EXAMINING MIDDLE SCHOOL SCIENCE STUDENT SELF-REGULATED LEARNING IN A HYPERMEDIA LEARNING ENVIRONMENT THROUGH MICROANALYSIS

by

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A Dissertation
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# Examining Middle School Science Student Self-Regulated Learning in a Hypermedia Learning Environment through Microanalysis

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**ABSTRACT**

EXAMINING MIDDLE SCHOOL SCIENCE STUDENT SELF-REGULATED LEARNING IN A HYPERMEDIA LEARNING ENVIRONMENT THROUGH MICROANALYSIS

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The purpose of the present embedded mixed method study was to examine the self-regulatory processes used by high, average, and low achieving seventh grade students as they learned about a complex science topic from a hypermedia learning environment. Thirty participants were sampled. Participants were administered a number of measures to assess their achievement and self-efficacy. In addition, a microanalytic methodology, grounded in Zimmerman's cyclical model of self-regulated learning, was used to assess student self-regulated learning. It was hypothesized that there would be modest positive correlations between Zimmerman's three phases of self-regulated learning, that high achieving science students would deploy more self-regulatory subprocesses than average and low achieving science students, that high achieving science students would have higher self-efficacy beliefs to engage in self-regulated learning than average and low achieving science students, and that low achieving science students would over-estimate their self-efficacy for performance beliefs, average achieving science students would slightly overestimate their self-efficacy for performance beliefs, and high achieving science students would under-estimate their self-efficacy for performance beliefs. All hypotheses were supported except for the high achieving science students who under-estimated their self-efficacy for performance beliefs on the Declarative Knowledge Measure and slightly overestimated their self-efficacy for performance beliefs on the Conceptual Knowledge Measure. Finally, all measures of self-regulated learning were combined and entered into a regression formula to predict the students' scores on the two science tests, and it was revealed that the combined measure predicted 91% of the variance on the Declarative Knowledge Measure and 92% of the variance on the Conceptual Knowledge Measure. This study adds hypermedia learning environments to the contexts that the microanalytic methodology has been successfully administered. Educational implications and limitations to the study are also discussed.

# INTRODUCTION

The purpose of this chapter is to provide a foundation for a study exploring the self-regulatory processes used by high, average, and low achieving adolescents as they learn about a complex science topic with a Hypermedia Learning Environment (HLE). Student understanding of the declarative and conceptual knowledge were collected before and after the learning task to determine the relationship self-regulation had on content acquisition. Other elements, such as the accuracy of the student's calibration between perceived self-efficacy and task outcomes were measured to determine potential differences between high, average, and low achievers in their ability to accurately calibrate their self-efficacy beliefs as they learned with HLEs.

## Background of the Problem

The widespread use of computer-based learning environments (CBLEs), such as HLEs, offers the potential to enhance learners' understanding of complex science topics (Azevedo, Cromley, & Seibert, 2004). HLEs, which can contain text, diagrams, images, digital videos, and audio files have the ability to provide an interactive, non-linear, and enriched visual experience to the learner. Unfortunately, learners do not always know how to control their own learning processes with HLEs and as such, the instructional effectiveness of these environments to enhance learning is severely limited (Azevedo, Johnson, Chauncey, & Graesser, 2011). Researchers have found that learning with open-ended environments such as hypermedia typically involves the use of numerous self-regulatory processes such as planning, knowledge activation, metacognitive monitoring and regulation, and reflection (Azevedo, 2005, 2008, 2009; Graesser, McNamara, & VanLehn, 2005; Greene & Azevedo, 2009; Moos & Azevedo, 2008; Schraw, 2007; Veenman, 2007; Winne & Nesbit, 2009; Zimmerman, 2008). Understanding how students self-regulate, or why some may not self-regulate, with HLEs will assist researchers, designers, and practitioners in designing environments and materials that help learners to develop academically on their own.

While most of the models of self-regulation have some common assumptions (e.g., students are actively constructing knowledge, contextual factors mediate one's ability to regulate aspects of learning), it is important to acknowledge that they differ in their views of fundamental issues regarding the nature of self-regulated learning (SRL), (e.g., aptitude vs. event, number and types of processes, specificity of the underlying internal and external mechanisms) (Azevedo, Johnson, Chauncey, & Graesser, 2011). To date, most of the literature examining SRL with HLEs uses Winne and Hadwin's (2008) model which posits that learning occurs in four basic phases: (a) task definition, (b) goal setting and planning, (c) studying tactics, and (d) adaptations to metacognition, and the way they assess for SRL is through a think aloud methodology. The think aloud methodology has some weakness, namely that it assesses what students may be thinking as they perform a task (Ericsson, 2006), and the idea that students may intentionally, or unintentionally, misrepresent what they are thinking (Bandura, 1986). Because of these issues a microanalytic methodology, based upon Zimmerman's cyclical model of SRL and using strategic context-specific questions during the learning event, was used because of its ability to assess the learner's cognitive changes and motivational beliefs as they engaged in a learning task that had a defined beginning, middle, and end.

**Statement of the Problem**

Learning complex science 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 and HLEs (Chi, 2000, 2005; Chi, de Leeuw, Chiu, & LaVancher, 1994). For example, self-regulatory processes such as monitoring and strategy use have been found to foster knowledge development of complex science topics during learning with HLEs (Greene, Moos, Azevedo, & Winters, 2008). If a student is asked to learn about a complex science topic with an HLE, and is not able to regulate his or her learning, there is a very real possibility declarative and conceptual knowledge acquisition will not occur. Conversely, if the student is able to regulate his or her learning, the student is more likely to learn the given material and will probably make several cognitive, motivational, and behavioral attributions that will affect subsequent learning tasks (Pintrich, 2000; Schunk, 2001). According to the social cognitive perspective of SRL, learning is a purposeful process in which the students are actively engaged as they perform an academic task (Zimmerman, 2008). Recognition of this process can empower students to take control of their learning, regardless of context.

Unfortunately, most students are not proficient self-regulators. Some students may set an accurate and attainable course of action prior to a learning task but fail to recognize when that plan is not working. Other students may be judicious in sustaining their attention during a learning task but be grossly inaccurate about their self-efficacy beliefs. In each case, this disconnect has the potential to create a mismanagement of cognitive resources that undercuts learning. This is certainly the case as students learn with HLEs, because these environments provide a multitude of learning paths in an unfamiliar structure, they place additional demands on the students. If we were able to assess for SRL in HLEs using the microanalytic method, then we may be able to explore, using Zimmerman's cyclical model of SRL as a frame, how and why some students self-regulate and others do not, and how accurate these students are at calibrating their performance.

## Purpose of the Study

The purpose of this study was to explore the self-regulatory processes used by high, average, and low achieving students as they learned about a complex science topic with an HLE. The assessment of SRL was undertaken by implementing a microanalytic methodology which is based upon Zimmerman's cyclical model of SRL. Current SRL microanalytic methodology includes several important features, such as individualized assessment protocols, strategic administration of context-specific questions during a particular event, recording participants' responses verbatim, and use of a scoring rubric to code responses (Cleary, 2011). This microanalytic methodology is structured as an embedded mixed method design in that it merges both quantitative and qualitative data. The use of the microanalytic methodology also allowed for the examination of the accuracy of the students' calibration between their self-efficacy and task outcomes as they learned with HLEs. This data was combined with and adds to the literature base examining SRL, HLEs, science, and microanalysis to discover how adolescents learn with HLEs.

## Significance of the Study

In a time when students are using smart phones, tablets, computers, and television programs for everything from entertainment to education it is important to be aware that many of these students have not learned how to be proactive, responsible, and adaptive learners. Many students confuse information access for information acquisition and as a consequence, they fail to develop the skills necessary for content acquisition. Reflect on the case of David, a seventh grade student who is obsessed with texting and listening to music on his smart phone.

David has a test coming up in one week on the systems of the body and has started studying. In addition to the notes, class activities, and projects he has collected and participated in, he has been given access to a HLE on the systems of the body to use as a review tool. He has decided to focus his studying on this one medium because of its appealing format and interactive design. David has not set any goals, made any detailed plans, or even thought about studying from the other information sources. He thinks he will be able to watch the videos on each body system and skim the hyperlinked articles detailing their overall functions to get the basic idea for each system. He never tests himself or asks a friend or family member to test him on the material. He does not feel particularly confident in this studying method but does not want to ask for help, because he does not want others to think he is not smart. In addition, he is planning to not study very hard so that he can blame his likely poor performance on effort as opposed to ability. These maladaptive behaviors are indicative of a student who believes that academic achievement is a product of innate learner ability and not something he has any control over (Kitsantas & Dabbagh, 2010). While there is no magic strategy that will work for David in every learning situation, an understanding of some basic elements of self-regulation will help him become more independent and responsible for his own learning. To do this, we need to explore how David self-regulates as he learns with HLEs.

According to Zimmerman (1989), students who are self-regulated are metacognitively, motivationally, and behaviorally active participants in their own learning process. According to Zimmerman (2011), there are three phases of self-regulation which students engage in when performing an academic task: the forethought phase, performance phase, and the self-reflective phase. There is ample empirical evidence to support the role of self-regulatory processes in optimal learning and performance (Ertmer, & Newby, 1996; Zimmerman, 2000). This is especially true as students learn with HLEs because these environments allow the learner to control the sequencing of information and provides them with multiple representations presented in a non-linear fashion (Jacobson & Archodidou, 2000). These options create potential challenges for learners who have difficulty simultaneously navigating HLEs and acquiring new content. For example, research has shown that adolescents who do not self-regulate while learning with HLEs produce small conceptual shifts in their understanding of complex science topics (Azevedo, Cromley, Winters, Moos, & Greene, 2005; Greene & Azevedo, 2009). One of the determining factors in the deployment of SRL processes as students learn with HLEs is self-efficacy.

According to Bandura (1997), self-efficacy is the self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of action needed, and cognitive resources. Self-efficacy is context specific. For example, a student may strongly believe he or she is capable of learning the material from a HLE (i.e. have high self-efficacy) and will therefore be more likely to deploy other self-regulatory processes regardless of the content. Self-efficacy is also task specific and research has shown that the difficulty level of a task may also influence one's accuracy in estimating one's capability to solve the task (Chen & Zimmerman, 2007). Social cognitive researchers have defined calibration as the degree of alignment between self-efficacy judgments and actual task performance (Brannick, Miles, & Kissamore, 2005). This calibration issue is a key issue in self-efficacy research because students who overestimate their capabilities embark on activities beyond their control and those who underestimate their capabilities are likely to engage in self-limiting activities, thereby, decreasing their successes (Bandura, 1986). To date, the accuracy of the students' calibration between their perceived self-efficacy and task outcomes has not been examined in conjunction with HLEs.

With the above issues in mind, a microanalytic methodology was needed to explore the SRL processes used by students as they learn from a HLE. The microanalytic methodology is based upon Zimmerman's cyclical phase of SRL and applies specific questions targeted to address specific psychological processes at key times during the act of learning (Kitsantas & Zimmerman, 2002). Because of these factors, the microanalytic method provides a foundation to explore the accuracy of the student's calibration between his or her perceived self-efficacy and task outcomes as the student learns with a HLE. This method has been used in an array of athletic studies and a traditional science task but never with HLEs. Findings from this line of research may have significant implications for adolescents who learn with HLEs. By successfully using Zimmerman's cyclical phase model to understand SRL in this new context, researchers may be better able to empower students to take control of their learning before, during, and after a learning opportunity. Another potential significant implication from this research is a greater awareness of adolescent calibration tendencies between perceived self-efficacy and task outcomes while learning from HLEs. Based upon the above discussion, this study proposes to answer the following research questions.

**Research Questions**

The first research question asks if there are any relationships among adolescent use of SRL processes while they learn about a complex science topic with a HLE. It is hypothesized that there will be modest positive correlations between Zimmerman's three phases of SRL. The second research question asks if there are any differences in the use of SRL processes among high, average, and low achieving adolescents while they learn about a complex science topic with a HLE. It is hypothesized that high achieving adolescents will deploy more self-regulatory processes than average achieving adolescents and average achieving adolescents will deploy more self-regulatory processes than low achieving adolescents as they learn with a HLE. The third research question sought to explain the predictive power of the microanalytic method in predicting student Declarative Knowledge and Conceptual Knowledge. It is hypothesized that the microanalytic method will prove to be moderately predictive of each measure. The fourth research question asks if there are differences between high, average, and low achieving adolescents in their self-efficacy beliefs to engage in self-regulated learning as they learn from a HLE. It is hypothesized that high achieving adolescents will have higher self-efficacy beliefs to engage in self-regulated learning than average achieving adolescents and average achieving adolescents will have higher self-efficacy beliefs to engage in self-regulated learning than low achieving students as they learn from a HLE. The final research question asks if there are any differences among high, average, and low achieving adolescents in the accuracy of their calibration between perceived self-efficacy and task outcomes while engaged in a scientific task presented with a HLE. It is hypothesized that low achieving adolescents will over-estimate their self-efficacy for performance beliefs, average achieving adolescents will slightly overestimate their self-efficacy for performance beliefs, and high achieving adolescents will under-estimate their self-efficacy for performance beliefs on the two science tasks.

**Definitions**

*Self-Regulation*: Self-regulation is defined by Zimmerman (2000) as a process that enables students to take responsibility for their own learning by employing specific strategies to achieve their goals based on self-efficacy perceptions.

*Self-Efficacy*: According to Bandura (1997), self-efficacy is the self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of action needed, and cognitive resources.

*Hypermedia Learning Environments*: Computer-based tools that consist of nodes of information interconnected using hyperlinks that contain multiple representations of information including video, audio, diagrams, text, and animation (Scheiter & Gerjets, 2007).

*Conceptual Knowledge*: Understanding the interrelationships between definitions, properties of concepts, and facts, which include declarative and procedural knowledge (Chi, 2000, 2005; Graesser et al., 2005).

*Declarative Knowledge*: Understanding of definitions, properties of concepts, and facts (Graesser et al., 2005; McCrudden, Schraw, and Kambe, 2005).

*Self-Efficacy for Performance*: Judgments of one's capability to solve particular problems (Zimmerman & Kitsantas, 2005).

*Self-Efficacy for Learning*: Students' beliefs that they can learn the necessary skills and strategies to solve a particular problem (Zimmerman & Kitsantas, 2005).

# LITERATURE REVIEW

This dissertation will synthesize aspects of research that have examined Self-Regulated Learning (SRL), hypermedia, academic achievement in science, and self-efficacy. The first section of this literature review will discuss the difficulties and benefits of learning with hypermedia environments. The second section will discuss how SRL relates to hypermedia. The third section will discuss SRL and academic achievement in science. The fourth section will discuss the relationship among SRL and student motivation, with an emphasis on learning with hypermedia. The last section will address the methods used to measure SRL.

## Learning in Hypermedia Environments: What are the Barriers and the Drivers?

New technologies have the potential to radically change education. Unfortunately, this change is generally initiated by budgetary necessities. As school budgets shrink and class sizes increase, teachers are less able to spend valuable one-on-one time with their students. Consequently, more is being asked of these new technologies. Computer-Based Learning Environments (CBLEs), including hypertext, multimedia, Hypermedia Learning Environments (HLEs), intelligent tutoring systems, virtual worlds, simulations, and other environments that use some type of technology to deliver instruction or instructional materials, can be powerful learning tools due to their ability to present multiple representations of information in a manner that affords a great deal of learner control (Lajoie & Azevedo, 2006). These new forms of CBLEs and HLEs differ from earlier forms of educational software because they allow the learner to control the learning goals, select the way information is represented, and provides them the flexibility to develop and test strategies to solve complex problems. Properly designed CLBEs and HLEs can support a range of modalities by generating authentic interactive learning tasks. Unfortunately, the potential of these new tools is offset by the fact that they also place additional demands upon the learner regarding navigation, organization, and planning (Azevedo, 2005; Shapiro, 2005). These technology rich environments have different designs and it is important to understand how HLEs and CBLE differ.

CBLEs are a type of cognitive tool, or 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). CBLEs were originally designed to convey information in a linear format and then assess whether or not that information was acquired by the user. The student was viewed as a passive recipient of information. The traditional role of computer as instructor was logical because it eliminated variables and the desired learning outcome was almost certain. Jonassen and Reeves (1996), believed that students needed to be more involved in the learning process for real, transferrable knowledge to be gained. More advanced forms of CBLEs were needed to provide the type of environment where students could select goals, build knowledge, and solve complex problems. These new forms of CBLEs allowed students to learn with CBLEs, instead of from them, by providing students with a cognitive tool that supported knowledge construction and exploration (Jonassen & Mandl, 1990). Even though learners were more involved in the construction of knowledge, they were not allowed complete freedom to choose the way information was delivered or the time they could spend with that information. The constructivist approach to the learning process had certainly made an impact in CBLEs, but it needed a more flexible delivery system.

Hypermedia Learning Environments (HLEs) are defined as a type of Computer-based tool that consist of nodes of information interconnected using hyperlinks that contain multiple representations of information including video, audio, diagrams, text, and animation (Scheiter & Gerjets, 2007). These environments allow students to access a wide array of information (Collier, 1987), support complex representations of the content, are engaging to the learner, and support meaningful learning (Jonassen, 1989). In the case of this study, the HLE to be used will be in the form of a web-based encyclopedia. The web-based encyclopedia fits the definition of a HLE because it offers a variety of digital content presented in a non-linear format. There are multimedia components (e.g. text, still images, and video), to this HLE but it is the way they are connected that makes them a HLE. It is important to note that a web-based encyclopedia is not the same as a web page or an online search engine. According to Jonassen (2000), the web is a massive, distributed hypermedia knowledge base that is lacking in organization and uses database structures to help users make their own content relationships. Search engines are database structures integrated into the HLE that allow the user to access, sort, and determine the value of information presented during the “search” process and in turn, act as an intermediary between the learner and the HLE (Hartshorne & Ferdig, 2006). The web-based encyclopedia does not contain a search engine therefore it is up to the user to access, organize, and connect the relevant information. Another important distinction for HLEs, is that they are not hypertext environments because hypertext environments do not provide multiple representations of content (Greene, Moos, & Azevedo, 2011).

One of the least understood aspects regarding HLEs, is not their non-linear design or that information can be presented with audio, video, and static pictures, but that it is up to the user to decide the appropriate order that information is accessed. Because users can decide the sequence of information they access, this dynamic environment is very much learner controlled. In other words, learners have the ability to control the construction of knowledge. Active participation in the construction of knowledge, afforded by the learner controlled environments of hypermedia, facilitates learning (Hartley, 1985). To fully realize the potential of learner controlled environments learners must be able to control and regulate their learning.

How well students exert this learner control is a concept known as academic self-regulated learning (SRL)(Pintrich, 2000; Zimmerman, 2008; Zimmerman & Schunk, 2011). Learning with these non-linear, multi-representational, open-ended learning environments typically involves the use of numerous metacognitive and self-regulatory processes such as planning, knowledge activation, metacognitive monitoring and regulation, and reflection (Azevedo, 2008, 2009; Green & Azevedo, 2009; Moos & Azevedo, 2008; Schraw, 2007; Veenman, 2007; Winne & Hadwin, 2008; Zimmerman, 2008), and the common thread running through each of the SRL processes is motivation.

Students’ level of motivation plays a vital role in initiating, guiding, and sustaining students’ efforts to self-regulate their learning (Zimmerman, 2011). Research has demonstrated that students who have trouble self-regulating their own learning within HLEs are much less likely to acquire deep, conceptual understanding than their peers who have these skills (White & Frederiksen, 2005). In order to achieve this goal, considering different methods of assessing for SRL and concentrating on how students regulate their learning in HLEs, are important issues to consider as we move education into the 21st century.

The previous studies illustrate the benefits and barriers to learning with HLEs. The benefits are profound in that these new environments can convey a wide array of content in a dynamic format, unfortunately this creates new cognitive and motivational demands for the students. They must monitor their performance and constantly assess the usefulness of the material they are observing. They must also set goals, strategize, and reflect on their learning experiences to be successful learners in HLEs. To better understand these processes the next section will discuss the relationship between SRL and HLEs.

## How Self-Regulated Learning Relates to Hypermedia

SRL is a complex construct, especially when one considers learning with HLEs. Learners are often pulled in a variety of directions in HLEs but must maintain a learning plan in order to achieve their desired goal. In order to understand this process further, a real example is provided to illustrate how these two concepts overlap. Imagine a middle school student required to learn about biomes of the world from a HLE (Azevedo, Johnson, Chauncey, & Graesser, 2011). The HLE is a school owned software program that provides information on all of the biomes in the form of dozens of articles, hundreds of pictures, and a few digital videos. To move from one information source to the next the student must click on a hyperlink, and a list of the visited pages is created on the top of the webpage. The biomes are organized alphabetically and can also be accessed on a map of the world. Each biome contains the same set of sub-categories consisting of plants, animals, and climate. Within each subcategory students are able to navigate to other biomes from a menu found on the bottom of the page.

A student who truly understands his or her own learning processes, also known as a self-regulated learner, will set goals and plan strategies, and reflect on similar prior experiences. During the learning task the self-regulated learner will use imagery, metacognitive monitoring, and motivational strategies to maintain focus and ensure content acquisition. Upon completion of the learning task, the self-regulated learner will evaluate his or her performance, attribute the performance to the selection of a certain strategy, and use this new knowledge in future learning tasks with identical structures (Pintrich, 2000; Schunk, 2001). This example is not unique; it presents a learning scenario that students are faced with on a daily basis. The unfortunate reality is with students unwilling or incapable of deploying the correct SRL process at the correct time you have students using HLEs who are engaged but not learning.

