagram to assist in learning	"...I'm trying to imitate the diagram as best as possible."
Evaluate Content as Answer to Question	Stating what was just read and/or seen meets an experimenter posed question	[Learner reads text]..." So, I think that's the answer to this question."
Inferences	Drawing a conclusion based on two or more pieces of information that were read within the same paragraph in the hypermedia environment.	<i>"Hypertension is elevated blood pressure, develops when the blood- body's blood vessels narrow, causing the heart to pump harder Which I'm guessing could cause a heart attack."</i>
Knowledge Elaboration	Elaborating on what was just read, seen, or heard with prior knowledge	<i>"Heat dissipates through the skin, effectively lowering the temperature. Like a car radiator."</i>
Memorization	Memorizing text, diagram, etc.	"I'm going to try to memorize this picture."
Re-reading	Re-reading or revisiting a section of the hypermedia environment	"I'm reading this again."

Review Notes	Reviewing notes	"Let me read over these notes now"
Summarization	Verbally restating what was just read, inspected, or heard in the hypermedia environment	"This says that white blood cells are involved in destroying foreign bodies."
Search	Searching the hypermedia environment	[Learner types in blood circulation in the search feature]
Taking Notes	Writing down information	"I'm going to write that under heart."

Appendix K: Example of coded transcript

Condition CS/SRL/SE/ UG10 "DS" 5
 3/09/06

Researcher: Here's the third question.

Participant: *When blood leaves the right side of the heart, it goes to one place and when blood leaves the left side it goes to a different place. What does the blood do when it leaves the right side of the heart?* All right, have this.. all right, when it leaves the right side it goes to the body, when it leaves the left side it goes to the body..right, lungs, left, body, right, lungs, left, body..right, lungs, left, body. *What does the blood do when it leaves the right side of the heart?* It goes to the lungs to get oxygen. Can I get the next question?

Researcher: Yep. So, here's the fourth question of five.

Participant: Right, so, again, right lungs, left to the body. Okay. *What does the blood when it leaves the left side of the heart? What does the blood do when it leaves the right side. What does the blood when it leaves the left side of the heart?* Looking at the notes... *What does the blood when it leaves the left side of the heart?* ...mmm...what does it do...it just goes to body...*what does it do...*[un]. This question, what does it do..gets pumped..okay.

Researcher: Here's the fifth question.

Participant: *Imagine that you are a blood cell that you are in the right side of the heart. Explain all the parts you would go through and eventually get back to the right side of the heart.* Okay, taking notes..right side of the heart. *Explain all the parts you would go through and eventually get back to the right side of the heart.*

FOK+
 RN
 MEM
 RGWM
 RN

 RN

 RN
 RGWM
 RN

 TN

 RGWM

References

- Ainley, M., Corrigan, M., & Richardson, N. (2005). Students, tasks and emotions: Identifying the contribution of emotions to students' reading of popular culture and popular science texts. *Learning and Instruction, 15*(5), 433-447.
- Ainsworth, S., & Loizou, A. (2003). The effects of self-explaining when learning with text or diagrams. *Cognitive Science, 27*(4), 669-681.
- Alexander, P.A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher, 32* (8), 10-14.
- Alexander, P.A. (2004). A model of domain learning: Reinterpreting expertise as a multidimensional, multistage process. In D. Y. Dai & R. J. Sternberg (Ed.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development*. (pp. 273-298). Mahwah, NJ: Erlbaum.
- Alexander, P.A., Schallert, D.L., & Hare, V.C. (1991). Coming to terms: How researchers in learning and literacy talk about knowledge. *Review of Educational Research, 61*(3), 315-343.
- Alexander, P.A., Jetton, T.L., & Kulikowich, J.M. (1995). Interrelationship of knowledge, interest, and recall: Assessing the model of domain learning. *Journal of Educational Psychology, 87*, 559-575.
- Alexander, P.A., & Murphy, K. P. (1998). Profiling the differences in students' knowledge, interest, and strategic processing. *Journal of Educational Psychology, 90*(3), 435-447.