To further support the conclusions from the example, empirically-based research on the topics of SRL and HLE are explained. Research has demonstrated that students' success in computer learning contexts is related positively to their development of self-regulated methods of learning (Greene, Moos, Azevedo, & Winters, 2008). In their study, researchers examined the self-regulated learning processes used by 98 middle school students and compared the results of the gifted students to grade level students. The researchers used a think aloud approach to capture the SRL processes as the students learned about the circulatory system from a HLE. Researchers discovered that the gifted students used more self-regulated processes, such as monitoring and strategy use, as compared to the grade level students. Researchers also discovered that the gifted students outperformed the grade level students in all outcome measures. Green, Moos, Azevedo, and Winters posited that these differences produced higher declarative knowledge posttest scores and mental model gain scores for the gifted students as compared to their grade level counterparts. This study illustrates the concept that effective deployment of SRL processes represents one way to increase performance on a challenging science task.

These findings mirror Greene and Azevedo's (2007) research that found students who were more self-regulating were better able to abstract a model of the circulatory system than those who were less self-regulating. In their study, also using the think aloud approach to gather SRL data, 148 adolescents were given a pretest and posttest asking the students to write down everything they could about the circulatory system making sure to include parts, their purpose, and how those parts work individually and together (Green & Azevedo). In between the pretest and posttest, students were given time to learn about the circulatory system with a HLE. For those participants who showed a gain in their understanding of the circulatory system it was discovered that they displayed differential use of six SRL processes, including metacognitive monitoring activities, learning strategies, and indications of task difficulty (Green & Azevedo). In these research studies, the challenges and potentials of learning in HLE are determined by the degree to which students self-regulate.

Other research has examined this dynamic by exploring the impact of scaffolding on SRL in HLEs (Azevedo, Cromley, & Seibert, 2004). In their study, three scaffolding conditions were created; the first was an adaptive scaffolding condition where a human tutor provided adaptive scaffolding by deploying certain self-regulatory "moves" (e.g. activating the students' prior knowledge, assisting the student in relating prior knowledge with new knowledge, or having the student construct their own representations of the topic), in the second or fixed scaffolding condition, the students were given a list of ten domain-specific questions designed to foster mental model development, and finally there was a no scaffolding condition (Azevedo, Cromley, & Seibert). It was discovered that students who were in the adaptive scaffolding condition developed more sophisticated mental models than those in a fixed or no scaffolding condition (Azevedo, Cromley, & Seibert). The college students in this study demonstrated that with active SRL scaffolding came greater deployment of SRL strategies, and consequently greater conceptual understandings. The next step in this research sequence was to explore this phenomenon from a different perspective, could SRL strategies be taught prior to a learning task and would this produce noticeable differences in the quality of the constructed performance outcomes?

Azevedo and Cromley (2004) conducted a study examining the impact of SRL education prior to a learning task by randomly assigning 131 undergraduate students into a training condition or a control condition. Students in the SRL group were given a 30 minute training session on the use of specific, empirically based SRL variables designed to foster their conceptual understanding; control students received no training (Azevedo & Cromley). Both groups were asked to complete the same four part pretest and posttest. The tests consisted of a matching, labeling, flow, and mental model essay section, all based on circulatory system knowledge, and it was discovered that the participants in the training group outperformed the control group in every one of the sections (Azevedo & Cromley). An interesting finding from this study was the inefficient strategy choices students made in the control group, students in this group recycled goals and engaged in random free searches as opposed to the students in the training condition who monitored their own cognitive progress towards goals (Azevedo & Cromley). This study has provided empirical evidence of the effectiveness of training students to regulate their learning as they learn from HLEs. Clearly, SRL is a key driver in learning from HLEs.

A number of empirically-based research articles were presented that discuss how SRL processes are essential to learning with HLEs. This is especially true when it comes to learning about complex science concepts. Complex science topics such as forces, atoms, DNA, the rock cycle, evolution, phase changes, and mitosis contain a variety of concepts and processes (Langley, Ronen, & Eylon, 1997). Mastery of these complex science topics requires students to synthesize facts into a coherent system, and to do this effectively they need SRL skills.

**Self-Regulation and Academic Achievement in Science**

Few would argue that science education in the United States is at a crisis point. Overcrowded classrooms, shrinking resources, meeting the needs of multi-lingual students, and pressure to promote high performance on state and national tests such as those mandated by No Child Left Behind are just a few of the everyday challenges confronting classroom science teachers (Marx & Harris, 2006). The product is a variety of achievement tests which show students in the United States lagging behind their international counterparts. For example, according to the 2007 TIMMS (Trends in International Mathematics and Science Study) assessment, American eighth graders performed more poorly in science than their peers in nine of 47 countries. On the 2006 PISA (Program for International Student Assessment), American 15 year-old students scored significantly below the science literacy average of the 29 participating countries, and U.S. students scored below 16 of the 29 participating countries (Baldi, Jin, Green, & Herget, 2007). The trends continue with the latest National Assessment of Educational Progress (NAEP) report from 2012 that reported 65% of the U.S. eighth graders in 47 states achieved at least a basic level in science, with only 2% scoring at the advanced level (National Center for Education Statistics, 2012). An additional source of concern within this area is the gender inequality within science. According to the latest NAEP report from 2011 eighth grade male students scored an average of five points higher than female students. These results are unfortunately in line with international averages where male students consistently outperform female students in science (Baldi, Jin, Green, & Herget, 2007). In this section, the case is made that within the context of HLEs academic performance in science and SRL are interconnected, and as a consequence it is critical to look to SRL to help increase the scientific proficiency of all students and science educators.

Self-regulation from a social cognitive view is unique because it involves the simultaneous interplay of several aspects of student learning including cognitive, motivational, affective, and contextual (Pintrich, 2004; Zimmerman, 2000). The cognitive component of self-regulation includes the knowledge and skills needed for tasks such as scientific problem solving, inquiry, and critical thinking (Taasoobshirazi & Sinatra, 2011). The motivational component includes the beliefs and attitudes that influence the use and development of one's cognition and metacognition (Schraw, Crippen, & Hartley, 2006). The affective and contextual components refer to the processes involved in becoming aware of one's emotional reaction to performance and having the ability to monitor one's experiences and how these factors are context dependent (Schutz & Davis, 2000; Thompson, 1994). In the next section, these components will be examined to see how they support effective self-regulation in science and then further studies will be described that observe the intersection of SRL, science, and HLEs.

The cognitive component of self-regulation includes the conceptual knowledge and problem-solving skills needed for success on important scientific tasks including problem solving, inquiry, and critical thinking (Taasoobshirazi & Sinatra, 2011). Conceptual knowledge refers to understanding the interrelationships between definitions, properties of concepts, and facts, which include declarative and procedural knowledge (Chi, 2000, 2005; Graesser et al., 2005). In a study by Taasoobshirazi and Sinatra (2011), they sampled 105 undergraduate students to determine the relationships between approach goal orientation, need for cognition, and motivation as the students were tested for conceptual change in physics. Conceptual change in physics, determined in this study by using gains from pre- to post-administration of a Force Concept Inventory (FCI), was found to have a positive influence on expert strategy use and problem-solving accuracy (Taasoobshirazi & Sinatra). In other words, the students who had a higher level of conceptual knowledge in physics were more likely to deploy appropriate strategies. The authors used structural equation modeling to uncover how motivation influenced change scores on the FCI both directly, and indirectly, through course grade and then how course grade directly influenced conceptual change. This study demonstrates that one of the most important variables to be considered when looking at creating an environment conducive to conceptual change is the conceptual knowledge of one's own cognitive processes and of the content. In addition to cognition, one of the key processes that drives critical thinking and science is the ability of the learner to select the appropriate strategy for the appropriate task.

Task strategies refer to analyzing tasks and identifying methods for learning various parts of a task (Zimmerman, 2000; Zimmerman, Bonner, & Kovach, 1996). Cognitive strategies refer to strategies such as elaboration, organization, and metacognitive strategies that typically result in higher levels of understanding (Schunk, Pintrich, & Meece, 2008). Success in high school and college-level science courses, including physics, chemistry, and biology courses, is typically assessed by asking students to solve problems that involve manipulating equations in order to solve for a single unknown quantity (Chi, 2006).

In Taasoobshirazi and Carr's study (2009), 374 college students were given a battery of tests to determine the relationships between strategy use, pictorial representations, categorization skills, and motivation and their impact on expert performance in physics. It was discovered that categorization skills, influenced student achievement through strategy use, which meant that the strategies these students had at their disposal were found to influence their success in solving the problems (Taasoobshirazi & Carr). An important skill in SRL is the ability to select the appropriate strategy for the appropriate problem and this clearly translates into the domain of science. Unfortunately, this is not always done because the students may be unwilling or incapable of maintaining motivation.

Motivation is a key component to consider for science because attaining science proficiency in a domain like biology, chemistry, or physics involves a considerable amount of practice that is distinguished by its high quality (Ericsson, 2006). One way to describe this process is by looking at the very nature of deliberate practice. During deliberate practice, students set a goal, act on that goal, assess the outcome, and adapt their behavior to achieve the goal (Taasoobshirazi & Sinatra, 2011). This process involves hard work, which is unlikely to occur without significant motivation and regulation (Ericsson, 2006; Zimmerman & Campillo, 2003). In a research study by Glynn, Brinkman, Armstrong, & Taasoobshirazi (2011), they viewed the role of motivation in SRL in science by examining 367 undergraduate science majors and 313 nonscience majors with the use of the Science Motivation Questionnaire II. It was discovered that science majors scored higher than the nonscience majors on all motivation items and that a key motivational construct, self-efficacy, was related to the students' college science grade point averages (Glynn, Brinkman, Armstrong, and Taasoobshirazi). Motivation to persevere, to maintain engagement, and to navigate the affective changes associated with learning frustrating or boring material is critical to the acquisition of scientific proficiency.

Looking at the intersection of SRL and science from another point of view, DiBenedetto and Zimmerman (2010) applied the microanalytic method to students studying a short passage on tornadoes. DiBenedetto and Zimmerman investigated the impact three expertise levels had on the use of SRL processes and they assessed this change by using two different science achievement measures. One was a ten question Tornado Knowledge Test and the other was a Conceptual Knowledge Test which asked the students to draw the three stages of tornado development covered in the article. Their results identified significant relations between self-regulatory processes across all three phases of SRL and expertise level. The other interesting finding indicated that self-reflection processes, such as self-evaluation and self-satisfaction reactions, were related significantly to not only students' acquisition of tornado knowledge but also to their formation of an abstract conceptual model of tornados (DiBenedetto & Zimmerman). These findings were nearly identical to Green and Azevedo's (2007) study that examined SRL, science, and HLEs.

Green and Azevedo (2007) conducted a study that found that middle and high school students who were more self-regulatory were better able to construct a model of the circulatory system than those who were less self-regulatory. In their study, 148 participants were asked to study the circulatory system from a HLE called Microsoft Encarta DVD. Participants were asked to take an identical pretest and posttest used to look for qualitative shifts in students' mental model shifts, a conceptual understanding framework, for the circulatory system. Findings from this study using the think-aloud protocol suggested that students who demonstrated a qualitative shift in science learning more frequently used six self-regulatory processes such as feeling of knowing (metacognitive monitoring), expecting the adequacy of information (monitoring their learning), and learning strategies such as control of context, coordinating informational sources, inferences, and knowledge elaboration (Green & Azevedo).

Clearly, based on this extensive empirical evidence SRL is important to science learning. Given the increased demands in the classroom, sophisticated HLE programs, and ever changing skills SRL must be considered as part of the solution. In the following section the cyclical view of SRL is explored and relevant research for each phase of SRL is discussed.

## Cyclical View of Self-Regulation

In general, students can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning process (Zimmerman, 1989). According to Zimmerman's social cognitive model of academic self-regulation there are three phases of SRL that students engage in when they perform an academic task (Dibenedetto & Zimmerman, 2010).

Forethought represents the first phase of Zimmerman's model. In this phase the learner examines his or her potential effectiveness to complete the task successfully by assessing and evaluating the results from previous performances on related tasks and domains (Pajares, 2008). The five processes that make up the forethought phase are goal setting, strategic planning, task value, goal orientation, and self-efficacy. According to Zimmerman and Martinez-Pons (1992), once a self-regulated learner sets a goal, he or she will select the appropriate strategy to achieve this goal. Task value refers to the internal value a learner places on the task at hand (Deci, 1975). Goal orientation would be towards mastery of a task, and an unskilled learner's goal orientation would be towards the appearance of performance rather than learning the task well (Ames, 1992). Arguably, the most critical piece of Bandura's social cognitive theory found in Zimmerman's model is the idea of self-efficacy. Self-efficacy can be defined as people's beliefs about their capabilities to learn or perform actions at designed levels (Bandura, 1997). The forethought processes form the basis of what is done before active learning, and they have a direct impact on how the learner executes and evaluates the learning plan during the performance phase.

The performance phase of Zimmerman's cyclical model represents the active learning efforts during a task, and consists of three processes: attention focusing, self-monitoring, and self-instruction (Zimmerman, 2000). Self-regulated learners have the ability to create opportunities that minimize distractions and maximize their ability to reach their goal (Corno, 1993). These self-regulated learners also are able to accurately monitor their performance and discover how to proceed in a task (Schunk, 1982). The performance phase is unique because it is done during the learning process and thereby demands a great deal of monitoring, this phase is followed by the self-reflection phase.

The third phase, self-reflection, describes how the learner monitors the effectiveness of the strategies implemented in the prior phase (Pajares, 2008). The four processes that make up the self-reflection phase of the learning cycle: self-evaluation, attribution, self-reaction, and adaptivity (Zimmerman, 2000). Self-evaluation refers to the learner's ability to compare his or her self-monitoring results to some external benchmark. Attributions or reasons provided for success or failure clearly impact how efficacious they will feel during future learning opportunities (Kitsantas & Zimmerman, 2002). Zimmerman's model emphasizes the idea that the findings from the final phase, self-reflection, influences the forethought phase in a cyclical feedback loop (2000; 2008).

These three phases are grounded in social cognitive theory which examines learners triadically in terms of interactions between their academic environment, behavior, and personal and cognitive factors (Bandura, 1986; Zimmerman, 2000). In other words, social cognitive theory represents the idea that individuals are capable of developing on their own and that they also have the ability to control their actions by manipulating their behavior, self-perception, and environment. Each variable impacts the other two. This triadic reciprocality can best be illustrated by investigating self-efficacy, a personal factor, with the same example of the middle school student learning about biomes from a HLE (Schunk & Usher, 2011).

Imagine the same middle school student preparing to study from the HLE, believing he was capable of learning the material from this environment because of successful prior experiences. Bandura (1997), tells us that self-efficacy influences behaviors such as persistence and effort. This is an example of the person influencing behavior link. This works in reverse as the same student makes progress navigating the HLE and learning about biomes, his self-perception of his capability increases for this learning task. Regarding the person influencing the social/environment link imagine the same student working with a peer who happens to have a low self-efficacy for learning from HLEs. The first student may think his peer has little prior knowledge on biomes when in reality he or she is quite knowledgeable, the problem is the student with low self-efficacy for learning from HLEs feel incapable of effectively navigating the HLE. The influence from the social/environmental to the person is easier to illustrate when feedback is considered. Imagine the first student, the one with high self-efficacy in learning with HLEs, telling his peer with low self-efficacy in learning with HLEs that, "they can do it" or that, "they can successfully learn from the HLE." This positive feedback can increase confidence and in turn improve the second students' self-efficacy beliefs for this learning context.

In the final reciprocal relationship the link from behavior to social/environmental factors are described. Using our original example, imagine the teacher introducing the biome project and giving the students a brief tutorial on how to navigate the HLE. If the class is attentive and the student is not fully engaged, he or she may sit quietly and not actively listen to the teacher, this is an example of the impact environmental factors have on behavior. As any teacher will attest, student behavior can certainly influence the social/environmental factors in a classroom. Imagine a class made up of students with little self-efficacy for learning with HLEs sitting through the teacher's tutorial. If the students ask the teacher enough questions on how to navigate HLEs, the teacher may realize more time is needed to teach the nuances of HLEs before moving on with the project. In each of the examples, a link between personal, behavioral, and social/environmental factors is used to connect social cognitive theory to learning. It is critical to consider this interaction because each factor must be accounted for during learning because a break in behavioral focus during the forethought phase of SRL can have a profound impact on the performance and self-reflective phases.

In sum, previous research has identified that a social cognitive perspective of SRL is an important construct for students of all ages in all disciplines. As a reminder, this theory examines learners triadically in terms of interactions between their academic environment, behavior, and personal and cognitive factors (Bandura, 1986, Zimmerman, 2000). Zimmerman's three phases of SRL are cyclical and begin with the forethought phase, then move on to the performance phase, and then move on to the self-reflection phase and ideally the reactions from the self-reflection phase will influence the forethought phase of the next learning task. Clearly, there is enough literature in the field of educational psychology to support the claim that becoming a proficient self-regulated learner can lead one to academic success. In the following section, the relationship between SRL, student motivation, and achievement is discussed.

**What is the Relationship between Self-Regulated Learning and Student Motivation in Hypermedia Learning Environments?**

Research on self-regulation incorporates behavioral, motivational, and metacognitive factors but the early focus of this new field was on the metacognitive and cognitive aspects of learning. For example, in the 1970s and the 1980s students were typically instructed to be trained to use a strategy, such as imagery or self-verbalization, during subsequent efforts to learn (Zimmerman, 2011). In other words, students were taught a simple strategy and then learning was assessed. Unfortunately, these results were not maintained, transferred, or used spontaneously when students studied or practiced in authentic contexts (Pressley & McCormick, 1995). The student's decision not to use a strategy may have been because they were not comfortable with it, did not like the content, did not like the context, or because they viewed the outcome was not worth the time and energy. Many of these issues dealt with the construct of motivation. In this section, the role motivation plays in student's SRL with HLEs will be described and supported with empirical evidence. The SRL processes to be discussed include goal orientation, self-reactions, self-efficacy, task interest, and attributions (Dweck & Leggett, 1988; Elliot & Dweck, 2005; Pintrich & De Groot, 1990; Weiner, 2010; Wolters, Yu, & Pintrich, 1996).

**Goal Orientation and Self-Regulated Learning**. Goal orientation refers to the purpose that individuals have for engaging in specific behaviors (Anderman & Wolters, 2006). These purposes have been subdivided in the literature into two types: performance and learning goals (Zimmerman, 2011). Performance and learning goals differ in the area that they emphasize. For example, with a performance goal the learner keeps the end in mind and with a learning goal the purpose is to increase one's competence (Zimmerman). Learning goals are also called mastery goals. The differences in motivational factors between performance and learning goals are important to discuss in context of SRL because they each have shown to impact academic achievement.

According to research by Blackwell, Trzesniewski, and Dweck (2007), learning goal orientation can be taught to at-risk junior high students, and this goal orientation was in turn associated with improved achievement. In their study, seventh graders with declining grades in math were given lessons on goal setting, time management, math study strategies, and memory tips (Blackwell, Trzesniewski, & Dweck). In the experimental group, consisting of 48 participants, students were given incremental belief training. This training consisted of recalling tasks that had been difficult for them , and then allowing them to put in the extra time to master the task. In the control group, consisting of 43 participants, students were given the same SRL lessons but no incremental belief training. Blackwell, Trzesniewski, and Dweck (2007), found that students in the experimental group increased their valuing of learning, increased their willingness to exert effort to self-regulate their learning, and reversed their declines in math grades as compared to the control group whose participants continued to show a decline in math grades. These results highlight the influence learning goal orientation has on student self-regulation, motivation, and academic performance.

Furthermore in a study by Hole and Crozier (2007) they go a step further and compared the impact learning goals and performance goals had on student engagement, self-efficacy, and persistence as they solved two Tangram puzzles. Based upon their scores on the Patterns for Adaptive Learning Survey (PALS), 53 students were placed in either a high or low mastery/learning goal experimental group or a performance goal experimental group. In each experimental group, the participants had to try and solve two Tangram puzzles. In the first puzzle solving task, students were given a Tangram puzzle that was impossible to solve, and as they worked on the task researchers observed students' time on task behavior to measure their persistence; they also were administered a 5-point Likert scale to each student after the impossible puzzle task to measure their self-efficacy in terms of their ability to solve the puzzle (Hole & Crozier).

In the second puzzle solving task, students were allowed to choose the difficulty of the puzzle and as the students were working to solve it, they were asked if they would like a clue to help them solve it (Hole & Crozier, 2007). In addition to the measures from the first puzzle task, the difficulty of the puzzle and the choice of clue size (big or small) were also collected. It was discovered that the students in the learning/mastery goal groups showed more persistence, engagement, and more adaptive patters of self-regulatory strategy use than the students in the performance group (Hole & Crozier). Hole and Crozier (2007) also found that the experience of failing to solve the first puzzle forced students in the performance group to stop earlier than the learning/mastery group on the second puzzle. This study compared the impact of learning and mastery goal orientation to performance goal orientation had on a number of motivational, SRL, and academic outcomes. Goal orientation is critical to improving learning because of the cyclical nature of SRL, and as a consequence, how goals are set in the forethought phase impacts the performance and self-reflective phases.

**Task Interest/Value and Self-Regulated Learning**. Task interest/values are a piece of the forethought phase and are another important variable to consider as we explore the relationship of motivation and SRL. Task interest/value refers to a person's enjoyment or satisfaction in the immediate context of a task that is independent of the usefulness of the task (Deci, 1975). Using the middle school student learning about biomes from a HLE scenario, imagine a student who is interested in learning from HLEs persevering through adversities associated with HLEs because he values or is interested in the task compared to another student who does not value or is interested in the task. The latter student may give up or fail to implement another strategy when his or her learning stops or is slowed. The idea of task interest/value is important to the study of motivation in an academic setting because task interest/value can provide motivation for students in challenging situations (Deci, 1975; Deci & Ryan, 1985). Like many other SRL processes, task interest/value is context specific so the student with high levels of task interest/value in HLEs and learning about biomes may not exhibit the same high level in another context or content area.

In a study by Wolters and Pintrich (1998), they explored this phenomenon by assessing 545 seventh and eighth grade students for differences in the students' task value, self-efficacy, test anxiety, cognitive strategy use, regulatory strategy use, and classroom academic performance (Wolters & Pintrich, 1998). Students were assessed in mathematics, English, and social studies. It was discovered that students' task value ratings predicted their use of cognitive and self-regulatory strategies significantly (Wolters & Pintrich). These results were virtually identical to a study by Metallidou and

Vlachou (2007), where they found that upper elementary school children's SRL behavior, in English and mathematics, involved high levels of motivation. Their study also produced results that support a strong domain-specific characteristic of task value beliefs (Metallidou & Vlachou). This means that students with high levels of task interest/values tend to deploy more SRL strategies on that task. Another feature in the relationship between SRL and motivation is in the final stage of SRL, student self-reactions.

**Self-Reactions and Self-Regulated Learning**. Self-reactions occur during the final phase of SRL, named the self-reflection phase of SRL, and due to the cyclical nature of SRL, self-reactions can have a profound impact on future learning experiences. Student self-reactions are a direct result of the way students internalize a learning experience, and how this can have an immediate influence on their affective states (Bandura, 1991). In a study by Zimmerman and Kitsantas (2005), it was discovered that a student who does not do well on a mathematics quiz may have a reaction to that experience that leads the student to believe he or she is not good at mathematics, that he or she is helpless when it comes to mathematics, or that the student simply does not like mathematics. Clearly, motivation is an important variable in self-reactions.

Self-satisfaction and adaptive inferences represent the two forms of self-reactions that have been studied in the research (Zimmerman, 2011). Self-satisfaction refers to the feelings associated with one's performance and it has been found that increases in self-satisfaction enhance motivation, whereas decreases in self-satisfaction undermine further efforts to learn (Schunk, 2001). Zimmerman and Kitsantas (1999) examined the ability of 84 high school girls to combine a series of kernel sentences into a single nonredundant sentence. Even though the focus of the study was on the impact of shifting from process to outcome goals, it was discovered that students' perceptions of satisfaction and positive affect can motivate them to continue efforts to learn (Zimmerman & Kitsantas). Adaptive or defensive inferences represent another form of self-reaction in the final phase of SRL. The adaptive or defense inferences form of self-reactions moves beyond the initial affective state of self-reaction to helping students make choices about their future learning efforts (Zimmerman & Kitsantas, 2005). Students who display some level of satisfaction and attributing poor outcomes to strategy problems are more likely to make adaptive inferences (Zimmerman & Bandura, 1994). A defensive inference is produced when students who are not satisfied with their performance attribute outcomes to external causes. Self-regulation and motivation play a role in these forms of self-reactions as well because more regulated students will adopt adaptive inferences designed to change an approach to learning based on a negative outcome, while less regulated students may adopt a more defensive stance that serves to protect them from more negative reactions instead of helping them formulate more effective courses of action for future learning experiences (Zimmerman & Kitsantas, 1997). Another piece that is critical to motivation within the self-reflection phase of SRL that should be considered is attributions.

**Attributions and Self-Regulated Learning**. Attributions or reasons provided for success or failure clearly impact how efficacious students will feel during future learning opportunities (Kitsantas & Zimmerman, 2002). Attributions are classified in terms of three causal dimensions: locus, stability, and control (Weiner, 1992). Locus refers to whether the student thinks the cause is external or internal in nature. Stability refers to whether the student thinks he or she can actually change the cause and finally, control refers to whether the student thinks he or she can actually control the cause. In terms of motivation and achievement, there is research to support the idea that attributions are important factors in determining students' success because students' choice of attributions can make a difference in their choice to persist in challenging situations or their expectancy of success (Pintrich & De Groot, 1990; Schunk & Zimmerman, 1998; Weiner, 1972, 2010; Zimmerman & Kitsantas, 2002). For example the scenario of the student learning about biomes from a HLE, if the student attributed his poor performance on the project to effort, something he has control over, then he will hopefully be more motivated to put forth more effort in a similar future learning task. On the other hand, if the student attributes his poor performance on the project to an innate lack of ability to learn from HLEs, then he will probably not be motivated to put in more effort or try another strategy in a similar future learning task. This difference can have profound impacts on student learning. In a study by Schunk and Cox (1986), they provided students with math subtraction instruction and attributional feedback, in the form of effort, while engaging in self-regulated practice. It was discovered that effort feedback improved the self-efficacy beliefs and subtraction skill more than the no effort feedback group (Schunk & Cox). Students in the effort feedback group did not receive any content assistance; the only change was the type and delivery time of the effort feedback. This changed their beliefs, motivation, and skill level. Clearly, motivation is a key player within SRL, and in the research these self-efficacy beliefs have been found to be incredibly influential.

**Self-Efficacy and Self-Regulated Learning**. According to Bandura (1997), self-efficacy is the self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of action needed, and cognitive resources. Social cognitive researchers (Bandura), consider self-efficacy to be a key factor in the relationship between SRL and motivation that contributes to the acquisition of academic outcomes. Self-efficacy beliefs were originally defined by Bandura (1977), and focused on how persistence and effort were influenced by personal motivation and expectations. Self-efficacy was further explored by Pajares (1996), to include the idea that students who feel efficacious about learning generally expend more effort and persist longer than those who doubt their capabilities, especially when they encounter difficulty. Of central importance to understanding self-efficacy, is differentiating between efficacy expectations and outcome expectancy.

Outcome expectancy refers to judgments of the likely consequences of behavior (Bandura, 1977). For example, students who feel confident learning about biomes will expect successful outcomes when learning about similar content, and this expectation will motivate them to work harder and persist longer than students who doubt their capabilities (Zimmerman, 2011). Bandura's explanation of human agency states that outcome expectations shape behavior and motivation because people generally approach tasks with the end in mind; they hope to achieve positive outcomes and avoid negative ones (Bandura, 1977, 1989). Unfortunately, high levels of outcome expectancy do not always translate into high levels of efficacy. A student may expect high scores on a presentation about biomes because of prior experiences but have low self-efficacy in giving presentations. Efficacy expectations is certainly influenced by outcome expectancy but stands alone in that it depends more on perceived capability than on actual ability.

Bandura (1977) defined efficacy expectations as a person's belief that he or she can implement the specific behavior required to achieve the desired outcomes within a specific context. Since efficacy expectations are context specific, the ability of the student to accurately set efficacy expectations is tied to the familiarity within the given context (Pajares, 1996). For example, a student will not be accurate with his or her efficacy expectations in giving a presentation on biomes, if the student has never given a presentation before. Efficacy expectations and outcome expectancy reflect two aspects of self-efficacy, and it is important for this study to detail some of the empirical evidence showing how it relates to achievement outcomes.

In a study by Collins (1982), children were identified into low, medium, and high mathematics ability and within each ability level, either high or low mathematics self-efficacy. When the students finished the instruction, a series of new problems were given to solve. The questions they answered incorrectly could be revised until correct. It was found that mathematics ability level was related to performance, but the more interesting finding was that regardless of ability level, children with high self-efficacy completed more problems correctly and reworked more of the ones they missed (Collins). This type of perseverance and effort has been found in other studies such as Bouffard-Bouchard's (1990) research that found 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. On a much larger scale Multon, Brown, and Lent (1991), conducted a meta-analysis of studies published between 1977 and 1988 that revealed that self-efficacy beliefs were positively related to academic achievement and accounted for approximately 14% of the variance. Clearly, self-efficacy represents a key contributor to performance and the research supports this positive relationship (Bandura & Schunk, 1981; Betz & Hackett, 1981; Pajares, 1996; Pajares & Miller, 1994; Pintrich & De Groot, 1990; Schunk, 1982, 1984, 1991; Wigfield, Guthrie, & Tonks, Perencevich, 2004; Zimmerman, Bandura, & Martinez-Pons, 1992).

One of the issues facing self-efficacy researchers, using microanalysis and self-report measures, is the questionable accuracy of the student's skill level to achieve certain tasks. This concept, known as calibration accuracy, has received increased support and attention because of its potential utility in predicting student achievement outcomes and for identifying gaps in students' metacognitive skills (Bandura, 1997; Klassen, 2006). There are students who can accurately calibrate their self-efficacy beliefs with task outcomes and those who cannot. Within the group of students who cannot accurately calibrate their self-efficacy beliefs with task outcomes there are students who are called over-estimators that believe they will attain higher performance outcomes than they actually achieve, and under-estimators who actually surpass their performance expectations (Klassen, 2006; Pajares & Kranzler, 1995).

In a study by Bol and Hacker (2001) they found that high achieving graduate students were more accurate in their calibration in mathematics than were lower achieving students. In a follow up study, also using mathematics, by Bol, Hacker, O'Shea, and Allen (2005), the authors measured the influence of calibration practice, achievement level, and explanatory style on calibration accuracy and exam performance. Their findings suggest that higher achieving students were significantly more accurate with their predictions, yet underconfident in their predictions; lower achieving students were less accurate and overconfident (Bol, Hacker, O'Shea, & Allen). These findings also exist across the domains of writing and spelling. In Klassen's (2006) study, he used conventional self-efficacy measures as well as predictions of performance to examine the spelling and writing efficacy beliefs of early adolescents with and without learning disabilities (LD). Klassen found that the students with LD over-estimated their spelling performance by 52% and their writing performance by 19%, whereas the non-LD students were generally accurate in their performance estimates and students' performance predictions and self-efficacy ratings were strong predictors of a composite writing performance. It should also be noted, because of their relevance to the current study, that similar results have also been found in science.

DiBenedetto and Zimmerman (2010), conducted a microanalytic investigation using 51 high school students, who were high, average, or low achieving in science. Their task was to learn as much as possible about tornados from a short reading passage. It was discovered that on both calibration bias analyses, the self-efficacy for learning and remembering the material in the tornado passage bias and the self-efficacy for performance bias, low achievers overestimated their competence in science the most, the average achievers showed lower levels of overestimation, and the high achievers showed a slight underestimate of self-efficacy (DiBenedetto & Zimmerman). In each of these studies, the authors found that low achievers over-estimated and high achievers slightly underestimated performance. This overestimation is an important phenomenon for both practitioners and researchers to examine because it often is an indication of deficient self-awareness or metacognitive skills and may distort the level of effort that students perceive is necessary to succeed in school (Butler & Cartier, 2004; Hacker et al., 2000). This study hopes to add to this literature base by examining self-efficacy calibration biases in relation to task outcomes while learning from HLEs.

The previous section highlighted the relationship between motivation, achievement, and SRL. Within the complex construct of SRL we examined how motivation is related to goal orientation, task interest/value, self-reactions, attributions, and self-efficacy and then used a number of empirical studies to support those relationships. Of particular interest within this section was how sometimes students are incapable of accurately calibrating their self-efficacy beliefs with task outcomes and how this can have profound impacts on the perceived level of effort needed to accomplish a given task. In order to understand the dynamic relationship between self-efficacy and HLEs, it is necessary to review the current literature.

**Student Self-Efficacy Beliefs and Learning with Hypermedia.** Even though the majority of self-efficacy research has been on learning within traditional learning environments, a number of relevant studies have been undertaken and will be reviewed that examine how this construct may impact learning with HLEs. For review, a HLE is a type of computer-based learning environment which includes audio, text, video, animation, graphics, text, is student centered, and is structured in a non-linear format

(Jonassen & Reeves, 1996), and self-efficacy is the self-perception of one's capabilities to meet situational demands based on current states of motivation, courses of action needed, and cognitive resources (Bandura, 1997). To see where these two intersect it is necessary to remember that HLEs are a more dynamic form of CBLEs, therefore, 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). In order to fully understand how self-efficacy relates to HLEs it is important to examine two factors that have been related to self-efficacy, psychological factors and behavioral factors.

According to Torkzadeh and Van Dyke (2002), research suggests that students' attitudes, a psychological factor, towards computers are significantly related to their self-efficacy in learning with CBLEs. In Torkzadeh and Van Dyke's study (2002) they sampled 189 undergraduates and found that positive attitudes towards computers were related to high self-efficacy in learning with CBLEs, while negative attitudes were related to lower self-efficacy in learning with CBLEs (Torkzadeh & Van Dyke). An example of a negative attitude assumption was, "Whenever I use something that is computerized, I am afraid I will break it," and an example of a positive attitude assumption was, "I feel I have control over what I do when I use a computer" (Torkzadeh & Van Dyke). In addition to overall attitudes, the psychological factor of preferences impact on self-efficacy was also researched. In a study by Gallini and Zhang (1997), they examined the relationship of students' preference for working alone or in collaboration with peers with self-efficacy for 88 fourth and fifth graders. It was discovered that students who preferred to work alone showed significantly higher self-efficacy when learning with a CBLE (Gallini & Zhang). Their preferences impacted their self-efficacy and in turn probably impacted their behavior.

Research examining the psychological factor of behavior and its relationship with self-efficacy in learning with CBLEs has primarily looked at student's prior use of computers. In a study by Houle (1996), he found a positive relationship between previous use of spreadsheets and database courses with self-efficacy in learning with CBLEs. His study reviewed a range of variables on college students who were taking a computer skills course, including whether they took a computer course in high school, the type of high school computer course, and when they had taken a computer class since high school (Houle). Houle's (1996) study found that previous experiences or behavior with computers was positively related to self-efficacy, research looking at frequency has recently reinforced Houle's findings.  In Salanova, Grau, and Cifre's (2000) research, they found that measuring the frequency of computer usage, above and beyond just assessing whether or not students have previously used computers represents another method to analyze the relationship between behavioral factors and self-efficacy in learning with CBLEs. Clearly, self-efficacy in learning from CBLEs is complex and can be assessed by reviewing previous and present beliefs in usage, but another method that looks at how students navigate these environments is needed to provide a complete picture of how self-efficacy and HLEs interact.

Research on self-efficacy and HLEs has also examined how students learn in these environments. Navigation is a critical variable to consider due to the non-linear nature of HLEs. The focus of MacGregor's (1999) study was to investigate the relationship between 7th and 11th grade students' self-efficacy and their navigation of a commercially produced instructional HLE. The students' navigation was grouped into three categories: Concept Connector, Sequential Studier, or Video Viewer. Concept Connectors were used if the student demonstrated need for further examples by cross-linking to other related pieces of information, Sequential Studiers were used if students accessed objects on the screen in a linear order, and finally Video Viewers were used if the students demonstrated an interest in videos (MacGregor). It was discovered that students with lower levels of self-efficacy tended to be Sequential Studiers and students with higher levels of self-efficacy tended to be Concept Connectors. This meant that students with high levels of self-efficacy were more strategic in their learning from the HLE than those students with low levels of self-efficacy. This line of research is similar to the findings of many researchers who look at monitoring as a variable that mediates the relationship between self-efficacy and learning with HLEs.

In Azevedo and colleagues' extensive line of research, they have used think aloud process data to examine the role of SRL in HLEs. They have specifically looked at the role of monitoring as a mediating variable during learning from HLEs. The definition of monitoring is found within the variables Judgment of Learning (JOL) and Feeling of Knowing (FOK), that can be measured to determine the students emerging understanding (Azevedo et al., 2004; Azevedo et al., 2005; Moos & Azevedo 2006, 2008). In a study by Moos and Azevedo (2009), they sampled 68 education majors using a self-report questionnaire, pretest, posttest, and the think aloud protocol; results indicated that the relationship between self-efficacy and specific monitoring processes (Monitoring Understanding, Monitoring Environment, and Monitoring Progress Towards Goals) was significant. This means that even if a student has sophisticated SRL strategies at his or her disposal, the student may not deploy them if he or she does not feel able to monitor accurately and have the necessary level of self-efficacy to carry out the task. Clearly, the relationship between self-efficacy and SRL is a powerful dynamic to consider when we explore learning in HLEs, which is why it is critical researchers are clear about the methods and theoretical foundations used to measure SRL.

**Methods used to Measure Self-Regulated Learning**

SRL can be described as having two properties, aptitude and event, and this description defines the method of measurement (Winne, 1997). An aptitude looks at how certain learner characteristics can be used to predict future behavior and an event looks at learner characteristics on a certain task in a specific time and place. For example, self-report measures such as the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991) and the Learning and Study Strategies Inventory (Weinstein, Palmer, & Schute, 1987), measure SRL as an aptitude because respondents are asked to answer questions with respect to their general actions, rather than responding with a specific study episode in mind (Winne & Perry, 2000). On the other hand, events look at learner characteristics completing a specific task in a specific time and place. Data such as think aloud protocols (Hofer, 2004), microanalytic measures, and trace methodologies (Winne, 1982), provide methods for measuring SRL as an event.

One of the most commonly used self-report measures in educational psychology is The Motivated Strategies for Learning Questionnaire (MSLQ). The MSLQ, based on Pintrich's General Framework assess students' motivational beliefs (task value, self-efficacy, and test anxiety) and self-regulation (metacognitive self-regulation and time management) (Pintrich, Garcia, McKeachie, & Smith, 1993). The MSLQ is an 81 item, self-report measure that uses a 7-point Likert scale to examine the motivation and learning strategies of college students taking a college course (Pintrich et al.). The original results for the MSLQ were gathered from a sample of 380 students at a public, 4-year university in the Midwest where thirty-seven classrooms were sampled, spanning fourteen subject domains and five disciplines, including natural science, humanities, social science, computer science, and foreign language (Pintrich et al.). Measuring SRL as an aptitude, the MSLQ focused on learning strategies, metacognitive self-regulation, and time and study environment management by asking the learners a series of questions (e.g., "If course materials are difficult to understand, I change the way I read the material") (Pintrich et al.). The MSLQ explored how students use of SRL strategies changed from one course to the next, with the understanding that the SRL strategies may change depending on the course they were taking. Two complaints of the MSLQ worth noting are the overall length, 81-items, and the self-report nature of the measure. Self-report measures have an inherent flaw, they depend on the learner being able to understand and recall his or her thinking. Regardless of the limitations, the MSLQ represents a very thorough measure of SRL and motivation.

Another self-report measure that examines SRL as an aptitude is the Learning and Study Strategies Inventory (LASSI). LASSI is composed of 77 items, including declarations and conditional relations, this self-report questionnaire was “designed to measure use of learning and study strategies” (Weinstein, Palmer, & Schulte, 1987, p. 2) by undergraduate students. Two independent samples of 527 college freshmen and 429 seniors completed the LASSI and their results were used to create three constructs that form the basis of this measure (Weinstein et al.). Within the three constructs of affective strategies, goal strategies, and comprehension monitoring strategies there are items that assess metacognition, self-concept, self-monitoring, motivation, strategy formation, and volition control strategies (Weinstein et al.). LASSI is unique in that it, like the MSLQ, looks at the different ways students use SRL strategies and not on the process or sequence of the SRL strategy use. Pintrich’s General Framework constructs can be seen in the LASSI method because of the focus on motivation and monitoring. The LASSI method has limitations. For example, special care must be taken to extract the items that best represent SRL processes. One of the limitations of the LASSI method for measuring SRL is that of the 77 items, many clearly look at SRL and others are more ambiguous (e.g., “I have difficulty identifying the important points in my reading”)(Weinstein et al.). This item is difficult to categorize as a SRL process since it could be examining strategy use and literacy.

Both the LASSI method and the MSLQ method measure SRL as an aptitude and use self-reporting to collect their data. The ability to use one of the preexisting methods as a template, assign it to a group, handout the questionnaires, and collect data reflects an efficient way to collect SRL data, although caution must be taken in any method that relies so heavily on self-report methodology. In addition to this concern, the two methods are not able to examine the cyclical nature of SRL or the small changes associated with SRL growth. For that we must look to the think aloud protocols and trace methodologies that are able to capture the way a learner processes information while working on a task.

Trace methodologies represent one way to assess a student's SRL as an event. Trace methodologies are derived from signs and observable indicators, such as personal comments, diagrams, footnotes, asterisks or summarizes, regarding cognitive processes that individuals perform while engaging in learning activities (Torrano Montalvo & Gonzales Torres, 2004). When students underline, it is considered an observable indicator of their cognition and researchers have labeled such indicators as traces (Winne, 1982). Traces represent a window into what the student is thinking about at a given instant during a task. Traces are typically collected and analyzed qualitatively, but with new technologies and powerful new computer programs there are other ways of collecting and analyzing this data.

One application of trace methodology is the use of log file analysis within CBLEs. Log file data consist of precise traces of a person's engagement with a computer system (Winne, Gupta, & Nesbit, 1994). In contrast to traditional means of assessment, hypermedia-based log file data can document the dynamic nature of learning, as well as individual event-based differences in activity (Winne et al.). Collecting traces of student's activity during a learning task can provide data on goals, strategies, and reflection. Each of these processes represents key themes in SRL and when analyzed together are capable of showing how SRL changes over time.

Another exciting application of trace methodology is the use of pedagogical agents. Pedagogical agents are able to interact with the student in a CBLE and help the student learn either by modeling good pedagogy and learning processes or by holding an interactive conversation (Moreno, Mayer, Spires, & Lester, 2001). Pedagogical agents have the potential to serve many roles in CBLEs, but for the purposes of this review we will only examine the ways these agents assist in the measurement of SRL. In a study by Graesser and McNamara (2010), they used the discourse between the user and an animated pedagogical agent within a CBLE to assess and scaffold learners' knowledge and self-regulation. As the user explored the CBLE a pedagogical agent would gather information about their SRL by asking questions that the user would answer. Questions in the form of hints and prompts and requests for further exploration in the form of a pump were used to collect more data (Graessner & McNamara). The authors used a process called latent semantic analysis and computational linguistics to distill verbal data into measures of learning processing that can inform what, how, and when to provide computerized support (Graessner & McNamara). The questions and responses could be used to determine the SRL processes deployed by the user, and then this information could be developed to support future learning. Trace methodologies, especially pedagogical agents, are capable of collecting large amounts of user data in a short period of time. One of the advantages of using trace methodologies is the idea that it does not seem to interrupt the learning process, a concern noted by some other measurement methods. Another advantage of trace methodologies is that they are capable of measuring SRL as an event. Clearly, log file analysis and trace methodologies represent an exciting area of SRL measurement that is capable of capturing and adjusting to the dynamic nature of SRL. Unfortunately, one concern of trace methodologies is that they fail to consider why students do certain things during learning. Conclusions and interpretations are difficult to make when there is no real participant input, especially with regards to motivation.