- Alexander, P.A., & Jetton, T.L. (2003). Learning from traditional and alternative texts: New conceptualizations for the information age. In A. Graesser, M. Gernsbacher, & S. Goldman (Eds.), *Handbook of discourse processes* (pp. 199-241), NJ: Erlbaum.
- Anderson, J.R. (1987). Methodologies for studying human knowledge. *Behavioral and Brain Sciences*, 10, 467-505.
- Anderson, J.R., Corbett, A.T., & Koedinger, K.R. (1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences*, 4(2), 167-207.
- Azevedo, R. (2005). Computer environment as metacognitive tools for enhancing learning. *Educational Psychologist*, 40(4), 193-197.
- Azevedo, R., & Cromley, J.G. (2004). Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology*, 96(3), 523-535.
- Azevedo, R., Guthrie, J.T., & Seibert, D. (2004a). The role of self-regulated learning in fostering students' conceptual understanding of complex systems with hypermedia. *Journal of Educational Computing Research*, 30(1), 87-111.
- Azevedo, R., Winters, F.I., & Moos, D.C. (2004b). Can students collaboratively use hypermedia to learn about science? The dynamics of self- and other-regulatory processes in an ecology classroom. *Journal of Educational Computing Research*, 31(3), 215-245.
- Azevedo, R., Cromley, J.G., & Seibert, D. (2004c). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia. *Contemporary Educational Psychology*, 29, 344 - 370

- Azevedo, R., Cromley, J.G., Winters, F.I., Moos, D.C., Greene, J.A. (2005). Adaptive human scaffolding facilitates adolescents' self-regulated learning with hypermedia. *Instructional Science*, 33, 381-412.
- Azevedo, R., Moos, D.C., Greene, J.G., Winters, F.I., & Cromley, J.C. (in press). Why is externally-regulated learning more effective than self-regulated learning with hypermedia? *Educational Technology Research and Development*
- Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. National Institute of Mental Health. NJ: Prentice-Hall.
- Bandura, A. (1991). Self-regulation of motivation through anticipatory and self-reactive mechanisms. In R. A. Dienstbier (Ed.), *Perspectives on motivation: Nebraska symposium on motivation* (Vol. 38, pp. 69-164). Lincoln: University of Nebraska Press.
- Bandura, A. (1994). Regulative function of perceived self-efficacy. In M. G. Rumsey, C. B. Walker, & J. H. Harris (Ed.) *Personnel selection and classification* (pp. 261-271). Mahwah, NJ: Erlbaum.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. NY: Freeman/Times Books/Henry Holt & Co.
- Bandura, A., & Schunk, D.H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology*, 41(3), 586-598.
- Bergin, D.A., Ford, M.E., & Hess, R.D. (1993). Patterns of motivation and social behavior associated with microcomputer use of young children. *Journal of Educational Psychology*, 84(3), 272-281.

- Betz, N.E., & Hackett, G. (1981). The relationship of career-related self-efficacy expectations to perceived career options in college women and men. *Journal of Counseling Psychology, 28*(5), 399-410.
- Boekaerts, M. (1993). Being concerned with well-being and with learning. *Educational Psychologist, 28*, 148-167.
- Boekaerts, M., Pintrich, P., & Zeidner, M. (Eds.) (2000). *Handbook of self-regulation*. San Diego, CA: Academic Press.
- Bouffard-Bouchard, T. (1990). Influence of self-efficacy on performance in a cognitive task. *Journal of Social Psychology, 130*(3), 353-363.
- Bouffard-Bouchard, T., Parent, S., & Larivee, S. (1991). Influence of self-efficacy on self-regulation and performance among junior and senior high-school age students. *International Journal of Behavioral Development, 14*, 153-164.
- Bransford, J.D., Zech, L., & Schwartz, D. (1996) Fostering mathematical thinking in middle school students: Lessons from research. In R. J. Sternberg & T. Ben-Zeev (Eds.), *The nature of mathematical thinking*. (pp. 203-218). Mahwah, NJ: Erlbaum.
- Brosnan, M..J. (1998). The impact of computer anxiety and self-efficacy upon performance. *Journal of Computer Assisted Learning, 14*(3), 223-234.
- Brown, A.L. (1975). The development of memory: Knowing, knowing about knowing, knowing how to know. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 10). New York: Academic.
- Brown, A.L. (1990). Domain-specific principles affect learning and transfer in children. *Cognitive Science, 14*(1), 107-133.

- Butler, D.L., & Winne, P.H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, 65(3), 245-281.
- Caliser, F., & Gurel, Z. (2003). Influence of text structure and prior knowledge of the learner on reading comprehension, browsing and perceived control. *Computers in Human Behavior*, 19(2), 135-145.
- Cervone, D. (1989). Effects of envisioning future activities on self-efficacy judgments and motivation: An availability heuristic interpretation. *Cognitive Therapy and Research*, 14, 401-416.
- Chen, S.Y., & Ford, C. (1998). Modeling user navigation behaviours in a hypermedia-based learning system: An individual differences approach. *Journal of Knowledge Organization*, 25, 67-78.
- Chen, S.Y., Fan, J-P., & Macredie, R.D. (2006). Navigation in hypermedia learning systems: Experts vs. Novices. *Computers in Human Behavior*, 22(2), 251-266.
- Chi, M.T.H. (2000). Self-explaining: The dual processes of generating inference and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology: Educational design and cognitive science* (Vo. 5, pp. 161-238). Mahwah, NJ: Erlbaum.
- Chi, M.T.H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *Journal of the Learning Sciences*, 14(2), 161-199.
- Chi, M.T.H., de Leeuw, N., Chiu, M.H., & LaVancher, C. (1994). Eliciting self-explanation improves understanding. *Cognitive Science*, 18, 439-477.
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112, 155-159.