Think aloud methodology is one way to measure the dynamic nature of SRL. The think aloud methodology is based upon the collection of the student's thoughts during a learning task. The researchers collect this data, code it, and can then compartmentalize it into certain SRL processes. While the think aloud protocol has been most popular in reading comprehension (Pressley & Afflerbach, 1995), it has been shown to be an excellent tool in mapping out the use of self-regulatory processes during learning (Azevedo & Cromley, 2004). In a recent study by Azevedo and colleagues, they looked at why externally-facilitated regulated learning is more effective than self-regulated learning. They used pre-test and post-test data to account for conceptual growth and an assessment of prior knowledge, but the specific focus of the research was on the determination of which SRL processes were used by 128 middle and high school students while using hypermedia (Azevedo, Moos, Greene, Winters, & Cromley, 2008). Azevedo and colleagues used the think aloud methodology to capture the SRL processes at work while students developed a new conceptual model of the circulatory system (Azevedo et al., 2008). The researchers determined that more students who used SRL processes reached a conceptual understanding of the circulatory system than students who did not use as many SRL processes (Azevedo et al.). Their findings support the usefulness of measuring SRL with think aloud methodology because the data provided information on what the students did and how they did it, rather than on what they thought they did. Unfortunately, think alouds are not without their weaknesses.

One main concern when using think alouds to measure SRL is that thinking aloud, while engaged in a task, alters the sequence of thoughts (Ericsson & Simon, 1993). For example, if a student articulates what he or she is thinking, in theory this does not interrupt the learning process, but if the student is asked to explain his or her thinking it does interrupt the learning process. In a research study by Green, Robertson, and Costa (2011), they demonstrated that merely verbalizing thinking does not affect cognitive processing; rather it is when participants are asked to explain their thinking that the cognitive process could be affected. One final criticism of the think aloud is the absence of a control group, whose participants have not been asked to think aloud, to determine whether the verbalizations of these types of SRL processes influences performance (Green, Robertson, & Costa). The validation and evaluation of this promising protocol across multiple academic domains will take time and energy, but it must be noted that incredible progress has been made over the last few years. Producing similar results to the work of Azevedo and colleagues, that high achievers use more extensive self-regulating processes than low achievers, DiBenedetto and Zimmerman (2010) used a different measurement technique of SRL identified as the microanalytic method.

The microanalytic method of SRL is based on Zimmerman's three phase model and applies specific questions targeted to address specific psychological processes at key times during the act of learning (Kitsantas & Zimmerman, 2002). The microanalytic method is very similar to the think aloud protocol in that the participant is asked to verbalize his or her thoughts and feelings while involved in a learning task. The main difference lies in the fact that in the microanalytic approach, questions are asked at strategic moments and in the think aloud protocol the participant is asked to verbalize his or her thoughts every few seconds.

In one article that validates the microanalytic method, authors examined the impact expertise level had on SRL processes. Kitsantas and Zimmerman (2002) examined three levels of volleyball players executing an overhand serve. The participants watched a video of an expert executing the desired task and were then asked a series of questions grounded in Zimmerman's forethought phase. These questions were followed by practice time and then more questions, this time the questions were based on Zimmerman's performance phase. Players were asked to evaluate their performance, reflect on the process, and participate in a final test of their overhand serving ability. The findings from this study identified statistically significant differences between the three expertise levels and the type and use of SRL processes (Kitsantas & Zimmerman, 2002). Using another athletic task, Cleary and Zimmerman (2001) assessed SRL processes using the microanalytic method prior to a free-throw practice session and after each attempted shot. The attempted shot was viewed as an independent event, and results indicated that free-throw shooting skill was related to self-regulatory phase and beliefs. DiBenedetto and Zimmerman (2010), also applied the microanalytic method to students studying science, this represented the first application of the approach to an academic domain. Like the previous article, DiBenedetto and Zimmerman investigated the impact three expertise levels had on the use of SRL processes. Their results also identified differences in the three expertise levels and the type of SRL processes. Another interesting finding indicated that self-reflection processes, such as self-evaluation and self-satisfaction reactions, were related significantly to not only students' acquisition of tornado knowledge but also to their formation of an abstract conceptual model of tornados (DiBenedetto & Zimmerman). In conclusion, the microanalytic method represents a reliable and flexible tool that uses Zimmerman's social cognitive model of SRL as its foundation.

**Argument for Measuring Self-Regulated Learning with the Microanalytic Method as Students Learn with a Hypermedia Learning Environment**. Assessing SRL is a complex task because of the idiosyncratic and often individualistic nature of SRL. A microanalytic methodology, using Zimmerman's three phase model of academic self-regulation as its foundation, has been used in various athletic studies, and a series of content related tasks, but to date, this methodology has not been used as participants learn from a HLE. The microanalytic method has proven itself to be reliable, valid, flexible, and predictive of a variety of outcome measures; it is only logical its reach be extended into HLEs. Clearly, SRL has been researched in HLEs and CBLEs by a variety of researchers using the think aloud methodology. The think aloud methodology, while accurate and useful, is incredibly time consuming to code and analyze. Another concern noted by Bandura (1986), is that think aloud thoughts are not always easy to put into words and that people may intentionally, or unintentionally, misrepresent what they are thinking. The microanalytic method offers other advantages in that it allows for a clear comparison of high, average, and low achievers, regardless of content. It is because of these concerns that a microanalytic method was used in this study.

**Rationale for Current Study**

The current study attempts to examine SRL differences, assessed with a microanalytic method, among high, average, and low achieving students as they learn about a complex science topic from a HLE. To review, learning with hypermedia typically involves the use of numerous metacognitive and self-regulatory processes such as planning, knowledge activation, metacognitive monitoring and regulation, and reflection (Azevedo, 2008, 2009; Greene & Azevedo, 2009; Moos & Azevedo; Schraw, 2007; Veenman, 2007; Winne & Hadwin, 2008; Zimmerman, 2008), and the deployment of these SRL processes depends on the nature of the task (Hadwin et al., 2001). The reality is many students fail to regulate their learning and consequently fail to develop new understandings as they learn from HLEs. On the other hand, some students are able to regulate their learning and because previous sections have articulated the interconnectedness of achievement and SRL processes employment, we can make the case there is much to learn about what high achievers do, and low achievers fail to do, as they learn about science from HLEs. This type of sectioning has proven to be particularly useful in identifying SRL process gaps between high, average, and low achievers in a variety of content areas and constructs (Cleary & Zimmerman, 2001; DiBenedetto &

Zimmerman, 2010; Kitsantas & Zimmerman, 2002;Winters & Azevedo, 2006). The goal of the current study was to recreate a scenario students are frequently faced with, learning a complex topic from a HLE, and assess their SRL by using methods that differ from the previous research.

The previous research studies examining learning complex science topics from HLEs, did not assess for SRL using the microanalytic method. Most SRL research focusing on learning from HLEs have used the think aloud protocol and unfortunately, this type of self-report method has some weakness, namely that it assesses what students may be thinking as they perform a task (Ericsson, 2006). Clearly, it is difficult to interpret what someone is thinking, regardless of the data they provide. The microanalytic methodology differentiates itself by involving context-specific self-report questions that are linked to specific tasks or situations, and by doing so it reduces the ambiguity or vagueness that is often encountered in more global or de-contextualized types of self-report scales (Cleary, 2011). The power of the microanalytic method comes from its ability to assess the learner's cognitive changes and motivational beliefs as they engage in a learning task that has a defined beginning, middle, and end. This approach to the microanalytic method is based upon Zimmerman's cyclical model of SRL. Previous microanalytic method protocols have included the following essential features: (a) individualized administration, (b) examination of multiple SRL processes outlined in Zimmerman's three-phase cyclical feedback loop, (c) context-specific nature of microanalytic questions, (d) linking phase-specific regulatory processes to the before, during, and after dimension of an event, and (e) verbatim recording and coding of participants' responses (Cleary, 2011). The current study expands upon this literature base by using the microanalytic method to assess for SRL in a brand new context, HLEs. By doing so, other motivational metrics such as self-efficacy can be measured and evaluated for accuracy.

Calibration accuracy is a critical concept within HLEs because of the ubiquitous environment and sheer volume of today's students' interaction with technology (Prensky, 2001). Accessing information with technology is not the same as learning from technology. The difference is stark, and can lead to misjudgments in the amount of effort needed to successfully learn the given material. Being able to assess self-efficacy calibration accuracy in relation to task outcomes as students learn from HLEs can provide researchers information on when and why students who feel capable of learning certain material do not. Calibration accuracy, which includes over-estimators, under-estimators, and those who can accurately calibrate their perceived self-efficacy with task outcomes, gets at the heart of SRL.

By building on the existing knowledge base, this study examined SRL of high, average, and low science achievers as they learned from a HLE. The microanalytic method was used to assess for SRL for reasons listed above and because of its ability to determine differences in achievement. Students in the seventh grade were selected to participate because there is little literature documenting the relationship between SRL, HLEs, and science for this age group. It should also be noted, that these students had not studied the circulatory system in their classes during the current school year. In addition, the seventh grade students were selected on their prior year's grades in science and their fifth grade Virginia Standards of Learning Science test score.

By using the microanalytic method, scores on declarative knowledge tests, scores on conceptual knowledge tests, and a scale on self-efficacy for learning completed by the students. The goal of this study was to provide a complete description of the students' SRL processes as they learn from a HLE. Findings from this study could be used to assist designers and practitioners with the creation of materials designed to support learning in HLEs that are based on Zimmerman's three-phase model of SRL. Findings from this study could also be used to help high, average, and low science achievers develop an awareness of their own self-efficacy calibration tendencies compared with task outcomes while learning with HLEs. Awareness of these cognitive and behavioral processes would help learners in all content areas gauge the appropriate amount of effort needed to accomplish a given task. It is my understanding that a study has not been conducted that addresses SRL, HLEs, self-efficacy, calibration, science, and microanalysis. This dissertation investigated these variables and framed these variables using the following research questions and associated hypotheses. The first research question asks if there are any relationships among adolescent use of SRL processes while they learn about a complex science topic with a HLE? It is hypothesized that there will be modest positive correlations between Zimmerman's three phases of SRL. The second research question asks if there are any differences in the use of SRL processes among high, average, and low achieving adolescents while learning about a complex science topic with a HLE. It is hypothesized that high achieving adolescents will deploy more self-regulatory processes than average achieving adolescents and average achieving adolescents will deploy more self-regulatory processes than low achieving adolescents as they learn with a HLE. The third research question sought to explain the predictive power of the microanalytic method in predicting student Declarative Knowledge, Conceptual Knowledge, and on their self-efficacy beliefs to engage in self-regulated learning measure. It is hypothesized that the microanalytic method will prove to be moderately predictive of all three measures. The fourth research question asks if there are differences between high, average, and low achieving adolescents in their self-efficacy beliefs to engage in self-regulated learning as they learn from a HLE. It is hypothesized that high achieving adolescents will have higher self-efficacy beliefs to engage in self-regulated learning than low achieving students as they learn from a HLE. The final research question asks if there are any differences among high, average, and low achieving adolescents in the accuracy of their calibration between perceived self-efficacy and task outcomes while engaged in a scientific task presented with a HLE. It is hypothesized that low achieving adolescents will over-estimate their self-efficacy for performance beliefs, average achieving adolescents will slightly overestimate their self-efficacy for performance beliefs, and high achieving adolescents will under-estimate their self-efficacy for performance beliefs on the two science tests.

# METHODS

This chapter describes the methods used to explore the SRL processes used by high, average, and low achieving science students as they learn with a HLE. This chapter begins with a description of the participants followed by a description of the HLE. The next section details the research design and then the measures used in this study. The following section offers a description of the procedures and finally a review of the data analysis will be provided.

## Participants

The participants in this study were 30 seventh graders (*n* = 30) randomly selected from two teaching teams at a middle school. The average age of the participants was 12.52 years, *SD* = .51. There were 18 male and 12 female participants. The racial/ethnic distribution was 4.5% African American, 59.1% European American, 22.7% Asian American, 9.1% Latino American, and the remainder of the participants identified themselves as “other”. The school’s location was near a major metropolitan city in the mid-Atlantic region of the United States of America. The students were grouped, in part based upon the school’s initial intervention criteria for upcoming seventh graders, as: High science achievers (students who have maintained an A in science from fifth grade to seventh grade and scored greater than or equal to 480 out of 600 on the Virginia fifth grade science Standards of Learning (SOL) exam), Average Science Achievers (students who scored between a 480 and a 420 on the Virginia fifth grade science SOL and maintained an A, B, or C in science from fifth grade to seventh grade), and Low science achievers (students who did not maintain at least an A or B in science from fifth grade to seventh grade and scored below 420 on the Virginia fifth grade science SOL). Passing score on the Virginia fifth grade science SOL was a 400. These students have not studied the circulatory system in their classes during the school year. The final sample consisted of 10 high science achievers, 10 average science achievers, and 10 low science achievers.

## Hypermedia Learning Environment

The students used the Microsoft Encarta Reference Suite™ (2003) electronic encyclopedia to study for the circulatory system. This software program fits the definition of a HLE in that it includes audio, text, video, animation, graphics, text, is student centered, and is structured in a non-linear format (Jonassen & Reeves, 1996). The Encarta Reference Suite™ has been used in a number of other research studies that have examined SRL in HLE (Azevedo & Cromley, 2004; Azevedo & Greene, 2007; Azevedo et al., 2008; Moos & Azevedo, 2006, 2008, 2009). This software program included three articles and an animation that were all related to the circulatory system, and these articles were comprised of 16,900 words, 35 illustrations, 107 hyperlinks, and 18 sections in an unstructured design (Moos, 2007).

## Research Design

The purpose of this study was to explore the self-regulatory processes used by high, average, and low achieving science students as they learned about a complex science topic with a HLE.  Using a microanalytic methodology, which uses both qualitative and quantitative data, this study was structured as an embedded mixed method design.  According to Johnson and Onwuegbuzie (2004), a mixed methodology is a class of research where the researchers mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts, or language into a single study.

An embedded mixed method design was selected because in this microanalytic method the qualitative data set provides a supportive, secondary role based primarily on the quantitative data type (Creswell, Plano Clark, et al., 2003). The closed-ended questions which were all quantitative in nature will target self-motivation beliefs, such as self-efficacy, outcome expectations, intrinsic interest, and task interest. In contrast, the open-ended questions targeted goal-setting, strategy use, attributions, and adaptive inferences. One of the strengths of the embedded mixed method design, is that it allows the researcher to include qualitative data to examine the mechanisms that relate to quantitative variables (Creswell, Plano Clark, et al.).

The qualitative aspect of the microanalytic methodology involves asking specific, brief, targeted questions such as “Is there anything you would do differently if you were given another chance to study the material? Please explain.” Open ended questions were asked during the interview so that the participants could create a response unconstrained by the researcher‘s views (Creswell, 2008). This qualitative data were supported and analyzed with the quantitative data collected from the measures listed below.

## Measures

**Declarative Knowledge Measure**. Participants completed the same matching science task for the pretest and posttest. For the declarative knowledge task, participants were given a sheet which asked participants to match 13 words with their corresponding definitions. This measure has been used in a number of studies that have examined circulatory system knowledge and HLEs (Azevedo et al., 2005; Moos & Azevedo, 2006). See Appendix A for details.

**Conceptual Knowledge Measure**. Participants completed the same conceptual knowledge task for the pretest and posttest. For the conceptual knowledge task, the participants were given a sheet which asked participants to write down everything they can about the circulatory system. They were asked 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. This conceptual knowledge measure and the declarative knowledge measure have been used in a number of studies that have examined circulatory system knowledge and HLEs (Azevedo et al., 2005; Moos & Azevedo, 2006). The coding method was broken down into 12 mental models which corresponded to low levels of conceptual understanding to high levels of conceptual understanding of the circulatory system (see Table 1.) See Appendix B for details.

Table 1

*Coding Scheme for the Conceptual Knowledge Measure*

| | |
|---|---|
| **1. No understanding** | **7. Single Loop with Lungs**<br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• mentions lungs as a “stop” along the way<br>• describe “purpose” – oxygen/nutrient transport |
| **2. Basic Global Concepts**<br>• blood circulates | **8. Single Loop with Lungs**<br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• mentions Lungs as a "stop" along the way<br>• describe “purpose” – oxygen/nutrient transport<br>• mentions one of the following: electrical system,<br>transport functions of blood, details of blood cells |
| **3. Global Concepts with Purpose**<br>• blood circulates<br>• describes “purpose” oxygen/nutrient transport | **9. Double Loop Concept**<br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describes “purpose” - oxygen/nutrient transport<br>• mentions separate pulmonary and systemic systems<br>• mentions importance of lungs |

| | |
|---|---|
| **4. Single Loop – Basic**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport | **10. Double Loop – Basic**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describe "purpose" - oxygen/nutrient transport<br>• describes loop: heart - body - heart lungs heart |
| **5. Single Loop with Purpose**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describe "purpose" - oxygen/nutrient Transport | **11. Double Loop – Detailed**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describe "purpose" - oxygen/nutrient transport<br>• describes loop: heart - body - heart - lungs heart<br>• structural details described: names vessels, describes flow through valves |
| **6. Single Loop - Advanced**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describe "purpose" – oxygen/nutrient transport<br>• mentions one of the following: electrical system,<br>transport functions of blood, details of blood cells | **12. Double Loop - Advanced**<br><br>• blood circulates<br>• heart as pump<br>• vessels (arteries/veins) transport<br>• describe "purpose" - oxygen/nutrient transport<br>• describes loop: heart - body - heart - lungs -heart<br>• structural details described: names vessels, describes flow through valves<br>• mentions one of the following: electrical system, transport functions of blood, details of blood cells |

**Self-Efficacy for Self-Regulated Learning Form-A** (SELF). The SELF scale is a 19 item survey that involves a five point rating scale. The questions in this survey assess a student's self-efficacy judgments of his or her capability to self-regulate learning and the term “science” was included into the questions to make them more specific to science content (Dibenedetto, 2010). It has demonstrated high levels of alpha reliability and predictive validity, to be specific the reliability coefficient for students’ scores on the SELF-A was .97. (Zimmerman & Kitsantas, 2007). Examples of questions were “When you miss a science class, can you find another student who can explain the lecture notes as clearly as your teacher did?” and “When problems with your friends and peers conflict with school work, can you keep up with your science assignments?” Student responses were on a scale ranging from 0% to 100% with 10% being definitely cannot do it and 50% being maybe, and 100% being definitely can do it (Dibenedetto). (See Appendix C for details).

**Microanalytic Processes Measure of Self-Regulated Learning**. This approach was adapted from DiBenedetto and Zimmerman’s work (2010). The current study looked at the subprocesses of Zimmerman’s three phase model of self-regulated learning. Scores using this approach have shown high levels of reliability and predictive validity in prior research, Kitsantas and Zimmerman’s work (2002) demonstrated that a measure of SRL, using the microanalytic method, predicted 90 percent of the variance in the women’s volleyball serving skill. In addition, DiBenedetto and Zimmerman’s work (2010), revealed that high science achievers engaged in more subprocesses of Zimmerman’s cyclical phase model of SRL, spent more time studying, and displayed higher test performance scores than average or low achieving science students. Students were asked closed and open ended questions at specific times during the study. Each question attempted  to measure the three subprocesses of Zimmerman's self-regulated learning model.

***Phase 1: Forethought Phase measures***. Self-motivational beliefs, intrinsic interest, self-efficacy for learning, and outcome expectations were the areas explored in self-motivational beliefs. Students were asked two questions for this area. The first question asked them to evaluate their interest and confidence in the specific content covered in this study, circulatory systems, and then we evaluated their interest and confidence in science in general. The questions were scored on a Likert Scale. The self-efficacy questions asked the participants "How confident do you feel in your capability to learn and remember all of the material on the circulatory system from this activity?" Participants were asked to point to a score from 1 (not sure) to 10 (very sure).

Task Analysis. Goal setting and strategic planning were the areas we explored in task analysis. The goal setting item asked the participants what grade goal they had for the test, once again the choices ranged from 1 (not sure) to 10 (very sure). The strategic planning item asked the participants if they had any plans on how they were going to study the material for the test. All responses were recorded and categorized into the following headings; no strategy planned, or at least one strategy planned.

***Phase 2: Performance***. There are two strategies that were measured in the Self-Control area, one focused on the strategies used during the first five minutes and the other focused on the strategies used during the next five minutes. The questions asked were; "I noticed while you were watching the video that you were pausing the video and writing down notes, could you explain to me what you are doing and why?" All responses and observations were recorded as either; no strategy used, or at least one strategy used. In order to determine the self-efficacy for performance, the instructor had to wait until the participant verbalized that they were ready to take the test. At that point the participant asked to point on the aforementioned Likert scale to the score that best demonstrate their capability to earn a perfect score on the declarative knowledge and conceptual knowledge tests.

Self-Observation. There was one question that examined the metacognitive monitoring processes used by the participant. The measure examined how confident the participant was in their ability to answer the Declarative Knowledge Measure by asking them to use the Likert scale. Once again, the scale ranged from 1 (not sure) to 10 (very sure). The next question asked the participant to estimate their score on the knowledge items. This question used another Likert scale, ranging from 10% to 100%. The same two questions, focusing on the confidence in their ability to answer the question and in their ability to estimate their score, were used for the Conceptual Knowledge Measure.

***Phase 3: Self-Reflection***. The self-judgment measure was assessed after the instructor graded the participants declarative knowledge test and the conceptual understanding test. The instructor asked the participant to tell them how well they believed they learned about the circulatory system. All responses were collected using another Likert Scale ranging from 1 (not well) to 10 ( very well) where the participants were asked to point to the answer. The follow-up question, identified the causal attribution, had two different formats. If the students scored a perfect 100% on the conceptual understanding test, they were asked “Why do you think you did so well on that question?" and if they did not score a 100% they were asked "Why do you think you didn't do better on this question?" All responses were recorded and categorized into the following headings; ability, effort, strategy, and don't know or not sure.

Self-Reaction. Self-reaction refers to the degree to which the participants were satisfied with their performance on a particular item. This was done by asking the students how satisfied they were with their score on the conceptual knowledge test. A Likert scale ranging from 1 (very dissastisfied) to 7 (very satisfied) was used and the participants were able to point to the answer that seemed most appropriate. Participants were then asked if there was anything they would do differently if they were given the same scenario. This question structure was designed to be the adaptive and defensive measure. All responses were recorded and categorized into the following headings; no, ability, effort, and strategy.

**Procedure**

Each participant interacted with the researcher and participated in a one-on-one setting for the entire process. They were shown their signed copy of the consent form and then asked if they had any questions before beginning the test. Students were provided with a paper and a pencil, afterwards they were given 15 minutes to complete the pretests on the circulatory system. After completing the pretests, participants were given a five minute training session and walkthrough of the HLE in which the most relevant articles for the topic were identified and they were also be shown how to navigate and access multiple representations (text, static diagrams, and digitized video clip) (Azevedo & Green, 2007). After completing the walkthrough a thorough description of the learning task was read to the participant. The following introduction of the task was read "*You are going to be presented with an electronic encyclopedia, which contains textual information, diagrams, and a digital 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, I will be asking you questions while you read and search Encarta. I'll be here in case anything goes wrong with the computer and the equipment if you don't have any questions we will begin."*(Moos & Azevedo, 2006).

As the students explored the HLE a microanalytic methodology was administered to assess the students goals, strategies, thoughts, and feelings while they moved from one phase of Zimmerman's SRL three phases to the next (See Appendix D for details). The three phases were forethought, performance, and self-reflection and questions were posed to the students as they processed the information. Students were presented with cue cards that contained answer choices, and the students were asked to point to the answer. If the answer was not present, the instructor wrote down the other answer given. A list of the questions, timing of questions, and phase identification is found below.

*Forethought phase: Self-efficacy for learning measure*

Q.1 How self-confident do you feel in your capability to completely learn and remember all of the material on the circulatory systems from this activity?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100

Not sure at all — somewhat unsure — pretty sure — very sure

Q.2 How self-confident do you feel in your capability to completely learn a new topic in science?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100

Not sure at all — somewhat unsure — pretty sure — very sure

*Forethought phase: Intrinsic interest measure*

Q.3 How interested are you personally in learning about the circulatory system?

|…...……….|………...….|……..……….|…...……….|

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| really not interested | not interested | neutral | interested | really interested |

Q.4 How interested are you personally in learning about new topics in science?

|…...……….|………...….|……..……….|…...……….|

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| really not interested | not interested | neutral | interested | really interested |

*Forethought phase: Outcome expectations measure*

Q.5 How important is information about the circulatory system to your future?

|…...……….|………...….|……..……….|…..……….|……..……….|……..……….|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| really unimportant | unimportant | somewhat unimportant | neutral | somewhat important | important | really important |

Q. 6 How important is information about science to your future?

|…...……….|………...….|……..……….|…..……….|……..……….|……..……….|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| really unimportant | unimportant | somewhat unimportant | neutral | somewhat important | important | really important |

*Forethought phase: Goal setting measure*

Q.7 What percentage grade will you set as your goal on the tests of knowledge?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

At this point, the task procedure will be read to the students reminding them of the purpose of the task and the assessments that will follow the learning task.

*Forethought phase: Strategic planning measure*

Q. 8 Before you get started, do you have any particular plan for how to study about the circulatory system?

If yes: Can you tell me about them?

If no: Do you have any particular methods of studying if you find the material difficult to understand or remember? Can you tell me about them?

Skimming the passage □

Rereading□

Reading aloud□

Underlining□

Highlighting□

Drawing pictures□

Writing down facts□

Studying facts/information□

Other___________________________

________________________________

No particular task strategy used

*Performance phase: Task strategy measure*

Time will be recorded and after five minutes have elapsed the following question will be asked.

Q.9 I noticed while you were studying that you are…could you explain to me what you are doing and why?

Q.10 Do you use these procedures in other courses besides science?

Yes____please explain

No____please explain

After ten more minutes have elapsed the same question will be asked.

Q.11 I noticed while you were studying that you are…could you explain to me what you are doing and why?

Q.12 Do you use these procedures in other courses besides science?

Yes____please explain

No____please explain

*Performance phase: Metacognitive monitoring measures*

Q. 13 Why do you think (whatever approach the student is using for Question 11) will work?

Q. 14 Has doing this helped you in studying for science tests in the past?

If yes: Please explain

*Forethought phase: Self-efficacy for performance measure*

Q.15 How confident do you feel in your capability to earn 100% on the first test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

Q. 16 How confident do you feel in your capability to earn 100% on the second test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

At this point, the students will begin taking the tests.

*Performance phase: Metacognitive monitoring measure*

Q. 17 How confident do you feel about your answers to the first test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

Q. 18 What score do you think you got on the first test?

|…..…….|…..……|…..…….|…..…….|……..….|…..…….|…..…….|…..…….|…..…….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Q. 19 How confident do you feel about your answers to the second test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

Q. 20 What score do you think you got on the second test?

|…..…….|…..……|…..…….|…..…….|……..….|…..…….|…..…….|…..…….|…..…….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Before the next question is asked, researcher will grade the second test and show the grade to the student.

*Self-Reflection phase: Self-evaluation measure*

Q. 21 How well did you learn about the circulatory system?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| poorly | | pretty poorly | | | | pretty well | | very well | |

Q. 22 What led you to that conclusion?

*Self-Reflection phase: Causal attribution measure*

Q. 23 Why do you think you didn't do better on this particular test question on the circulatory system? Please explain.

For students who earned a 100% on this test question the following question will be asked.

Q. 24 Why do you think you did so well on this particular question on the circulatory system? Please explain

*Self-Reflection phase: Self-satisfaction measure*

Q. 25 How satisfied are you with your score on the second test?

|…...……….|………...….|……..……….|…...……….|……..……….|……..……….|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| very dissatisfied | dissatisfied | somewhat dissatisfied | neutral | somewhat satisfied | satisfied | very satisfied |

*Self-Reflection phase: Adaptive/defensive measure*

Q. 26 Is there anything you would do differently on this particular test if you were given another chance to study the material? Please explain.

The time to explore the HLE was 30 minutes. Total time for the posttests, follow-up questions, and the SELF A questionnaire was approximately 15 minutes. Total time for the entire study was approximately one hour. Table 2 presents a summary of the microanalytic questions listed above as they address Zimmerman's three phases of SRL.

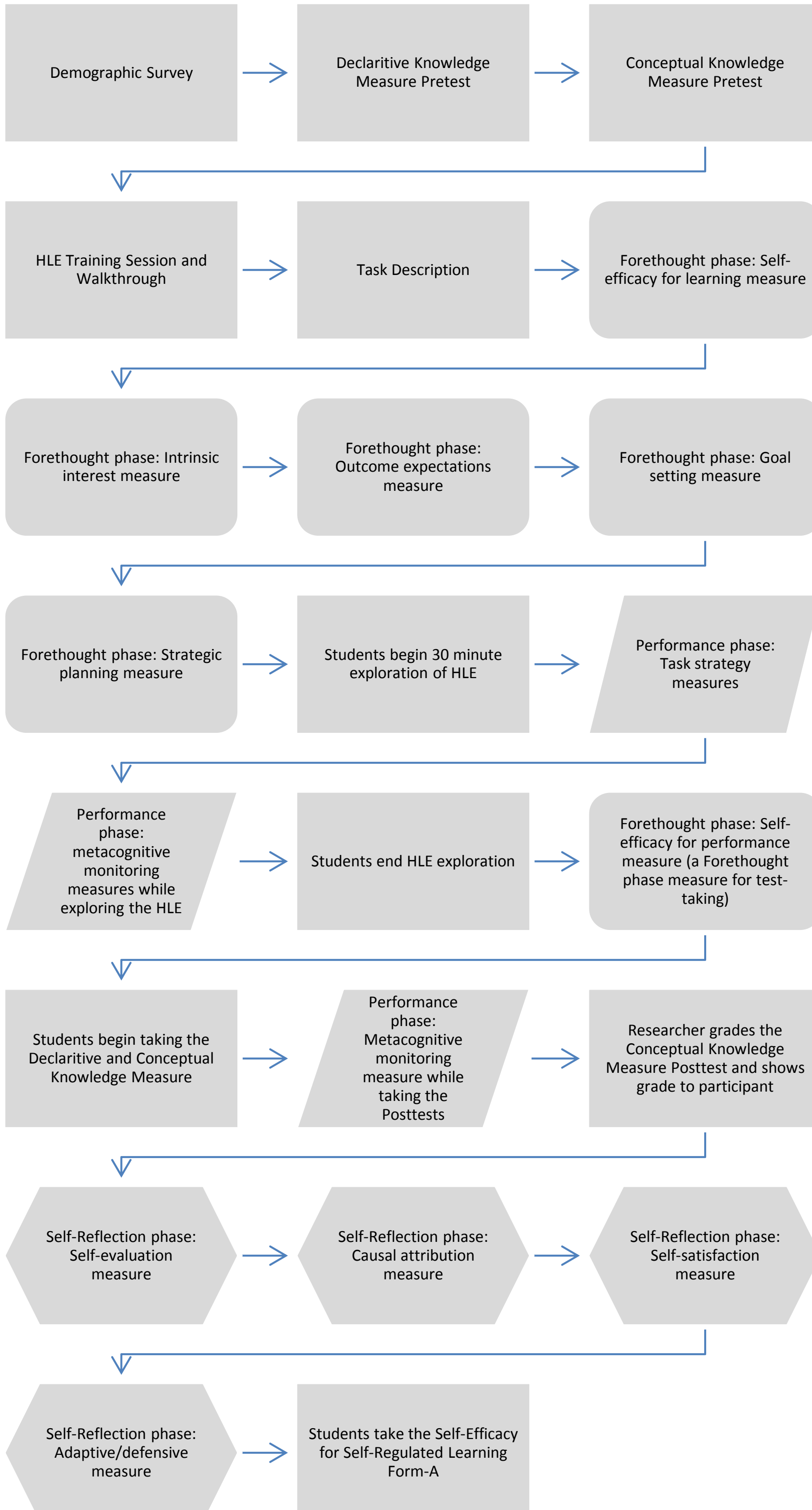



*Figure 1*. Procedure Flow Chart

Table 2

*Summary of Microanalytic Questions addressing Zimmerman's Cyclical Model of Self-Regulated Learning*

| ***Phase*** | ***Microanalytic Measures Obtained*** |
|---|---|
| Phase 1: Forethought | - Self-efficacy (learning Q.1, Q.2 and performance Q.15-16)<br>- Outcome expectations Q.5, Q.6<br>- Intrinsic values/interest Q.3, Q.4<br>- Goal setting Q.7<br>- Strategic Planning Q.8 |
| Phase 2: Performance | - Task strategy Q.9-12<br>- Metacognitive monitoring while studying Q.13-14<br>- Metacognitive monitoring after the test Q.17-20 |
| Phase 3: Self-Reflection | - Self-evaluation Q.21-22<br>- Self-satisfaction Q.25<br>- Causal attribution Q.23-24<br>- Adaptive/defensive responses Q.26 |

**Data Analysis**

The Statistical Package for Social Science (SPSS) 11.0 program was used for all statistical calculations and analyses.

**Declarative Knowledge Measure**. The Declarative Knowledge Measure was a matching task where 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)(Azevedo et al., 2005). Each participant received two matching task scores, one for their pretest and one for their posttest, and 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 (Azevedo et al.).

**Conceptual Knowledge Measure**. The Conceptual Knowledge Measure was intended to assess the participant's conceptual understanding of the circulatory system. The essays of the circulatory system were examined using Azevedo and colleagues' method (Azevedo & Cromley, 2004; Azevedo, et al., 2004, 2005), that is based on Chi and colleagues' research (Chi, 2000; Chi et al., 1994). Using the coding scheme (see Table 1) inter-rater agreement scores for previous studies using this mental model essay ranged between .90 and .96 (Azevedo et al., 2005). Inter-rater agreement (sampling 30% of all conceptual knowledge test responses) was also calculated for this study.

**Self-Efficacy for Self-Regulated Learning Form-A** (SELF). The SELF form has proven itself to be highly reliable, in previous studies the Cronbach's alpha was found to be .92 (Dibenedetto, 2010). Cronbach's alpha was found to be .89 on the Self-efficacy for Self-Regulated Learning Form A for the current study. For the purposes of this study, a one-way analysis of variance (ANOVA) was used to reveal differences between high, average, and low achieving science students as they learned from a HLE.

**Microanalytic Processes Measure of Self-Regulated Learning**. For the microanalytic method the forethought, performance, and self-reflective phases of SRL were measured. A one-way analysis of variance (ANOVA) was used to assess differences in microanalytic measures for all three phases based on students' achievement level. If statistically significant results were determined, a chi-squared test was calculated to determine differences between the groups. Prior to each analysis, assumptions of independence, normality, and homogeneity were met (Dimitrov, 2008). For the strategy planning and the task strategy measures, an inter-rater reliability was assessed for the three achievement levels. In the self-reflection phase, two measures were categorical, and after calculating descriptive statistics, a chi-squared test was calculated (Dibenedetto, 2010).

**Inter-rater Agreement**. The author first coded all of the participants' responses for the qualitative items. Then, a doctoral student with experience in inter-rater reliability and education completed an inter-rater reliability for this dissertation by independently recoding thirty percent of the student responses for each of the measures (*n* = 10). For the Forethought Phase task strategy planning subprocess there was agreement on 25 of 29 strategies, yielding a reliability coefficient of .90. For the Performance Phase task strategy subprocess measure after five minutes, there was agreement on 19 of 24 strategies, yielding a reliability coefficient of .80. For the Performance Phase task strategy subprocess measure after ten minutes, there was agreement on 15 of 19 strategies, yielding a reliability coefficient of .80. For the Self-Reflective phase casual attribution measure there was agreement on 9 of 12 attributions, yielding a reliability coefficient of .75. For the Self-Reflective phase adaptive or defensive inferences, there was agreement on 9 of 12 inferences, also yielding a reliability coefficient of .75. As for the Conceptual Knowledge Measure, the same doctoral student reviewed 30% of the pre and post Conceptual Knowledge Measures (n = 20). There was agreement on 17 of 20 Conceptual Knowledge Measures, yielding a reliability coefficient of .85. Differences on the coding of strategies, counting of strategies, and scores on the Conceptual Knowledge Measure were resolved through discussion.

# RESULTS

This study sought to examine the self-regulatory processes used by adolescents as they learned from a HLE. By using the microanalytic data collection method, both qualitative and quantitative data were collected and analyzed to answer the five research questions, 1) Are there any relationships among adolescent use of SRL processes while they learn about a complex science topic with a HLE? 2) Are there any differences in the use of SRL processes among high, average, and low achieving adolescents while learning about a complex science topic with a HLE? 3) What is the predictive power of the microanalytic method in predicting student Declarative Knowledge and Conceptual Knowledge? 4) Are there any differences between high, average, and low achieving adolescents in their self-efficacy beliefs to engage in self-regulated learning as they learn from a HLE? 5) Are there any differences among high, average, and low achieving adolescents in their ability to calibrate their self-efficacy for performance beliefs with task outcomes while learning about a complex science topic presented with a HLE? This chapter presents a thorough explanation of the results for each research question focusing on group differences and correlations of the measures.

**Research Question #1**: Are there any relationships among adolescent use of SRL processes while they learn about a complex science topic with a HLE?

***Correlational Analyses.*** To test Zimmerman's cyclical model of SRL, correlations were calculated between the Forethought Phase, Performance Phase, and the Self-reflective Phase. Table 3 below, identifies the correlations with significant correlations marked with either one or two asterisks. Significant correlations were found between the Forethought Phase goal setting measure and the deployment of Performance Phase task strategies after five minutes ($r = .54$, $p < .01$), and the Performance Phase Conceptual Knowledge metacognitive monitoring measure for score ($r = .49$, $p < .01$). In addition, correlations were also found between the Forethought Phase strategic planning measure and the Performance Phase Conceptual Knowledge metacognitive monitoring measure for score ($r = .45$, $p < .05$) and the Performance Phase Declarative Knowledge metacognitive measure for score ($r = .41$, $p < .05$). Correlations were also found between Forethought Phase Self-efficacy for learning new topics in science and Performance Phase Declarative Knowledge metacognitive monitoring measure ($r = .37$, $p < .05$). Correlations were also found between Forethought Phase intrinsic interest in science and the Performance Phase Declarative Knowledge metacognitive monitoring measure ($r = .36$, $p < .05$), and the Self-Reflective adaptive and defensive self-reflection measure and Performance Phase task strategy after five minutes ($r = .42$, $p < .05$). Overall, significant correlations were found between the Performance Phase Declarative Knowledge metacognitive monitoring measure and the Self-Reflective self-evaluative measure ($r = .76$, $p < .01$), and the Performance Phase Declarative Knowledge metacognitive monitoring measure and the Self-Reflective self-satisfaction measure ($r = .42$, $p < .05$). Significant correlations were also found between the Performance Phase Conceptual

Knowledge metacognitive monitoring measure and the Self-Reflective self-evaluative measure ($r = .67$, $p < .01$), and the Performance Phase Conceptual Knowledge metacognitive monitoring measure and the Self-Reflective self-satisfaction measure ($r = .52$, $p < .01$). Further significant correlations were found between the Performance Phase Declarative Knowledge metacognitive monitoring measure for score and the Self-Reflective self-evaluative measure ($r = .77$, $p < .01$), and the Performance Phase Declarative Knowledge metacognitive monitoring measure for score and the Self-Reflective self-satisfaction measure ($r = .56$, $p < .01$). Lastly, significant correlations were found between the Performance Phase Conceptual Knowledge metacognitive monitoring measure for score and the Self-Reflective self-evaluative measure ($r = .60$, $p < .01$), and the Performance Phase Conceptual Knowledge metacognitive monitoring measure for score and the Self-Reflective self-satisfaction measure ($r = .46$, $p < .01$).

Table 3

*Correlations between the three phases of Zimmerman's Cyclical Model of Self-Regulated Learning*

| | Performance Task-strategy: Five minutes | Performance Task-strategy: Ten minutes | Performance Meta-cognitive monitoring: Declarative Knowledge Measure | Performance Meta-cognitive monitoring: Conceptual Knowledge Measure | Performance Meta-cognitive monitoring: Declarative Knowledge Measure Score | Performance Meta-cognitive monitoring: Conceptual Knowledge Measure Score |
|---|---|---|---|---|---|---|
| Forethought: Goal setting | .54* | .20 | .34 | .35 | .35 | .49** |
| Forethought: Strategic planning | .15 | -.08 | .31 | .20 | .41* | .45* |
| Forethought: Self-efficacy for | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| learning about Circulatory System | .13 | -.01 | .17 | .09 | .25 | .06 |
| Forethought: Self-efficacy for learning new topics in science | -.01 | -.31 | .37* | -.03 | .27 | -.02 |
| Forethought: Outcome expectations: Circulatory System | .06 | -.04 | .26 | -.11 | .21 | -.15 |
| Forethought: Outcome expectations: Science | .17 | -.21 | .03 | -.13 | .08 | -.23 |
| Forethought: Intrinsic interest: Circulatory System | .15 | -.33 | -.01 | -.11 | .14 | .02 |
| Forethought: Intrinsic interest: Science | .12 | -.28 | .36* | .10 | .24 | .15 |
| Self-Reflection: Self-evaluative standards | .10 | .17 | .76** | .67** | .77** | .60** |
| Self-Reflection: Attribution | -.21 | .11 | .03 | -.05 | -.20 | -.18 |
| Self-Reflection: Self-satisfaction | -.18 | .05 | .42* | .52** | .56** | .46** |
| Self-Reflection: Adaptive/defensive | .42* | .34 | .30 | .28 | .37* | .27 |

* significant at the .05 level
** significant at the .01 level

**Research Question #2:** Are there any differences in the use of SRL processes among high, average, and low achieving adolescents while learning about a complex science topic with a HLE?

A one way analysis of variance was used to assess for differences in microanalytic measures for all three phases in Zimmerman's model based on achievement level. If statistically significant results were determined, a Post hoc comparisons using Tukey test was calculated to determine differences between the groups. For the two categorical measures found in the self-reflection phase, inter-rater reliability was assessed followed by a chi-square test. The Plan Follow Through categorical variable, which calculated the degree to which the participant followed through on their task strategy plan, was also calculated with a chi-square test. A summary table (Table 6), with means and standard deviation differences between achievement groups, is presented after the findings on each of Zimmerman's three phase model of self-regulation.

**Forethought Phase**

The Forethought Phase contains two processes according to Zimmerman's three phase model of SRL: task analysis and self-motivational beliefs. Within the self-motivational belief process there were three subprocesses measured: self-efficacy, outcome expectations, and intrinsic interest.