- Collins, W. (1982). Some correlates of achievement among students in a supplemental instruction program. *Journal of Learning Skills*, 2(1), 19-28.
- Corno, L. (1993). The best-laid plans: Modern conceptions of volition and educational research. *Educational Researcher*, 22, 14-22.
- Corno, L., & Mandinach, E.B. (2004). What we have learned about student engagement in the last twenty years. In D. M. McInerney & S. Van Etten (Eds.), *Big Theories Revisited* (pp. 299-328). Greenwich, CN: Information Age Publishing.
- CTGV (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher*, 19(6), 2-10.
- Debowski, S., Wood, R.E., & Bandura, A. (2001). Impact of guided exploration and enactive exploration on self-regulatory mechanisms and information acquisition through electronic search. *Journal of Applied Psychology*, 86(6), 1129-1141.
- Deffner, G. (1989). Interaction of thinking aloud, solution strategies and task characteristics? An experimental test of the Ericsson and Simon model. *Spracher und Kognition*, 9, 98-111.
- Derry, S., & Lajoie, S. (Eds.) (1993). *Computers as cognitive tools*. Mahwah, NJ: Erlbaum.
- Dochy, F., & Alexander, P.A. (1995). Mapping prior domain knowledge: A framework for discussion among researchers. *European Journal of Psychology of Education*, 10(3), 225-242.
- Dreher, M. J., & Guthrie, J.T. (1993). Searching for information. *Contemporary Educational Psychology*, 18(2), 127-179.

- Duffy, T. M., & Jonassen, D.H. (1992). *Constructivism and the technology of instruction: a conversion*. Hillsdale, NJ: Erlbaum.
- Eccles, J.S., & Wigfield, A., & Schiefele, U. (1998). Motivation to succeed. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology* (Vol. 3, pp. 1017-1095). NY: Wiley.
- Ericsson, K.A. (2006). Protocol analysis and expert thought: Concurrent verbalizations of thinking during experts' performance on representative tasks. In K.A. Ericsson, N. Charness, R.R. Hoffman, & P.J. Feltovich (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 223-242). Cambridge, MA: Cambridge University Press.
- Ericsson, K.A., & Simon, H.A. (1994). *Protocol analysis: Verbal reports as data* (2nd Ed.). Cambridge, MA: MIT Press.
- Eva-Wood, A.L. (2004). Thinking and feeling poetry: Exploring meanings aloud. *Journal of Educational Psychology*, 96(1), 182-191.
- Flavell, J.H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, 34, 906-911.
- Flavell, J.H. (1985). *Cognitive development*. Englewood Cliffs, NJ: Prentice Hall.
- Gallini, Joan K., & Zhang, Y-L. (1997). Socio-cognitive constructs and characteristics of classroom communities: An exploration of relationships. *Journal of Educational Computing Research*, 17(4). pp. 321-339.

- Garcia, T., & Pintrich, P. (1994). Regulating motivation and cognition in the classroom: The role of self-schemas and self-regulatory strategies. In D. H. Schunk & B. J. Zimmerman (Eds.), *Self-regulation and learning and performance: Issues and educational applications* (pp. 127-153). Hillsdale, NJ: Erlbaum.
- Grace-Martin, M. (2001). How to design educational multimedia: A “loaded” question. *Journal of Educational Multimedia & Hypermedia, 10*(4), 397-409.
- Graesser, A.C., McNamara, D.S., & VanLehn, K. (2005). Scaffolding deep comprehension strategies through Point&Query, AutoTutor, and iStart. *Educational Psychologist, 40*(4), 225-234.
- Greene, S., & Ackerman, J.M. (1995). Expanding the constructivist metaphor: A rhetorical perspective on literacy research and practice. *Review of Educational Research, 65*, 383-420.
- Greene, B., & Land, S. (2000). A qualitative analysis of scaffolding use in resource-based learning environments involving the world wide web. *Journal of Educational Computing Research, 23*(2), 151-179.
- Greene, J.G., & Azevedo, R. (in press). A theoretical review of Winne and Hadwin’s model of self-regulated learning: New perspectives and directions. *Review of Educational Research*
- Guthrie, J.T., & Wigfield, A. (1999). How motivation fits into the science of learning. *Scientific Studies of Reading, 3*(3), 199-205.