Regarding the goal setting measure, a subprocess of task analysis, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = .79, $p > .05$. The mean and standard deviation scores for the high science achievement group were $M$ = 85.00, $SD$ = 8.82, the mean and standard deviation scores for the average science achievement group were $M$ = 82.5, $SD$ = 10.34, while the mean and standard deviation scores for the low science achievement group were $M$ = 79.5, $SD$ = 10.12.

Regarding the task strategy planning measure, a subprocess of task analysis, required the counting and analyzing of strategies listed by the participants. Inter-rater reliability was $r$ = .90, $p < .01$. Regarding task strategy planning, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = .65, $p > .05$. The mean and standard deviation scores for the high science achievement group were $M = 2.1$, $SD = .99$, the mean and standard deviation scores for the average science achievement group were $M = 2.0$, $SD = 1.15$, while the mean and standard deviation scores for the low science achievement group were $M = 1.6$, $SD = .97$.

The self-efficacy measure, a subprocess of self-motivation, measured the student's self-efficacy for learning and their self-efficacy for performance for each measure. Regarding self-efficacy for learning all the material on the circulatory system, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = 2.12, $p > .05$. The mean and standard deviation scores for the high science achievement group were $M = 54.00$, $SD = 14.30$, the mean and standard deviation scores for the average science achievement group were $M = 62.50$, $SD = 16.20$, while the mean and standard deviation scores for the low science achievement group were $M = 50.00$, $SD = 10.54$.

Regarding self-efficacy for learning about new topics in science, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 3.84, $p < .01$. The effect size is large (partial eta squared .22). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p = .03$), but not between the high science achievers and the low science achievers ($p = .18$) or the high science achievers and the average science achievers ($p$=.64). The mean and standard deviation scores for the high science achievement group were $M = 70.00$, $SD = 14.14$, the mean and standard deviation scores for the average science achievement group were *M* = 75.00, *SD* = 11.79, while the mean and standard deviation scores for the low science achievement group were *M* = 60.00, *SD* = 10.80.

Regarding self-efficacy for performance on the Declarative Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 5.26, $p < .05$. The effect size is large (partial eta squared .28). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p$ = .01), but not between the high science achievers and the low science achievers ($p$ = .40) or the high science achievers and the average science achievers ($p$=.15). The mean and standard deviation scores for the high science achievement group were *M* = 65.00, *SD* = 12.47, the mean and standard deviation scores for the average science achievement group were *M* = 55.50, *SD* = 16.67, while the mean and standard deviation scores for the low science achievement group were *M* = 71.50, *SD* = 10.01.

Regarding self-efficacy for performance on the Conceptual Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 11.04, $p < .01$. The effect size is large (partial eta squared .45). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p$ = .01) and between the high science achievers and the low science achievers ($p$ = .01), but not between the high science achievers and the average science achievers ($p$=.83). The mean and standard deviation scores for the high science achievement group were *M* = 63.50, *SD* = 11.56, the mean and standard deviation scores for the average science achievement group were *M* = 61.00, *SD* = 6.99, while the mean and standard deviation scores for the low science achievement group were *M* = 79.50, *SD* = 9.56.

Regarding outcome expectations about the importance of information about the circulatory system to his/her future, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, *F* (2, 27) = 2.86, *p* > .05. The mean and standard deviation scores for the high science achievement group were *M* = 4.50, *SD* = 1.27, the mean and standard deviation scores for the average science achievement group were *M* = 5.40, *SD* = 1.71, while the mean and standard deviation scores for the low science achievement group were *M* = 3.90, *SD* = 1.20.

Regarding outcome expectations about the importance of information about science to his/her future, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, *F* (2, 27) = 2.14, *p* > .05. The mean and standard deviation scores for the high science achievement group were *M* = 5.30, *SD* = 1.06, the mean and standard deviation scores for the average science achievement group were *M* = 5.90, *SD* = .74, while the mean and standard deviation scores for the low science achievement group were *M* = 5.10, *SD* = .88.

The final Forethought Phase subprocess of intrinsic interests contained two analyses. The first analysis assessed students' interest in learning about the circulatory system and the second analysis gauged students' interest in learning new topics in science. For the first analysis, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, *F* (2, 27) = .06, *p* > .05. The mean and standard deviation scores for the high science achievement group were *M* = 3.20, *SD* = .79, the mean and standard deviation scores for the average science achievement group were *M* = 3.20, *SD* = .63, while the mean and standard deviation scores for the low science achievement group were *M* = 3.10, *SD* = .88.

For the students' interest in learning new topics in science, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = 1.06, $p > .05$. The mean and standard deviation scores for the high science achievement group were *M* = 4.10, *SD* = .88, the mean and standard deviation scores for the average science achievement group were *M* = 3.90, *SD* = .74, while the mean and standard deviation scores for the low science achievement group were *M* = 3.60, *SD* = .70.

**Performance Phase**

The Performance Phase contained two main processes according to Zimmerman's three phase model of SRL: self-control and self-observation. Within the self-control process, the subprocess of task strategy was measured during two separate observations. The first measure was assessed after five minutes of studying had taken place and the second measure was assessed after another five minutes of studying had taken place. For the self-observation process the subprocess metacognitive monitoring was assessed on the Declarative Knowledge Measure and the Conceptual Knowledge Measure. The participants were asked how confident they felt about their answers and to estimate their score on each item of the measure.

The task strategy measure, a subprocess of self-control, was analyzed by counting the number of strategies used by the participant after five minutes of studying had transpired. Inter-rater reliability was $r = .80$, $p < .01$, which means there was moderate agreement regarding the scoring of the task-strategy measure. For the task strategy subprocess, analysis after five minutes of studying, a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = .23, $p > .05$. The mean and standard deviation scores for the high science achievement group were $M$ = 1.80, $SD$ = .42, the mean and standard deviation scores for the average science achievement group were $M$ = 1.60, $SD$ = .70, while the mean and standard deviation scores for the low science achievement group were $M$ = 1.80, $SD$ = 1.03.

The task strategy subprocess was analyzed by counting the number of strategies used by the participant after five more minutes of studying had transpired. Inter-rater reliability was $r = .80$, $p < .01$, which means there was moderate agreement regarding the scoring of the task-strategy measure. For the task strategy subprocess analysis after ten minutes of studying a one-way analysis of variance did not reveal a statistically significant main effect for Achievement, $F$ (2, 27) = .74, $p > .05$. The mean and standard deviation scores for the high science achievement group were $M$ = 1.70, $SD$ = .82, the mean and standard deviation scores for the average science achievement group were $M$ = 1.40, $SD$ = .52, while the mean and standard deviation scores for the low science achievement group were $M$ = 1.40, $SD$ = .52.

One additional analysis was conducted for the task strategy subprocess. This analysis calculated the degree to which the participant followed through on their task strategy plan. In addition to a descriptive analysis, a chi-square test was calculated to determine the relationships between the variables. The three categories measured for this additional analysis were *No, Somewhat*, and *Yes*. *No* represented a participant whose task strategy actions did not follow their plan at all. *Somewhat* represented a participant whose task strategy actions moderately followed their plan. For example, if a participant identified reading, watching a video, and taking notes in their plan and at some point during their studying they took some notes this would meet the *somewhat* category requirements. *Yes* represented a participant whose task strategy actions followed their plan exactly as it was identified. Descriptive statistics were collected and can be seen in Table 4 and a chi-square test revealed significant differences across achievement levels, $\chi^2$ (4) = 11.30, $p$ = .023, $\varphi$ = .43.

Table 4

*Plan follow through frequency distribution*

| ***Plan Follow Through*** | ***High Achiever (% of Total)*** | ***Average Achiever (% of Total)*** | ***Low Achiever (% of Total)*** |
|---|---|---|---|
| Yes | 6 (60%) | 2 (20%) | 0 (0%) |
| Somewhat | 3 (30%) | 5 (50%) | 4 (40%) |
| No | 1 (10%) | 3 (30%) | 6 (60%) |

The metacognitive monitoring measure, a subprocess of self-observation, was assessed for the Declarative Knowledge Measure and the Conceptual Knowledge Measure. On the Declarative Knowledge Measure, participants were asked how confident they felt in their answers and then they were asked to predict their score on the measure. The same questions were asked for the Conceptual Knowledge Measure. For the metacognitive monitoring of the Declarative Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for Achievement, $F$ (2, 27) = 42.89, $p < .01$. The effect size was large (partial eta squared .76). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p = .01$), between the high science achievers and the low science achievers ($p = .01$), and between the high science achievers and the average science achievers ($p=.01$). The mean and standard deviation scores for the high science achievement group were $M = 82.00$, $SD = 9.49$, the mean and standard deviation scores for the average science achievement group were $M = 60.00$, $SD = 7.82$, while the mean and standard deviation scores for the low science achievement group were $M = 41.00$, $SD = 11.97$.

For the metacognitive monitoring of the Conceptual Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for Achievement, $F$ (2, 27) = 19.65, $p < .01$. The effect size is large (partial eta squared .59). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and high science achievers ($p = .01$) and between the high science achievers and the average science achievers ($p = .01$), but not between the high science achievers and the average science achievers ($p=.98$). The mean and standard deviation scores for the high science achievement group were $M = 79.50$, $SD = 10.12$, the mean and standard deviation scores for the average science achievement group were $M = 53.00$, $SD$

= 12.52, while the mean and standard deviation scores for the low science achievement group were *M* = 52.00, *SD* = 10.59.

For the metacognitive monitoring of the Declarative Knowledge Measure score, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 24.85, $p < .01$. The effect size is large (partial eta squared .65). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and high science achievers ($p$ = .01) and between the high science achievers and the average science achievers ($p$ = .01), but not between the low science achievers and the average science achievers ($p$=.13). The mean and standard deviation scores for the high science achievement group were *M* = 79.50, *SD* = 9.85, the mean and standard deviation scores for the average science achievement group were *M* = 55.50, *SD* = 11.17, while the mean and standard deviation scores for the low science achievement group were *M* = 45.5, *SD* = 12.12.

For the metacognitive monitoring of the Conceptual Knowledge Measure score, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 11.09, $p < .01$. The effect size is large (partial eta squared .45). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and high science achievers ($p$ = .01) and between the high science achievers and the average science achievers ($p$ = .01), but not between the low science achievers and the average science achievers ($p$=.85). The mean and standard deviation scores for the high science achievement group were *M* = 80.50, *SD* = 11.65, the mean and standard deviation scores for the average science achievement group were *M* =

57.00, *SD* = 12.52, while the mean and standard deviation scores for the low science achievement group were *M* = 60.00, *SD* = 12.25.

**Self-Reflection**

The Self-Reflection Phase contained two processes according to Zimmerman's three phase model of SRL: self-judgment and self-reaction. Within the self-judgment process there were two subprocesses analyzed: self-evaluation and causal attribution. Within the self-reaction process two subprocesses were analyzed: self-satisfaction and adaptive or defensive inferences. Each measure focused solely on the Conceptual Knowledge Measure.

For the self-evaluation measure, a subprocess of self-judgment, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 9.05, $p < .01$. The effect size is large (partial eta squared .40). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and high science achievers ($p = .01$) and between the high science achievers and the average science achievers ($p = .03$), but not between the low science achievers and the average science achievers ($p$=.36). The mean and standard deviation scores for the high science achievement group were *M* = 80.00, *SD* = 11.55, the mean and standard deviation scores for the average science achievement group were *M* = 63.00, *SD* = 14.18, while the mean and standard deviation scores for the low science achievement group were *M* = 54.50, *SD* = 14.99.

The causal attribution subprocess required the analysis of an open-ended question that asked the participants to what cause they attribute their score on the Conceptual

Knowledge Measure.  The responses were coded according to the following categories: don't know/not sure, ability (for example: I can't find it), effort (for example: I didn't study hard enough), and strategy (I did not draw a diagram when I was studying) (Dibenedetto, 2010).  The inter-rater reliability was $r = .75$, $p < .01$.  A chi-square test revealed significant differences across achievement level, $\chi^2$ (6) = 12.93, $p = .044$, $\varphi = .46$. Frequency results indicate high achievers were more likely to identify a strategy as a reason why they did not achieve higher scores on the Conceptual Knowledge Measure compared to average and low science achievers, who were more likely to not provide an answer or identify ability and effort as a reason for their score.

Table 5

*Attribution Frequency Results for the Self-Reflection Phase*

| Attribution: Why do you think you didn't do better on this particular question? | Achievement Level Count | | | |
|---|---|---|---|---|
| | Attribution | High Achievers | Average Achievers | Low Achievers |
| | Do not know | 4 | 5 | 8 |
| | Ability | 0 | 0 | 2 |
| | Effort | 1 | 3 | 0 |
| | Strategy/perfect score | 5 | 2 | 0 |
| | Total | 10 | 10 | 10 |

For the self-satisfaction measure, a subprocess of self-reaction, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 4.61, $p < .05$. The effect size is large (partial eta squared .25). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and high science achievers ($p = .02$), but not between the high science achievers and the average science achievers ($p = .08$) or between the low science achievers and the average science achievers ($p$=.81). The mean and standard deviation scores for the high science achievement group were $M = 5.50$, $SD = .85$, the mean and standard deviation scores for the average science achievement group were $M = 4.40$, $SD = 1.26$, while the mean and standard deviation scores for the low science achievement group were $M = 4.10$, $SD = 1.10$.

The adaptive or defensive inference subprocess required the analysis of an open-ended question that asked the participants if they would do anything differently given another opportunity to prepare for the Conceptual Knowledge Measure.

Table 6

*Adaptive/Defensive Frequency Results for the Self-Reflection Phase*

| Adaptive/defensive: Is there anything you would do differently if given another chance to study the material? | Achievement Level Count | | | |
|---|---|---|---|---|
| | Adaptive/defensive | High Achievers | Average Achievers | Low Achievers |
| | No, I would not do anything differently | 2 | 0 | 3 |
| | Ability | 0 | 0 | 0 |
| | Effort | 2 | 6 | 5 |
| | Strategy/perfect score | 6 | 4 | 2 |
| | Total | 10 | 10 | 10 |

The responses were coded according to the following categories: no, I would not do anything differently, ability (e.g., I can't do any better), effort (e.g., I would try harder next time), and strategy (e.g., I would have visualized the flow of blood) (DiBenedetto, 2010). The inter-rater reliability was $r = .75$, $p < .01$. Chi-square tests did not reveal significant differences across achievement level, $\chi^2$ (4) = 6.80, $p = .147$, $\varphi = .34$. Frequency of responses indicated that high achievers were slightly more likely to identify a strategy or effort as something they would do differently if given another chance to study the material compared to average and low science achievers who were more likely to identify effort or to not do anything differently.

Table 7

*Means and Standard Deviations for Self-Regulated Learning Processes by Achievement Level*

| SRL Processes and Outcomes | High Achievers | | Average Achievers | | Low Achievers | |
|---|---|---|---|---|---|---|
| *Forethought Phase* | Means | SD | Means | SD | Means | SD |
| Goal setting | 85.00 | 8.82 | 82.50 | 10.34 | 79.50 | 10.12 |
| Strategic planning | 2.10 | .99 | 2.00 | 1.15 | 1.60 | .96 |
| Self-efficacy for learning about the Circulatory System | 54.00 | 14.30 | 62.50 | 16.20 | 50.00 | 10.54 |
| Self-efficacy for learning new topics in Science | 70.00 | 14.14 | 75.00 | 11.79 | 60.00 | 10.80 |
| Outcome expectations: Circulatory System | 4.50 | 1.27 | 5.40 | 1.71 | 3.90 | 1.20 |
| Outcome expectations: Science | 5.30 | 1.06 | 5.90 | .74 | 5.10 | .88 |
| Intrinsic interest: Circulatory System | 3.20 | .79 | 3.20 | .63 | 3.10 | .88 |
| Intrinsic interest: science | 4.10 | .88 | 3.90 | .74 | 3.60 | .70 |
| *Performance Phase* | | | | | | |
| Task-strategy: Five minutes | 1.80 | .42 | 1.60 | .70 | 1.80 | 1.03 |
| Task-strategy: Ten | 1.70 | .82 | 1.40 | .52 | 1.40 | .52 |

| | | | | | | |
|---|---|---|---|---|---|---|
| minutes | | | | | | |
| Metacognitive monitoring: Declarative Knowledge Measure | 82.00 | 9.49 | 60.00 | 7.82 | 41.00 | 11.97 |
| Metacognitive monitoring: Conceptual Knowledge Measure | 79.50 | 10.12 | 53.00 | 12.52 | 52.00 | 10.59 |
| Metacognitive monitoring: Declarative Knowledge Measure Score | 79.50 | 9.84 | 55.50 | 11.17 | 45.50 | 12.12 |
| Metacognitive monitoring: Conceptual Knowledge Measure Score | 80.50 | 11.65 | 57.00 | 12.51 | 60.00 | 12.25 |
| *Self-Reflection Phase* | | | | | | |
| Self-evaluative standards | 80.00 | 11.54 | 63.00 | 14.18 | 54.50 | 14.99 |
| Attribution | - | - | | | - | - |
| Self-satisfaction | 5.50 | .85 | 4.40 | 1.26 | 4.10 | 1.10 |
| Adaptive/defensive | - | - | | | - | - |

**Research Question #3**. What is the predictive power of the microanalytic method in predicting student Declarative Knowledge, Conceptual Knowledge, and on their self-efficacy beliefs to engage in self-regulated learning measure?

For this research question, a regression analysis was calculated to test the overall predictive power of Zimmerman's cyclical model of SRL. To do this, two of the categorical variables had to be converted into metric variables. The remaining variables were metric. The SRL measures included in the analysis were as follows: (a) intrinsic interest for learning about the circulatory system, (b) intrinsic interest for learning about new topics in science, (c) self-efficacy for learning about the circulatory system, (d) self-efficacy for learning new topics in science, (e) outcome expectations about the circulatory system, (f) outcome expectations for learning about new topics in science, (g) goal setting, (h) strategic planning, (i) task strategy at five and ten minutes, (j) metacognitive monitoring measure for the answers to the Declarative Knowledge Measure, (k) metacognitive monitoring measure for the answers to the Conceptual Knowledge Measure, (l) metacognitive monitoring measure for the score to the Declarative Knowledge Measure, (m) metacognitive monitoring measure for the score on the Conceptual Knowledge Measure, (n) self-satisfaction measure, (o) attribution measure, (p) adaptive or defensive measure, and (q) the self-evaluative measure. To transform the attribution measure, originally coded into four categories, the responses were coded on the presence or absence of a particular attribution (DiBenedetto, 2010). For example, participants who had no response as to why they did not do better on the Conceptual Knowledge Measure were coded as a zero and those who identified ability, effort, or strategy were coded with a one. The adaptive or defensive variable was also transformed based upon the presence or absence of a response (DiBenedetto). For example, participants who identified that they would not do anything differently when given another opportunity to study for the test were given a zero and participants who indicated effort, strategy, or effort level were coded as a one. It should also be noted, that only the Conceptual Knowledge Measure was included as the dependent measure in the regression analysis, because this was the only measure participants were able to receive feedback.

SRL processes also explained a significant portion of the variance in the Conceptual Knowledge Measure scores, $F$ (18) = 7.52, $p < .01$, $R^2 = .92$. This result indicated that 92% of the variance in the participants' scores on the Conceptual Knowledge Measure were predicted by the 18 microanalytic processes included in this regression analysis (DiBenedetto, 2010). SRL processes also explained a significant portion of the variance in the Declarative Knowledge Measure scores, $F$ (18) = 3.05, $p < .05$, $R^2 = .91$. This result indicates that 91% of the variance in the participants' scores on the Declarative Knowledge Measure were predicted by the 18 microanalytic processes included in this regression analysis. Finally, SRL processes explained a significant portion of the variance in the Self-Efficacy to engage in SRL measure, $F$ (18) = 2.75, $p < .05$, $R^2 = .90$. This result indicates that 90% of the variance in the participants' scores on the Self-Efficacy to engage in SRL measure were predicted by the 18 microanalytic processes included in this regression analysis

**Research Question #4**: Are there differences between high, average, and low achieving adolescents in their self-efficacy beliefs to engage in self-regulated learning as they learn from a HLE?

A one-way analysis of variance revealed a statistically significant main effect for achievement on the Self-Efficacy for Self-Regulated Learning Form, $F$ (2, 27) = 15.22, $p < .01$. The effect size is considered large (partial eta squared .53). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between all three achievement groups. The mean and standard deviation scores for the high science achievement group were $M$ = 86.00, $SD$ = 7.38, the mean and standard deviation scores for the average science achievement group were $M$ = 72.5, $SD$ = 9.79, while the mean and standard deviation scores for the low science achievement group were $M$ = 58.50, $SD$ = 14.92.

**Research Question #5**: Are there any differences among high, average, and low achieving adolescents in their ability to calibrate their self-efficacy for performance beliefs with task outcomes while engaged in a scientific task presented with a HLE?

The motivational measures addressed in this research question were found to be statistically significant. Regarding self-efficacy for performance on the Declarative Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 5.26, $p < .05$. The effect size is large (partial eta squared .28). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p = .01$), but not between the high science achievers and the low science achievers ($p = .40$) or the high science achievers and the average science achievers ($p$=.15). The mean and standard deviation scores for the high science achievement group were $M$ = 65.00, $SD$ = 12.47, the mean and standard deviation scores for the average science achievement group were $M$ =

55.50, *SD* = 16.67, while the mean and standard deviation scores for the low science achievement group were *M* = 71.50, *SD* = 10.01.

Regarding Self-efficacy for performance on the Conceptual Knowledge Measure, a one-way analysis of variance revealed a statistically significant main effect for achievement, $F$ (2, 27) = 11.04, $p < .01$. The effect size is large (partial eta squared .45). Post hoc comparisons using Tukey tests indicated statistically significant pairwise differences between the low and average science achievers ($p = .01$) and between the high science achievers and the low science achievers ($p = .01$), but not between the high science achievers and the average science achievers ($p$=.83). The mean and standard deviation scores for the high science achievement group were *M* = 63.50, *SD* = 11.56, the mean and standard deviation scores for the average science achievement group were *M* = 61.00, *SD* = 6.99, while the mean and standard deviation scores for the low science achievement group were *M* = 79.50, *SD* = 9.56. In addition to these analyses, a calibration analysis was conducted to determine students' bias in reporting their self-efficacy scores for the Declarative Knowledge Measure and the Conceptual Knowledge Measure.

The self-efficacy for performance measures were given before the participants had an opportunity to receive feedback, therefore it was possible some overestimated their self-efficacy beliefs, some underestimated their self-efficacy beliefs, and others were very accurate in their self-efficacy belief estimations in relation to the two task outcomes. To calculate the self-efficacy biases students' score predictions on the Declarative Knowledge Measure and the Conceptual Knowledge Measure were subtracted from their self-efficacy for performance scores for each measure. Negative scores indicated an underestimation of their self-efficacy for performance and positive scores indicated an overestimation of their self-efficacy for performance. The magnitude of their estimation biases can be determined by looking at how far away their results are from zero. For example, if a student scored a 70% on the Declarative Knowledge Measure and their self-efficacy for performance score on that measure was a 100% then their calibration bias for this would be a 30. A 30 represents an overestimation of their self-efficacy for performance beliefs on this measure.

Table 8

*Means and Standard Deviations for Self-Efficacy Calibration Measures by Achievement Level*

| | High Achievers | | Average Achievers | | Low Achievers | |
|---|---|---|---|---|---|---|
| | Means | SD | Means | SD | Means | SD |
| Declarative Knowledge Measure: Self-efficacy for performance bias | -1.15 | 13.29 | 10.89 | 18.52 | 45.34 | 12.43 |
| Conceptual Knowledge Measure: Self-efficacy for performance bias | 6.83 | 10.11 | 28.50 | 13.20 | 61.17 | 10.83 |

The mean and standard deviation self-efficacy for performance calibration bias for the high science achiever on the Declarative Knowledge Measure was $M = -1.15$, $SD = 13.29$, the mean and standard deviation self-efficacy for performance calibration bias on the Declarative Knowledge Measure for the average science achievers was $M = 10.89$, $SD = 18.52$, and the mean and standard deviation self-efficacy for performance calibration bias on Declarative Knowledge Measure for the low science achievers was $M = 45.34$, $SD = 12.43$. The mean and standard deviation self-efficacy for performance calibration bias for the high science achiever on the Conceptual Knowledge Measure was $M = 6.83$, $SD = 10.11$, while the mean and standard deviation self-efficacy for performance calibration bias on the Conceptual Knowledge Measure for the average science achievers was $M = 28.50$, $SD = 13.20$, and the mean and standard deviation self-efficacy for performance calibration bias on Conceptual Knowledge Measure for the low science achievers was $M = 61.17$, $SD = 10.83$. On each measure, low achieving students drastically overestimated their self-efficacy for performance beliefs. Average science achieving students moderately overestimated their self-efficacy for performance beliefs on both measures. High achieving students slightly underestimated their self-efficacy for performance beliefs on the Declarative Knowledge Measure and slightly overestimated their self-efficacy for performance beliefs on the Conceptual Knowledge Measure.

# DISCUSSION

The present study used an embedded mixed method design to explore the self-regulatory processes used by high, average, and low achieving science students as they learned about a complex science topic with a HLE. The HLE used in this study was the Microsoft Encarta Reference Suite™ (2003) electronic encyclopedia which presented content with text, audio, and video in a non-linear format. Using a microanalytic methodology, which used both qualitative and quantitative data, this study sampled 30 seventh graders from a mid-Atlantic middle school. The students were placed into three achievement groups based upon their prior performance in their science classes and their performance on the Virginia fifth grade science Standards of Learning (SOL) exam. Each participant was given a Declarative Knowledge Measure and a Conceptual Knowledge Measure pretest, provided time to explore a HLE, and then given identical Declarative Knowledge Measure and Conceptual Knowledge Measure posttests. As the students explored the HLE, a microanalytic method was undertaken, which involved asking strategic questions at specific times during the learning activity. After the posttests were administered, the SELF survey was given to the participants to complete.

This chapter begins with an interpretation of the overall findings from the research and concludes with implications for practice, implications for the design of

HLEs, recommendations for future research, limitations of the current study, and concluding thoughts.

## Differences in the Three Phases of Self-Regulation across High, Average, and Low Performing Students

**Achievement**. With regard to achievement, significant differences were found between the high, average, and low achievement groups. The high achievers performed better than the average achievers, who performed better than the low achievers on both the Declarative Knowledge Measure and the Conceptual Knowledge Measure. The results were similar to that of DiBenedetto and Zimmerman's (2010) work that found high school students who were categorized as high science achievers showed greater gains on the Acquired tornado knowledge test and the Tornado conceptual model test compared to average science achievers, who performed better than the low science achievers. One key difference between the current study's Conceptual Knowledge Measure and DiBenedetto and Zimmerman's Tornado conceptual model test, is in their measure students were asked to abstract a model of the formation of tornados from text, and in the current study students had the opportunity to view text, images, and videos on the circulatory system and were then required to articulate their conceptual knowledge in essay format. Percentages of over sixty for the high achievers, slightly under fifty for the average achievers, and slightly over thirty for the low achievers were discovered on the Declarative Knowledge Measure and slightly under sixty for the high achievers, slightly over thirty for the average achievers, and slightly under twenty for the low achievers were discovered on the Conceptual Knowledge Measure. The significant differences discovered between the high, average, and low achievement groups for both measures validated this study's grouping approach.

**Self-regulatory processes**. Using the microanalytic assessment for the self-regulatory processes, this section focuses on the differences between the three achievement groups with respect to the Forethought, Performance, and Self-Reflective. phases of self-regulation.

***Forethought phase***. The task analysis measure of goal setting did not reveal a significant difference between the three achievement groups. The task analysis measure for task strategy planning also did not reveal a significant difference between the three achievement groups.  These findings indicate that high, average, and low science achievers have similar goals and number of strategies in mind as they prepare to learn from a HLE.  These results lie in contrast to DiBenedetto's (2010) work that found experts and non-experts with more strategies in mind compared to the at-risk group as they learned from a traditional learning task. The lack of difference between the achievement groups in this study may be due to a higher degree of goal setting input from the adolescents' teachers. The results also may differ from DiBenedetto's work because the task of learning about the circulatory system from a HLE is more proximal than learning about tornados from an essay. The argument has also be made that students who demonstrate qualitative shifts in their conceptual understanding in science while learning from HLEs may use the same number of strategies as their lower achieving counterparts but use more sophisticated self-regulatory processes such as planning throughout the learning session, the creation of sub-goals, and the evaluation of their own cognitive processes (Azevedo, Johnson, Chauncey & Graesser, 2011). One important implication from these findings is that researchers may want to explore how well each achievement group truly understands how to set goals or how to use the strategies identified. Just because a participant identifies "summarize key points" as part of strategy planning, it does not mean he or she actually understands how to summarize.

The self-motivational belief measure of self-efficacy for learning all the material on the circulatory system did not reveal a significant difference between the three achievement groups. Regarding the self-efficacy for learning about new topics in science, a significant difference between the low and average science achievement groups was discovered with average achievers having a higher self-efficacy for learning all the material on the circulatory system than the low achievers, but not between the high science achievement group and the other two groups. This suggests that low science achievers may have moderate problems accurately judging their capability to learn new topics in science as they learn from a HLE. These findings extend DiBenedetto's (2010) work that also did not reveal a statistical difference between the experts, non-experts, and at-risk group when it came to their self-efficacy for learning as they learned from a traditional learning environment. One possible reason for this finding is that students had not been taught anything about the circulatory system during the school year and when students are faced with tasks in which they have limited prior domain knowledge, they may not be able to simultaneously process information and apply self-regulatory processes (Winne, 2001).

The self-motivational belief measure of self-efficacy for performance on the Declarative Knowledge Measure revealed significant differences between the low and average science achievers with low achievers having a higher self-efficacy for performance beliefs than the average achievers, but not between the high and low science achievers. The self-motivational belief measure of self-efficacy for performance on the Conceptual Knowledge Measure revealed significant differences between the low and average science achievers with low science achievers having a higher self-efficacy for performance than the other two groups, but not between the high and the average science achievement group. These results, while significant for some group comparisons, reveal a general issue with accurately predicting their capability to perform with actually performing on the two measures. This calibration issue will be discussed in more detail later on in the discussion.

The self-motivational belief measure for outcome expectations and intrinsic interest in science and intrinsic interest in the circulatory system also did not reveal a significant difference between the three achievement groups. The lack of differences between the three achievement groups for outcome expectation and intrinsic interest could be also be explained because the interviews took place at the end of the school year and at the end of the day. Students were probably not very motivated to learn about a new topic in science and as a consequence did not put a great deal of thought into predicting how their behavior might produce a certain outcome.

***Performance phase***. The self-control task strategy measure consisted of counting the number of strategies used by the participants after studying for five and then ten minutes. The results did not reveal any significant differences between the three achievement groups as they learned from a HLE. These results lie in contrast to DiBenedetto's (2010) work that revealed students who were experts used more strategies while reading a science passage and while studying for a science test when compared to students who were at-risk. While one would expect high science achievers to deploy more strategies than low science achievers, when students learn from a HLE the dynamic nature of the environment appears to have an impact. Greene and Azevedo (2007) found that a student's poor Control of Context, or any time a participant choses to click on a hyperlink or otherwise leave a current representation for a new one, shows a lack of goal directed behavior and can have negative consequences on content acquisition. Deploying strategies while navigating the non-linear nature of HLEs is a cognitively taxing activity, and it requires students to make decisions throughout the entire learning session. This balancing act between off-loading content and deploying self-regulatory strategies requires an analysis of working memory capacity. Working memory is responsible for temporarily maintaining and manipulating information during cognitive activity (Baddeley, 2002). All too often students get lost in this exploration. They click from page to page or improperly use one or more self-regulatory strategies and their working memory capacity is reached. The result is little content acquisition occurs. Findings from a study by Moos (2013) support this logic, where he found that higher cognitive load experienced after responding to a guiding question was associated with the use of fewer self- regulatory processes for the remainder of the hypermedia learning task. Providing students with opportunities to off-load content, while learning from a HLE, should help free up some of their working memory for processing new content.

The Plan Follow Through measure calculated the degree to which the participant followed through on his or her task strategy plan. It was revealed that there were significant differences across the three achievement groups. High science achievers were far more likely to follow their task strategy plan compared to average science achievers, who were more likely to follow their task strategy plan than low science achievers as they learned from a HLE. These findings revealed that as students learned from a HLE, high science achievers were better able to remember their plan and stick to the plan as they were learning. Low science achievers were far less likely to stick with their plan as they learned from a HLE. The results of this difference can significantly impact the ability of each group to reflect on the successes and failures of learning strategies, which has the potential to completely interrupt the cyclical nature of learning. In Zimmerman and Kistantas' (1997) study, they found that girls, who focused on the proper execution of the final two steps in dart throwing as opposed to the numeric score outcome displayed stronger self-efficacy beliefs, intrinsic interest, and had more positive self-reactions. Proper focus on the execution of strategies may have had a positive impact on a variety of variables for the participants in this study as well. One important implication from this finding is that teachers and designers may want to consider providing students with a road map or planning document for self-recording before, during, an after learning with HLEs. After the learning activity, students may reflect on the choices and strategies deployed in a more accurate way with their original thoughts already recorded. This idea has been confirmed. Peters Burton (2013), explored the self-regulatory processes used by elementary school teachers as they learned about inquiry based learning during professional development and established that by allowing them to create and use a rubric as a guide for the new teaching technique that teachers were more likely to set more advantageous goals, reach more of their goals, and had higher self-efficacy for implementing the new teaching technique. There is also evidence that self-recording enhances the effects of all forms of goal setting, self-efficacy beliefs, and self-reactions which are concordant with the presence of a self-oriented feedback loop that underlies self-regulation (Zimmerman, 1989).

The self-observation metacognitive monitoring measure for the Declarative Knowledge Measure revealed significant differences between all three achievement groups. These findings revealed that high science achievers were more accurate in their metacognitive monitoring than the average science achievers, who were then more accurate than low science achievers. The self-observation metacognitive monitoring measure for the Conceptual Knowledge Measure revealed significant differences between high and low science achievers and between low and average science achievers in their ability to align and check their own thinking with what was being learned, but not between high and average science achievers. Using a slightly different variable but producing similar results, Azevedo and colleagues (2005) discussed and demonstrated the metacognitive monitoring activity Judgment of Learning (JOL), which occurs when a student monitors his or her emerging understanding relative to the information provided in the learning environment, and the crucial role it plays in learning with hypermedia.

The results from this study suggest that high science achievers were more sophisticated and accurate in what they did and did not know as they learned from a HLE than their counterparts. Prompts for average and low science achievers to identify their perceived level of understanding during the learning process as they learn from HLEs may help these groups become more aware and accurate with their metacognitive monitoring.

***Self-Reflection phase***. For the self-evaluation measure, significant differences were revealed between the high and low science achievers, high and average science achievers, but not between the low and the average science achievers. These results revealed that high science achievers had a more positive perception of their performance than their counterparts. This may be a result of their recognition of the choices and decisions they strategically made as they learned from the HLE, and how they impacted their performance. Research has demonstrated that positive self-evaluations of progress lead to continued use of strategies and motivation for achievement (Zimmerman, 1998; 2000). Low science achievers relatively low evaluation of their performance may be a result of the perceived disconnect between their actions and performance.

The causal attribution measure revealed significant differences between the three achievement groups. High science achievers were more likely to attribute their performance to the selection and deployment of self-regulatory strategies compared to average science achievers, and low science achievers who either could not identify a single reason why they performed the way they did, identified effort or ability as the reason for their performance. These results are logical since in the earlier findings high science achievers systematically thought about and were aware of the strategies used during learning, more so than the average and low science achievers. This awareness is seen once again when students are asked to attribute their performance. Attributions based upon something other than the self, like strategies, empower learners to self-correct and adjust. Creating supports for average and low achieving students to attribute performances to strategic choices instead of allowing them to fall back on ability, effort, or nothing in particular, will have positive impacts on future learning situations because at least strategies are a correctable problem (Zimmerman & Kitsantas, 1997; 1999, Kitsantas, Zimmerman, Cleary, 2000).

The self-satisfaction measure revealed significant differences between high and low science achievers, but not between high and average science achievers or between average and low science achievers. These findings revealed high science achievers were more satisfied with their performance on the Conceptual Knowledge Measure than the average and low science achievers. This finding can be explained because high science achievers probably feel that their choices and decisions made during the learning process led to their performance.

The final subprocess assessed within the self-reflection phase was the adaptive or defensive inference. Even though no significant differences were discovered, the frequency of responses indicated that high science achievers were slightly more likely to identify a strategy or effort as something they would do differently if given another chance to study the material, compared to average and low science achievers who were more likely to identify effort or not do anything differently. In a different context but producing similar results, Kitsantas and Zimmerman (2002) discovered that when asked about their methods of adaptation after missing two volleyball serves, more Experts thought about their errors and were likely to change things than either Non-Experts or Novices. Struggling learners must be taught to be reflective and adaptive while learning, because the alternative defensive inferences can lead to a feeling of helplessness, procrastination, task avoidance, and the cessation of active engagement due to apathy (Garcia & Pintrich, 1994).

**Motivational beliefs**. The SELF form measured the student's overall self-efficacy beliefs to engage in self-regulated learning as they learned about science. Self-efficacy is a critically important motivational variable. This measure revealed a significant difference between the three achievement groups. The mean score for students in the high science achievement group was higher than the average science achievement group, which was higher than the low science achievement group. This suggests that students who were high science achievers were more confident in their capability to engage in self-regulated learning than their counterparts. This general assessment of self-efficacy beliefs to engage in self-regulated learning for science was not related to a specific task, but does provide some level of validation to the idea that motivational beliefs, the deployment of self-regulatory process, and performance are all interconnected.

**Predictive Power of the Microanalytic Method**: The data showed that a significant amount of the variance (92%) in the participants' scores on the Conceptual Knowledge Measure was predicted by the eighteen SRL processes included in this study as students learned with a HLE. It was also revealed that a significant amount of the variance (91%), in the participants' scores on the Declarative Knowledge Measure was predicted by the same eighteen SRL subprocesses as students learned with a HLE. The eighteen SRL subprocesses consisted of a series of open and closed questions that were asked in close proximity to the learning environment and the performance measures. Using a slightly different combination of SRL processes in their microanalyses, Kitsantas and Zimmerman (2002) found that 90% of the variance of volleyball serving skill could be predicted with the microanalytic method and DiBenedetto (2010) revealed that 77% of the variance in student performance on a science test could be predicted with the microanalytic method. The predictive power of the microanalytic method has significant educational implications since it only reinforces Zimmerman's cyclical model of self-regulation as students learn from a HLE. The results of this study demonstrated that students who prepare and deploy self-regulatory processes before, during, and after learning with HLE, are likely to perform better on academic tasks. Teachers should use the microanalytic method to diagnose the self-regulated learning processes used by all achievement groups in an attempt to help students identify and take control of their own learning processes.

**Differences in Self-Efficacy Calibration Bias across High, Average, and Low Performing Students**. The findings revealed that high science achievers tended to underestimate their capability to perform on the Declarative Knowledge Measure while average science achievers tended to slightly overestimate their capability to perform, and low science achievers tended to overestimate their capability to perform after they studied with a HLE. These differences in the accuracy of the student's calibration between perceived self-efficacy and task outcomes on the Declarative Knowledge Measure indicated that high science achievers were more accurate in the estimation of their capabilities than both average and low science achievers. These findings are consistent with previous research that found at-risk or low achieving groups overestimated their competence, non-expert or average groups slightly overestimated their competence, and the expert or high achieving groups slightly underestimated their competence (Dibenedetto, 2010; Chen & Zimmerman, 2007; Klassen, 2006; Bol, Hacker, & Bahbahani, 2008). It can be seen in each study that the higher achievers tend to be more accurate in assessing their study needs. For example, a high science achiever might underestimate his or her capability to learn from a HLE and will compensate by exerting ample cognitive resources to studying. In contrast, an average or low science achiever might overestimate his or her capabilities and probably not study very hard due to the misguided belief he or she understands the content. A similar trend was seen with the accuracy of the student's calibration between perceived self-efficacy and task outcomes for Conceptual Knowledge Measure.

The Conceptual Knowledge Measure represented a much more complex task compared to the Declarative Knowledge Measure. Participants were asked to articulate all they knew about the circulatory system on the Conceptual Knowledge Measure as opposed to matching 13 terms with their definitions on the Declarative Knowledge Measure. As a consequence of the increased item difficulty, all achievement groups overestimated their self-efficacy for performance beliefs in relation to the Conceptual Knowledge Measure. It should be noted the magnitudes of their overestimation were drastically different, low science achievers overestimated their self-efficacy for performance beliefs by over sixty percentage points, average science achievers by almost thirty percentage points, and high science achievers by almost seven percentage points on the Conceptual Knowledge Measure. These results were expected since self-efficacy beliefs are dependent on the level of the task, which means the simpler the task the more accurate the apparent self-efficacy for that task (Bandura, 1997). These results extend Chen and Zimmerman's (2007) work which confirmed students in both America and Taiwan decrease their self-efficacy calibration accuracy as the math items become more difficult. It is clear that low achievers overestimate their self-efficacy for performance beliefs with task outcomes, and that item difficulty impacts self-efficacy beliefs. It is also clear that high achievers are much more accurate with their self-efficacy for performance beliefs on the Declarative Knowledge Measure compared to the more complex Conceptual Knowledge Measure. These findings may be a result of the frequency with which students are exposed to these items and the rate at which feedback is provided by their teachers or assessment systems. Over the course of a school year, student exposure to multiple choice or matching items, such as the Declarative Knowledge Measure, most likely far outweighs their exposure to open response items, such as the Conceptual Knowledge Measure. Students feel more comfortable with those items and probably feel more capable in providing a complete answer. This also means a disproportionate amount of time for reflection and feedback on those multiple choice and matching items compared to the open response items. This line of thinking is supported by O'Connor's (1989) belief that there are three things that influence calibration, (a) familiarity with task requirements, (b) familiarity with the topic of interest, and (c) adequate feedback on the accuracy of prior judgments.

## Implications for Teaching

The findings from this study suggest three main outcomes: (a) That the microanalytic method for assessing SLR is predictive of student performance as they learn from a HLE, (b) That teachers should scaffold and support student use, documentation, and reflection of SRL strategies while their students learn from HLEs, and (c) Teachers should incorporate self-efficacy perceptions into their student's assessment platform. Regarding the first outcome, the microanalytic method was predictive of the Declarative and Conceptual Knowledge Measure as students learned with a HLE. In the current study, 18 SRL subprocesses were used in the regression analysis. Teachers could use the microanalytic method as a diagnostic assessment to assess how students implement and regulate their use of SRL strategies during academic-related activities (Cleary & Zimmerman, 2004). Since the microanalytic method was predictive of student performance as they learned with a HLE, teachers who plan on using HLEs as an educational tool could use the data from a microanalytic method to then help identify which areas of SRL to focus remediation. This has been done before in more traditional education settings. The Self-Regulation Empowerment Program (SREP) is a program designed as an assessment and intervention program that was recently developed to microanalytically evaluate students' regulatory processes as they engage in a comprehensive self-regulation intervention program (Cleary & Zimmerman, 2004; Cleary et al., 2008). Targeting a small group of adolescents, researchers used SREP to focus on students' self-reflective processes following biology tests, and through a series of training sessions focusing on SRL strategies they were able to shift students' attributions from effort and ability to controllable factors such as SRL strategies (Cleary et al.) This sequence, applied at a classroom level as students learn with a HLE, could help teachers better understand and navigate the academic obstacles associated with learning from HLEs and empower students to understand that learning within this new environment is something they can control.