- Guthrie, J.T., Wigfield, A., Barbosa, P., Perencevich, K.C., Taboada, A., Davis, M.H., Scaffiddi, N.T., & Tonks, S. (2004). Increasing reading comprehension and engagement through concept-oriented reading instruction. *Journal of Educational Psychology, 96*(3), 403-423.
- Hacker, D.J. (1998). Definitions and empirical foundations. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 1-23). Mahwah, NJ: Erlbaum.
- Hacker, D.J., Dunlosky, J., & Graesser, A.C. (Eds.). (1998). *Metacognition in educational theory and practice*. Mahwah, NJ: Erlbaum.
- Hadwin, A.F., Wozney, L., & Pontin, O. (2005). Scaffolding the appropriation of self-regulatory activity: A socio-cultural analysis of changes in teacher-student discourse about a graduate research portfolio. *Instructional Science, 33*(5-6), 413-450.
- Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: Foundation, methods, and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory, Vol. II* (pp. 115-140). Hillsdale, NJ: Erlbaum.
- Harackiewicz, J.M., Barron, K.E., & Elliot, A.J. (1998). Rethinking achievement: When are they adaptive for college students and why? *Educational Psychologist, 33*, 1-21.
- Hartley, J.R. (1985). Some psychological aspects of computer-assisted learning and teaching. *Programmed Learning and Educational Technology 22*(2), 140-149.

- Hartwig, F., & Dearing, B.E. (1979). *Exploratory Data Analysis*. CA: Sage.
- Hasan, B. (2003). The influence of specific computer experiences on computer self-efficacy beliefs. *Computers in Human Behavior, 19*(4), 443-450.
- Heydemann, M. (1986). The relation between eye-movements and think aloud for Raven matrices. *Psychologische Beitrage, 28*, 76-87.
- Hill, J. R., & Hannafin, M. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. *Educational Technology Research and Development, 49*(3), 37-52.
- Hmelo-Silver, C.E., & Pfeffer, M.G. (2004). Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science, 28*(1), 127-138.
- Holladay, C.L., & Quiñones, M.A. (2003). Practice variability and transfer of training: The role of self-efficacy generality. *Journal of Applied Psychology, 88*(6), 1094-1103.
- Holliday, W.G., Whittaker, H.G., & Loose, K.D. (1984). Differential effects of verbal aptitude and study questions on comprehension of science topics. *Journal of Research in Science Teaching, 21*(2), 143-150.
- Houle, P.A. (1996). Toward understanding student differences in a computer skills course. *Journal of Educational Computing Research, 14*(1), 25-48.
- Jacobson, M. J., & Archodidou, A. (2000). The design of hypermedia tools for learning: Fostering conceptual change and transfer of complex scientific knowledge. *Journal of the Learning Sciences, 9*(2), 145-199.

- Jacobson, M.J., & Kozma, R.B. (Eds.) (2000). *Innovations in science and mathematics education: Advanced designs for technologies of learning*. Mahwah, NJ: Erlbaum.
- Jacobson, M.J., & Azevedo, R. (in press). Scaffolding learning with hypertext and hypermedia: Theoretical, empirical, and design issues. *Educational Technology Research and Development*
- Järvenoja, H., & Järvelä, S. (2005). How students describe the sources of their emotional and motivational experiences during the learning process: A qualitative approach. *Learning and Instruction, 15*(5), 465-480.
- Jonassen, D., & Reeves, T. (1996). Learning with Technology: Using computers as cognitive tools. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp.694-719). NY: Macmillan.
- Jonassen, D., & Land, S.M. (2000). *Theoretical foundations of learning environments*. Mahwah, NJ: Erlbaum.
- Kanfer, R. (1990). Motivation and individual differences in learning: An integration of developmental, differential and cognitive perspectives. *Learning and Individual Differences, 2*(2), 221-239.
- Karabenick, S.A., & Sharam, R. (1994). Seeking academic assistance as a strategic learning resource. In P. Pintrich, D. Brown, & C. Weinstein. (Eds.) *Student motivation, cognition, and learning* (pp. 189-211). Mahwah, NJ: Erlbaum.
- Koriat, A., & Goldsmith, M. (1996). Monitoring and control processes in the strategic regulation of memory accuracy. *Psychological Review, 103*, 490-517.
- Lajoie, S.P. (Ed.) (2000). *Computers as cognitive tools: No more walls, Vol. II*. Mahwah, NJ: Erlbaum.

- Lajoie, S.P., & Azevedo, R. (2006). Teaching and learning in technology-rich environments. In P. Alexander & P. Winne, (Eds.), *Handbook of Educational Psychology* (2nd ed.) (pp. 803-821). NJ: Erlbaum.
- Land, S., & Greene, B. (2000). Project-based learning with World Wide Web: A qualitative study of resource integration. *Educational Technology Research and Development*, 48(1), 45-67.
- Last, D.A., O'Donnell, A.M., & Kelly, A.E. (2001). The effects of prior knowledge and goal strength on the use of hypermedia. *Journal of Educational Multimedia and Hypermedia*, 7(1), 51-69.
- Lawless, K.A., & Brown, S.W. (1997). Multimedia learning environments: Issues of learner control and navigation. *Instructional Science* 25(2), 117-131.
- Lenski, S., & Nierstheimer, S. (2002). Strategy instruction from a sociocognitive perspective. *Reading Psychology*, 23, 127-143.
- Lepper, M.R., Woolverton, M., Mumme, D.L., & Gutner, J.L. (1993). Motivational techniques of expert human tutors: Lessons for the design of computer-based tutors. In S.P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 75-105). Hillsdale, NJ: Erlbaum.
- Lepper, M. & Wolverton, M. (2004). The wisdom of practice: Lessons learned from the study of highly effective tutors. In J. Aranson (Ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 135-158). New York, NY: Academic Press.

- MacGregor, S.K. (1999). Hypermedia navigation profiles: Cognitive characteristics and information processing strategies. *Journal of Educational Computing Research*, 20(2), 189-206.
- Markman, A.B., & Gentner, D. (2000). Structure mapping in the comparison process. *American Journal of Psychology*, 113(4), 501-538.
- Martin, V.L., & Pressley, M. (1991). Elaborative-interrogation effects depend on nature of question. *Journal of Educational Psychology*, 83, (1), 113-119.
- Mayer, R.E. (2003). Learning environments: The case for evidence-based practice and issue-driven research. *Educational Psychologist*, 40, 257-265.
- McCrudden, M.T., Schraw, G., & Kambe, G. (2005). The effect of relevance instructions on reading time and learning. *Journal of Educational Psychology*, 97(1), 88-102.
- McDonald, S., & Stevenson, R.J. (1998). Effects of text structure and prior knowledge of the learner on navigation in hypermedia. *Human Factors*, 40(1), 18-27.
- McManus, T.F. (2000). Individualizing instruction in a Web-based hypermedia learning environment: Nonlinearity, advance organizers, and self-regulated learners. *Journal of Interactive Learning Research*, 11(2), 219-251.
- McNamara, D.S., Kintsch, E., & Songer, N.B. (1996). Are good texts always better? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction*, 14(1), 1-43.
- McNamara, D.S., & Shapiro, A. (2005). Multimedia and hypermedia solutions for promoting metacognitive engagement, coherence, and learning. *Journal of Educational Computing Research*, 33(1), 1-29.

- Meyer, J.P., & Gellatly, I.R. (1988). Perceived performance norm as a mediator in the effect of assigned goal on personal goal and task performance. *Journal of Applied Psychology, 73*(3), 410-420.
- Micceri, T. (1989). The unicorn, the normal curve, and other improbable creatures. *Psychological Bulletin, 105*, 156-166.
- Mitchell, T.R., Hopper, H., Daniels, D. (1994). Predicting self-efficacy and performance during skill acquisition. *Journal of Applied Psychology, 79*(4), 506-517.
- Mitchell, T., Chen, S., & Macredie, R. (2005). Hypermedia learning and prior knowledge: Domain expertise vs. system expertise. *Journal of Computer Assisted Learning, 21*(1), 53-64.
- Moos, D.C. (2004). *The role of goal structure in undergraduates' use of self-regulatory variables in two hypermedia learning tasks*. Unpublished Master's Thesis. University of Maryland, College Park.
- Moos, D.C., & Azevedo, R. (April 2006a). *The role of prior knowledge in self-regulated learning with hypermedia*. Poster presented at the annual meeting of the American Educational Research Association, San Francisco, CA.
- Moos, D.C., & Azevedo, R. (2006b). The role of goal structure in undergraduates' use of self-regulatory variables in two hypermedia learning tasks. *Journal of Educational Multimedia and Hypermedia, 15*(1), 49-86.
- Moos, D.C. & Azevedo, R. (2006c). *The impact of conceptual scaffolds on students' motivation and self-regulatory processes during learning with hypermedia*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

- Moos, D.C., & Azevedo, R. (April, 2007a). Learning with hypermedia: The role of cognitive, motivational, and contextual factors. Paper to be presented at the 2007 annual meeting of the American Educational Research Association, Chicago, IL.
- Moos, D.C., & Azevedo, R. (April, 2007b). Students' monitoring, planning, and self-efficacy during learning with hypermedia: The impact of conceptual scaffolds. Paper to be presented at the 2007 annual meeting of the American Educational Research Association, Chicago, IL.
- Moos, D.C., & Azevedo, R. (in press). Self-regulated learning with hypermedia: The role of prior domain knowledge. *Contemporary Educational Psychology*
- Moos, D.C., & Azevedo, R. (accepted pending revisions). Exploring the fluctuation of motivation and use of self-regulatory processes during learning with hypermedia. *Instructional Science*
- Müller-Kalthoss, T., & Möller, J. (2003). The effects of graphical overviews, prior knowledge, and self-concept on hypertext disorientation and learning achievement. *Journal of Educational Multimedia and Hypermedia*, 12(2), 117-134.
- Murphy, K.P., & Alexander, P.A. (2000). A motivated exploration of motivation terminology. *Contemporary Educational Psychology*, 25, 3-53.
- Multon, K.D. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology*, 38(1), 30-38.

- Nelson, T. (1980). Replacing the printed word: a complete literary system. In S. H. Lavingston, (Ed.) *Proceedings of the IFIP Congress*, (pp. 1013-23). Amsterdam: North-Holland.
- Newell, A., & Simon, H.A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.
- Nielson, J. (2000). *Designing web usability: The practice of simplicity*. USA: New Rider Publishing.
- Norris, S.P. (1991). Informal reasoning assessment: Using verbal reports of thinking to improve multiple choice test validity. In J. F. Voss, D. N. Perkins, & Segal, J. W. (Eds.), *Informal reasoning and education*. Hillsdale: NJ: Erlbaum.
- Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research*, 66(4), 543-578.
- Pajares, F., & Miller, D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology*, 86(2), 193-203.
- Paris, S.G., & Newman, R.S. (1990). Developmental aspects of self-regulated learning. *Educational Psychologist*, 8, 293-316.
- Pea, R.D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences*, 13, 423-451.
- Perez, R., & Solomon, H. (2005). Effect of Socratic animated agent on student performance in a computer-simulated disassembly process. *Journal of Educational Multimedia and Hypermedia*, 14(1), 47-59.

- Perry, N.E. (1998). Young children's self-regulated learning and contexts that support it. *Journal of Educational Psychology, 90*(4), 715-729.
- Perry, N.E., VandeKamp, K.O., & Mercer, L.K. (2002). Investigating teacher-student interactions that foster self-regulated learning. *Educational Psychologist, 37*(1), 5-15.
- Pintrich, P. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 452-502). San Diego, CA: Academic Press.
- Pintrich, P., & de Groot, E.V. (1990). Motivational and self-regulated learning components of Classroom academic performance. *Journal of Educational Psychology, 82*(1), 33-40.
- Pintrich, P., Smith, D.F., Garcia, T., & McKeachie, W.J. (1991). *The manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)* (Tech. Rep. No. 91-B-004). Ann Arbor: University of Michigan, School of Education.
- Pintrich, P., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In A. Wigfield & J. S. Eccles (Eds.) *Development of achievement motivation*, (pp. 249 -284). San Diego, CA: Academic Press.
- Pressley, M., & Afflerbach, P. (1995). *Verbal protocols of reading: The nature of constructively responsive reading*. Hillsdale, NJ: Erlbaum.
- Pressley, M., Wharton-McDonald, R., & Allington, R. (2001). A study of effective first grade literacy instruction. *Scientific Studies of Reading, 15* (1), 35-58.

- Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist, 40*(1), 1-12.
- Quintana, C., Zhang, M., & Krajcik, J. (2005). A framework for supporting metacognitive aspects of online inquiry through software-based scaffolding. *Educational Psychologist, 40*(4), 235-244.
- Rao, N., & Sachs, J. (1999). Confirmatory factor analysis of the Chinese version of the Motivated Strategies for Learning Questionnaire. *Education and Psychological Measurement, 59*(6), 1016-1029.
- Rheinberg, F. (1996). From motivation to learn to learning outcome. What's between both? In J. Möller & O. Köller (Eds.), *Emotion, cognition, and academic achievement* (pp. 23 - 51). Weinheim, Germany: PVU.
- Rhenius, D., & Heydemann, M. (1984). Think aloud during the administration of Raven's matrices. *Zeitschrift für experimentelle und angewandte Psychologie, 76*, 308-327.
- Ryan, A., & Pintrich, P. (1997). "Should I ask for help?" The role of motivation and attitudes in adolescents' help seeking in math class. *Journal of Educational Psychology, 89*, 329-341.
- Salanova, M., Grau, R.M., & Cifre, E.. (2000). Computer training, frequency of usage and burnout: The moderating role of computer self-efficacy. *Computers in Human Behavior, 16*(6), 575-590.

- Sansone, C., Weir, C., Harpster, L., & Morgad, C. (1992). Once a boring task, always a boring task? The role of interest as a self-regulatory mechanism. *Journal of Personality and Social Psychology*, 379-390.
- Saye, J.W., & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, 50(3), 77-96.
- Schraw, G. (2006). Knowledge: Structures and processes. In P. Alexander & P. Winne (Eds.) *Handbook of educational psychology* (pp. 245-263). Mahwah, NJ: Erlbaum.
- Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, 7, 351-371.
- Schraw, G., & Sinatra, G.M. (2004). Epistemological development and its impact on cognition in academic domains. *Contemporary Educational Psychology*, 29(2), 95-102.
- Schunk, D.H. (1981). Progress self-monitoring: Effects on children's self-efficacy and achievement. *Journal of Experimental Education*, 51(2), 89-93.
- Schunk, D.H. (1983). Ability versus effort attributional feedback: Differential effects on self-efficacy and achievement. *Journal of Educational Psychology*, 75(6), 848-856.
- Schunk, D.H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist*, 19(1), 48-58.
- Schunk, D.H. (1991). Self-efficacy and academic motivation. *Educational Psychologist*, 26(3-4), 207-231.

- Schutz, P.A., & Lanehart, S.L. (2002). Introduction: Emotions in education. *Educational Psychologist, 37*(2), 67-68.
- Shapiro, A. (1999). The relationship between prior knowledge and interactive overviews during hypermedia-aided learning. *Journal of Educational Computing Research, 20*(2), 143-167.
- Shapiro, A. (2000). The effect of interactive overviews on the development of conceptual structure in novices learning from hypermedia. *Journal of Educational Multimedia and Hypermedia, 9*(1), 57-78.
- Shapiro, A. (2004). How including prior knowledge as a subject variable may change outcomes of learning. Research. *American Educational Research Journal, 41*(1), 159-189.
- Shapiro, A., & Niederhauser, D. (2004). Learning from hypertext: Research issues and findings. In D. Jonassen (Ed.), *Handbook of research on educational communications and technology* (Vol. 2, pp. 605-620). NJ: Erlbaum.
- Shapka, J.D., & Ferrari, M. (2003). Computer-related attitudes and actions of teacher candidates. *Computers in Human Behavior, 19*(3), 319-334.
- Shin, E.C., Schallert, D.L., & Savenye, W.C. (1994). Effects of learner control, advisement, and prior knowledge on young students' learning in a hypertext environment. *Educational Technology Research and Development, 42*(1), 33-46.
- Snow, R., Corno, L., & Jackson, D. (1996). Individual differences in affective and cognitive functions. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 243-310). New York: Macmillan.

- Taylor, R. (1980). *The computer in the school: tutor, tool, tutee*. New York: Teachers College Press.
- Thompson, L.F., Meriac, J.P., & Cope, J.G. (2002). Motivating online performance: The influence of goal setting and Internet self-efficacy. *Social Science Computer Review*, 20(2), 149-160.
- Torkzadeh, G., & Koufteros, X. (1993). Computer user training and attitudes: A study of business undergraduates. *Behaviour & Information Technology*, 12(5), 284-292.
- Torkzadeh, G., & Van Dyke, T. (2002). Effects of training on Internet self-efficacy and computer user attitudes. *Computers in Human Behavior*, 18(5), 479-494.
- Turner, J.C. (1995). The influence of classroom contexts on young children's motivation for literacy. *Reading Research Quarterly*, 30, 410-441.
- Veenman, M., Bernadette, H., Hout-Wolters, V., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning*, 1, 3-14.
- Vuorela, M., & Nummenmaa, L. (2004). How undergraduate students meet a new learning environment? *Computers in Human Behavior*, 20(6), 763-777.
- Wang, A., & Newlin, M.H. (2002). Predictors of web-student performance: The role of self-efficacy and reasons for taking an on-line class. *Computers in Human Behavior*, 18, 151-163.
- Weinstein, C.E. (1987). *LASSI user's manual*. Clearwater, FL: H & H Publishing.
- Whipp, J.L., & Chiarelli, S. (2004). Self-regulation in a Web-Based Course: A case study. *Educational Technology Research and Development*, 52(4), 5-22.

- White, B., & Frederiksen, J. (2005). A theoretical framework and approach for fostering metacognitive development. *Educational Psychologist, 40*(4), 211-223.
- Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review, 6*, 49-78.
- Wigfield, A., & Eccles, J. (1989). Test anxiety in elementary and secondary school students. *Educational Psychologist, 24*, 159-183.
- Wigfield, A., & Guthrie, J.T. (1997). Relations of children's motivation for reading to the amount and breadth of their reading. *Journal of Educational Psychology, 89*(3), 420-432.
- Wigfield, A., & Eccles, J.S. (Eds.) (2002). *Development of Achievement Motivation*. San Diego, CA: Academic Press.
- Wigfield, A., Guthrie, J.T., & Tonks, S. (2004). Children's motivation for reading: Domain specificity and instructional influences. *Journal of Educational Research, 97*(6), 299-309.
- Wilder, G., Mackie, D., & Cooper, J. (1985). Gender and computers: Two surveys of computer-related attitudes. *Sex Roles, 12*(3-4), 215-228.
- Williams, M. (1996). Student control and instructional technologies. In D. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 957-983). NY: Macmillan.
- Winne, P.H. (1982). Minimizing the black box problem to enhance the validity of theories about instructional effects. *Instructional Science, 11*, 13-28.
- Winne, P.H. (1997). Experimenting to bootstrap self-regulated learning. *Journal of Educational Psychology, 89*, 1-14.

- Winne, P.H. (2001). Self-regulated learning viewed from models of information processing. In B. Zimmerman & D. Schunk. (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 153-189). Mahwah, NJ: Erlbaum.
- Winne, P.H. (2005). A perspective on state-of-the-art research on self-regulated learning. *Instructional Science*, 33(5-6), 559-565.
- Winne, P.H., & Hadwin, A.F. (1998). Studying self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277-304). Hillsdale, NJ: Erlbaum.
- Winne, P.H., & Perry, N.E. (2000). Measuring self-regulated learning. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 531-566). Orlando, FL: Academic Press.
- Winne, P.H., & Jamieson-Noel, D. (2003). Self-regulating studying by objectives for Learning: Students' reports compared to a model. *Contemporary Educational Psychology*, 28(3), 259-276.
- Winne, P.H., Nesbit, J.C., Kumar, V., Hadwin, A.F., Lajoie, S., & Perry, N. (2005). Supporting self-regulated learning with gStudy: The learning kit project. *Technology, Instruction, Cognition, and Learning*, 3, 105-113.
- Witherspoon, A., Azevedo, R., Greene, J., Moos, D.C., Baker, S., Trousdale, A., & Scott, J. (July, 2007). The dynamic nature of self-regulated behavior in self-regulated learning and externally-regulated learning episodes. Paper presented at the Artificial Intelligence in Education 2007 Conference.

- Wolters, C.A. (2003). Regulation of Motivation: Evaluating an underemphasized aspect of self-regulated learning. *Educational Psychologist, 38*(4), 189-205.
- Wood, D., & Middleton, D. (1975). A study of assisted problem-solving. *British Journal of Psychology, 66*(2), 181-191.
- Wood, D., Bruner, J.S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89-100.
- Wood, R., & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology, 56*(3), 407-415.
- Zimmerman, B.J. (1998). Academic studying and the development of personal skill: A self-regulatory perspective. *Educational Psychologist, 33*, 73-86.
- Zimmerman, B.J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R., Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-39). San Diego, CA: Academic Press.
- Zimmerman, B.J. (2001). Theories of self-regulated learning and academic achievement: An overview and analysis. In B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 1-37). Mahwah, NJ: Erlbaum.
- Zimmerman, B.J. (2006). Development and adaptation of expertise: The role of self-regulatory processes and beliefs. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 705-722). NY: Cambridge.

- Zimmerman, B.J., & Martinez-Pons, M. (1986). Development of a structured interview for assessing student use of self-regulated strategies. *American Educational Research Journal*, 23, 614-628.
- Zimmerman, B.J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal*, 29(3), 663-676.
- Zimmerman, B.J., & Bandura, A. (1994). Impact of self-regulatory influences on writing course attainment. *American Educational Research Journal*, 31, 845-862.
- Zimmerman, B.J., & Schunk, D.H. (Eds.) (2001). *Self-regulated learning and academic achievement: Theoretical perspectives* (2nd ed). NJ: Erlbaum.
- Zimmerman, B. J. & Tsikalas, K. (2005). Can computer-based learning environments (CBLEs) be used as self-regulatory tools to enhance learning? *Educational Psychologist*, 40(4), 267-271.