The second outcome relates to how teachers should scaffold and support student use, documentation, and reflection of SRL strategies while their students learn from HLEs.  The data from this dissertation found that while there was no real difference between the number of strategies identified prior to or used while students studied from the HLE, there were significant differences in how the three achievement groups attributed their performance. High science achievers attributed their performance to the selection of a strategy more often than average and low science achievers. This discrepancy could be minimized by providing all students with a brief planning document to complete before they begin learning from a HLE, a log sheet detailing the type of media and content accessed to complete while they are using the HLE, and a reflection page where the students can see how their performance relates to the planning document and the log sheet. By charting their learning process from beginning to end, students with poor SRL skills should be able to better connect their performance to strategic choices made while exploring the HLE. Students will be able to see what strategy worked, what strategy sequence was most effective, or why certain strategies were unsuccessful as they attempted to learn new content from a HLE. This solution has proven itself to be successful in other settings as well, such as Kitsantas and Zimmerman's (2006) research where they found that novice learners who graphed their performance and evaluated their outcomes based on graduated standards significantly improved their dart-throwing performance and experienced more positive motivational beliefs than students who did not graph their performance. While moderately time intensive, this proposed solution could help students connect task strategy planning to the task strategies, and then task strategies to performance, so that they could better monitor their learning plan and be adaptive about their learning.

The final outcome for this section addresses the need to have teachers incorporate self-efficacy perceptions into their student's assessment platform. This suggestion stems from the data collected in this dissertation related to the accuracy of student's calibration between their perceived self-efficacy and task outcomes. Based on their self-efficacy beliefs, it was discovered that high science achievers were better able to predict their performance than average science achievers, who were better able to predict their performance than low science achievers on both science tests. For teachers who are tasked with improving performance and confidence, these trends provide information that could allow them to focus remediation strategies and for students, these trends might illuminate miscalibration tendencies. For example, imagine a chronically low achieving science student being asked to articulate how confident he or she felt in solving a science problem correctly after working on it and before receiving feedback. The teacher could review the student's answer in addition to the self-efficacy belief on that item. These two pieces of information could provide a much more complete picture of the reasons behind the student's performance on that item. Using the data from this dissertation as a guide for this example, imagine the same student providing an incomplete and incorrect answer for the problem and yet believing he or she was more than capable in solving it. Drastic overestimations of self-efficacy beliefs like this could be a product of being unaware of the requirements of the item or being unaware of the strategies necessary to solve the item. Either way, the issue remains that by not addressing this calibration issue a student's desire to learn new skills and strategies would be hindered because the cycle of overestimation and attributing failure to effort and ability would be allowed to continue. As for teachers, this new awareness of what their students think they are capable of could help them tease out the reasons why their students are not performing. This type of metacognitive information, for both teacher and student, is invaluable because it can initiate discussions to help the students become more self-aware of their behaviors and to directly target processes that are essential to successful task completion (Cleary, 2011).

## Implications for the Design of Hypermedia Learning Environments

The findings from this study suggest two main outcomes for the design of HLEs: 1) That this study provides empirical evidence, using Zimmerman's cyclical model of SRL, on the extent to which students use self-regulatory processes while learning with HLEs, and 2) That while adolescents learn from a HLE, there is a need to support the use of and connection to their strategy planning and task strategy implementation to their self-evaluations and causal attributions.

This dissertation represents one of the first studies that explored student learning with HLEs using a microanalytic method. The microanalytic method is grounded in Zimmerman's model of SRL which depicts SRL as a three-phase process of thought and action that occurs in three sequential phases: forethought (i.e., processes that precede efforts to learn or perform), performance control (i.e., processes occurring during learning efforts), and self-reflection (i.e., processes occurring after learning or performance) (Zimmerman, 2000). According to the forethought phase of this theory, students will set goals, engage in some form of strategic planning, assess their self-efficacy, outcome expectations, and intrinsic interests prior to learning. Data from this dissertation suggests that while learning from HLEs all achievement groups set goals, evaluated their capability to learn from the HLE, had an expected outcome in mind, and at least considered how interested they were in the topic. Representing the lone open ended item from the forethought phase, almost every student was able to articulate some type of strategic plan.

According to the performance phase of this theory, students will select and deploy task strategies and self-monitor their performance during learning. Data from this dissertation suggests that while each achievement group deployed task strategies and monitored their performance while learning from a HLE, more high achievers stuck with the original plan compared to the other two achievement groups. These data suggests that high achievers were more selective, probably based upon similar tasks in similar contexts, of the task strategies identified in the forethought phase and were quite comfortable and confident in executing their plan. This dynamic is indicative of a reflective learner who uses the cyclical nature of learning to his or her advantage because the student is above all, self-reflective.

According to the self-reflection phase of this theory, students will evaluate their performance, attribute causation, assess their satisfaction with their performance and make adaptive or defensive inferences after learning. Data from this dissertation suggests that while learning from a HLE, each achievement group evaluates their performance and determines their level of satisfaction with their performance. Data also suggests that high achievers attribute their performance to strategic choices and make adaptive inferences more often than average and low achievers. Cleary and Chen (2009) demonstrated that self-regulation and motivation variables reliably differentiated high achievers and low achievers in academically rigorous or intensive math classrooms, but did not consistently differentiate achievement groups in environments that did not require high levels of self-directedness and persistence. It is clear, based upon the data in this dissertation, that HLEs represent an environment that requires a great deal of self-regulation. With this in mind, designers should use Zimmerman's model to help embed research based supports for users before, during, and after the user's exploration of HLEs.

Regarding the second outcome for the design of HLEs, while other SRL subprocesses were certainly determined to be significant factors of student performance, these four have the potential to improve the effectiveness of the HLEs and be seamlessly embedded within the environment. This dissertation revealed that there was little difference between strategy planning and the task strategies implemented at five and ten minutes after studying for all three achievement groups, and yet there was a significant difference between the high science achievers and the low science achievers on the Plan Follow Through measure. It was revealed that high science achievers tend to follow their strategy plan while low science achievers do not. Based on these data, it is recommended that one way designers could support low science achievers as they learn from HLEs is to provide a planning document they students could fill out prior to exploring the HLE and a log file document they could fill out while they are learning from the HLE. As for scaffolding strategy planning, this could be as simple as having the students select, prior to the exploration of the HLE, from a series of drop down options (for example: "I plan on taking notes"), or ("I plan on watching a video"), and putting them in some order. The designers could make this strategic plan visible on the screen to help low achievers remember their original plan as they explored the HLE.

The significant differences found in this dissertation for the Plan Follow Through measure are supported by Schunk and Zimmerman's (1998) suggestion that the more skillful self-regulated learners are, the more likely it is that they have more-adaptive motivational beliefs (e.g., mastery goal orientation, high sense of self-efficacy) that result in more effective task strategies. Some high achievers identified one strategy in the strategy planning question and diligently implemented that strategy for the entire learning session, while other high achievers identified three strategies in a specific order and then systematically followed that plan. Regardless of the complexity of the strategy plan identified by the student, following it while learning from HLEs seems to improve performance and opportunity for substantive reflection. Examples of learning tools that designers could incorporate into HLEs which could support effective use of and documentation of task strategies include the ability to (a) annotate text while exploring course content, (b) take notes (online), (c) bookmark and link information, (d) perform a contextualized search, and (e) build a personal folder of relevant course material (Kitsantas & Dabbagh, 2010). Creating onscreen visuals for the student of task strategies and the possible sequence of those strategies while they explore HLEs has the potential to help organize and sequence content, and engage in elaboration and monitoring of understanding (Smith & Ragan, 1993). Providing students with an easy way to document their strategy plan and task strategies is a first step for designers to harness the potential of these new environments, but the ultimate goal remains to adaptively guide all learners to select the appropriate task strategy for the appropriate task using the appropriate medium at the appropriate time.

The self-evaluation measure in this dissertation was determined to be highly correlated with the other SRL subprocesses and produced significant differences between the three achievement groups. These findings were substantiated by Zimmerman's (2000) statement that research has shown that more-frequent self-evaluation leads to higher self-efficacy beliefs and more adaptable and controllable attributions. Designers could act on these findings to create opportunities for students to engage in self-evaluation while they learn from HLEs. Kitsantas and Dabbagh (2010) discovered that the most frequent self-evaluation strategies used by expert college instructors were checklists for content creation and delivery tools, grade tools, email, and online rubrics. Building upon this knowledge base, designers could provide simple Likert style measures much like the ones used in this dissertation, at strategic points during the learning process. This information could then be used to facilitate student self-reflections and help them compare their performance to previous performances or to explicit or implicit standards, to reveal knowledge gaps and to modify their behavior accordingly (Kitsantas & Dabbagh).

The final design feature that, based upon the findings from this dissertation, should be incorporated into HLEs is a feature that allows students to attribute their performance. It was discovered that there were significant differences between the three achievement groups as to how the students attributed their performance. High science achievers were more likely to attribute their performance to the selection and deployment of self-regulatory strategies compared to average science achievers and low science achievers, who either could not identify a single reason why they performed the way they did, identified effort, or identified ability as the reason for their performance. After receiving feedback on an assessment where they were learning from a HLE, low achievers should be prompted to examine their strategic plan and implemented task strategies. This redirect might help struggling learners to attribute performances to strategic choices and help them develop a more proactive approach to learning with HLEs.

**Recommendations for Future Research**

The first recommendation for future research based upon these findings is that researchers may want to explore how well each achievement group truly understands how to use the strategies they identify. As it was stated earlier, just because a participant identifies "summarize key points" as a strategy does not mean he or she actually knows how to summarize.  It may help future researchers to understand some of the struggles of low achievers to assess the effectiveness of the user's strategy implementation. Future research should also explore the Plan Follow Through measure in more traditional learning environments.  Learning with HLEs puts certain cognitive and metacognitive demands on students, and without these demands students may not feel the need to adhere to their original strategic plan (Azevedo, 2005). By combining the first two recommendations in a research study, future research may reveal how effectively students plan, package, deploy, adjust, and persist in the implementation of their strategy plan while engaged in a learning task.

The third recommendation for future researchers would be to include the Rating Student Self-Regulated Learning Outcomes: A Teacher Scale (RSSRL). The RSSRL was developed by Zimmerman and Martinez-Pons (1989), to measure teacher's perceptions of the self-regulated learner in class, and would have been particularly useful in capturing the teacher's perspective of the learner and comparing it with the microanalytic method and the SELF to gain a more complete picture of the self-regulated learner.

The fourth recommendation for future researchers would be to perform the microanalytic method in the classroom.  From a researcher's perspective, classrooms are challenging and messy contexts, with an almost infinite number of variables that may impact student learning. For this very reason, more in-class research is needed. Classrooms present opportunities to study SRL in naturally occurring events and activities, and it is vitally important to enhance our knowledge about how features of contexts afford and constrain opportunities for and instances of regulating learning (Perry

& Rahim, 2011). By assessing for SRL in the classroom, using a multidimensional variation of the microanalytic method that includes an online portion, researchers may be able to better understand what the students are doing, why they are doing what they are doing, how students' peers are influencing their learning, and how teachers may be able to create opportunities for the adoption of self-regulatory processes in the classroom.

The fifth recommendation for future researchers would be to include a follow-up task in a content area other than the one studied in the original design, either directly following the interview or at a later date, to determine if the self-reflective feedback would have an impact on other SRL processes during future learning activities. This recommendation gets to the heart of the cyclical nature of SRL and was not addressed in the current study. The final recommendations for future researchers would be to examine the ways adolescents use social media to self-regulate their learning, research and design the most effective ways to use learning analytics to scaffold SRL in cutting edge learning technologies, and explore the different mobile applications adolescents use to regulate their learning.

**Limitations**

This embedded mixed method study contained both qualitative and quantitative data. These data sources each presented unique limitations. With regard to the quantitative data, the small sample size and relative uniform nature of the participants represented the most impactful limitation. Due to these factors, there are obvious limits to this dissertation's generalizability. Another limitation worth noting is found within the self-report items of the microanalytic method. Self-report measures always involve the bias of the participants' perceptions, and there is recent evidence showing that student self-ratings of regulatory processes as gathered on self-report surveys often do not correspond strongly with actual behaviors (Winne & Jamieson-Noel, 2002). The main limitation from the qualitative portion of the study is researcher bias. As Maxwell (2005) identified, the issue of researcher bias emerges when qualitative analysis is employed because researchers may knowingly or unknowingly include or exclude certain data. The final limitation worth noting is the cognitively taxing nature of the pretests, microanalytic method, posttests, and the time of the interviews. From beginning to end, each interview took an hour and occurred at the end of the school year at the end of the day. Many seventh grade students probably had difficulty sustaining focus and as a consequence experienced some form of respondent fatigue.

**Conclusion**

This dissertation provides an empirically-based study grounded in Zimmerman's cyclical model of SRL that explored the topics of HLEs, self-regulation, science, adolescents, self-efficacy, motivation, and self-efficacy calibration accuracy with task outcomes. This dissertation revealed that high science achievers deployed more SRL processes and were more strategic about their learning plan than average and low science achievers as they learned from a HLE. This dissertation provides teachers and designers with new data to help maximize the instructional potential of HLEs. By successfully using the microanalytic method to assess for SRL as students learned from a HLE, this study adds a new learning context to the literature base.

## APPENDIX A: DECLARATIVE KNOWLEDGE TEST (AZEVEDO ET AL.,2005)

### 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 B: CONCEPTUAL KNOWLEDGE TEST (AZEVEDO ET AL.,2005)

**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.**

Please use the back of this sheet if you need more space…..

## APPENDIX C: SELF-EFFICACY FOR LEARNING FORM-A (DIBENEDETTO, 2010)

Name:___________________________ Date:____________

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Definitely<br>*cannot do it* | | | Probably<br>*cannot* | | Maybe | | Probably<br>*can* | | | Definitely<br>*can do it* |
| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |

Choose a percentage to indicate your answer:

_____1. When you miss a science class, can you find another student who can explain the science lecture notes as clearly as your teacher did?

_____2. When your teacher's science lecture is very complex, can you write an effective summary of your original science notes before the next class?

_____3. When a science lecture is especially boring, can you motivate yourself to keep good science notes?

_____4. When you had trouble understanding your instructor's science lecture, can you clarify the confusion before the next science class by comparing notes with a classmate?

_____5. When you have trouble studying your science class notes because they are incomplete or confusing, can you revise and rewrite them clearly after every science lecture?

_____6. When you are taking a science course covering a huge amount of material, can you condense your science notes down to just the essential facts?

_____7. When you are trying to understand a new science topic, can you associate new science concepts with old ones sufficiently well to remember them?

_____8. When another student asks you to study together for a science course in which you are experiencing difficulty, can you be an effective study partner?

_____9. When problems with friends and peers conflict with schoolwork, can you keep up with your science assignments?

_____10.When you feel moody or restless during studying science, can you focus your attention well enough to finish your assigned science work?

_____11. When you find yourself getting increasingly behind in a science course, can you increase your study time sufficiently to catch up?

_____12. When you discover that your science homework assignments for the semester are much longer than expected, can you change your other priorities to have enough time for studying science?

_____13. When you have trouble recalling a science abstract concept, can you think of a good example that will help you remember it on the test?

_____14. When you have to take a science test in an area of science that you dislike, can you find a way to motivate yourself to earn a good grade?

_____15. When you are feeling depressed about a forthcoming science test, can you find a way to motivate yourself to do well?

_____16. When your last science test results were poor, can you figure out potential questions before the next test that will improve your score greatly?

_____17. When you are struggling to remember the technical details of a concept for a science test, can you find a way to associate them together that will ensure recall?

_____18. When you think you did poorly on a science test you just finished, can you go back to your science notes and locate all the information you had forgotten?

_____19. When you find that you had to "cram" at the last minute for a science test, can you begin your test preparation much earlier so you won't need to cram next time?

## APPENDIX D: MICROANALYTIC PROCESSES MEASURE OF SELF-REGULATED LEARNING (FROM DIBENEDETTO, 2010)

Thank you for agreeing to do this study. Before we begin, I need to return your consent form and ask you to take a minute to review it. …. Do you have any questions?

OK, great. Now before we actually begin, can you tell me if any of the other students who already participated have said anything to you about the study?

Yes_____No_____

*If yes,*

Can you tell me what they told you?

______________________________________________________________________

"*You are going to be presented with an electronic encyclopedia, which contains textual information, diagrams, and a digital 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, I will be asking you questions while you read and search Encarta. I'll be here in case anything goes wrong with the computer and the equipment if you don't have any questions we will begin*?"

(Give student access to the HLE and begin tutorial)

OK, before we begin I'm going to ask you a few quick questions. Please respond by pointing to the number on the scale that applies to you.

Q.1 How self-confident do you feel in your capability to completely learn and remember all of the material on the circulatory system from this activity?"

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100

Not sure at all — somewhat unsure — pretty sure — very sure

Q.2. How self-confident do you feel in your capability to completely learn a new topic in science?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100

Not sure at all — somewhat unsure — pretty sure — very sure

Q.3. How interested are you personally in learning about the circulatory system?

|…...……….|………...…|……..……….|…...……….|

1 really not interested — 2 not interested — 3 neutral — 4 interested — 5 really interested

Q.4. How interested are you personally in learning about new topics in science?

|…...……….|………...…|……..……….|…...……….|

1 really not interested — 2 not interested — 3 neutral — 4 interested — 5 really interested

Q.5. "How important is information about circulatory systems to your future?"

|…...……….|………...….|……..……….|…...……….|……..……….|……..……….|

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| really unimportant | unimportant | somewhat unimportant | neutral | somewhat important | important | really important |

Q.6. "How important is information about science to your future?

|…...……….|………...….|……..……….|…...……….|……..……….|……..……….|

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| really unimportant | unimportant | somewhat unimportant | neutral | somewhat important | important | really important |

Q.7. "What percentage grade will you set as your goal on the tests of knowledge?"

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

OK, you have access to the activity that contains the material you are going to be tested on. As I said, it is really important that you do as well as you can on the seasons test. After you are done studying, tell me when you are ready to take the test and I will give that to you. When I give you the test, I will have to take away the activity and any study material you have. If you have any questions, now is a good time to ask me.

_________ # of questions asked

Q.8. "Oh, I meant to ask you before you get started; do you have any particular plans for how to study about the circulatory system?"

*If yes:* Can you tell me about them?

*If no:*Do you have any particular methods of studying if you find the material difficult to understand or remember? Can you tell me about them?

Skimming the passage □

Rereading□

Reading aloud□

Underlining□

Highlighting□

Drawing pictures□

Writing down facts□

Studying facts/information□

Other___________________________

_________________________________

No particular task strategy used□

Ok, great, you can go ahead and begin.

**Record the time student begins: ____________________**

After five minutes have elapsed

Q. 9.I noticed while you were studying that you are …. could you explain to me what you are doing and why?

______________________________________________________________________

______________________________________________________________________

Q.10. Do you use these procedures in other courses besides science?

Yes ____ please explain ________________________________________

No ____ please explain ________________________________________

OK, please continue.

**After ten minutes have elapsed.**

Q. 11.I noticed while you were studying that you are …. could you explain to me what you are doing and why?

_______________________________________________________________

_______________________________________________________________

Q.12. Do you use these procedures in other courses besides science?

Yes ____ please explain ________________________________________

No ____ please explain ________________________________________

Q. 13. Why do you think this (whatever approach the student is using) will work?

_______________________________________________________________

_______________________________________________________________

Q. 14. Has doing this helped you in studying for science tests in the past?

If yes: Please explain. ____________________________________________

OK, please continue. Let me know when you are ready to take the test.

Remember, you need to do as well as you can on the test.

**Remove the reading passage and any study material.**

Give the student the test and state:

Please read the test questions without responding to them.

Q.15. "How confident do you feel in your capability to earn 100% on the first test?"

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

Q.16. "How confident do you feel in your capability to earn 100% on the second test?"

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Not sure at all | | somewhat unsure | | | | pretty sure | | very sure | |

OK, you may take the test.

**Record the following:**

Begin time: _________

What is the student doing while taking the test:

______________________________________________________________________

End time: _________

**Upon completion of the test:**

Q. 17. How confident do you feel about your answers to the first test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100
Not sure at all — somewhat unsure — pretty sure — very sure

Q. 18.“What score do you think you got on the first test?”

|…..…….|…..…….|…..…….|…..…….|……..….|…..…….|…..…….|…..…….|…..…….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Q. 19. How confident do you feel about your answer to the second test?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

10 20 30 40 50 60 70 80 90 100
Not sure at all — somewhat unsure — pretty sure — very sure

Q. 20.“What score do you think you got on the second test?”

|…..…….|…..…….|…..…….|…..…….|……..….|…..…….|…..…….|…..…….|…..…….|

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

**Grade the second test question and show the question grade to the student and observe their responses. Record reactions:**

____________________________________________________________

____________________________________________________________

Q.21. How well did you learn the about the circulatory system?

|……….|………|……….|……….|……….|……….|……….|……….|……….|

| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| poorly | | pretty poorly | | | | pretty well | | | very well |

Q.22.What led you to that conclusion?

_______________________________________________________________

_______________________________________________________________

Q.23. Why do you think you didn't do better on this particular question on the circulatory system? Please explain.

_______________________________________________________________

**For students who earn 100% on this test question:**

Q.24 Why do you think you did so well on this particular question on the circulatory system? Please explain.

_______________________________________________________________

Q.25. How satisfied are you with your score on the second test?

|…...……….|………..….|……..……….|…...……….|……..……….|……..……….|

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| very dissatisfied | dissatisfied | somewhat dissatisfied | neutral | somewhat satisfied | satisfied | very satisfied |

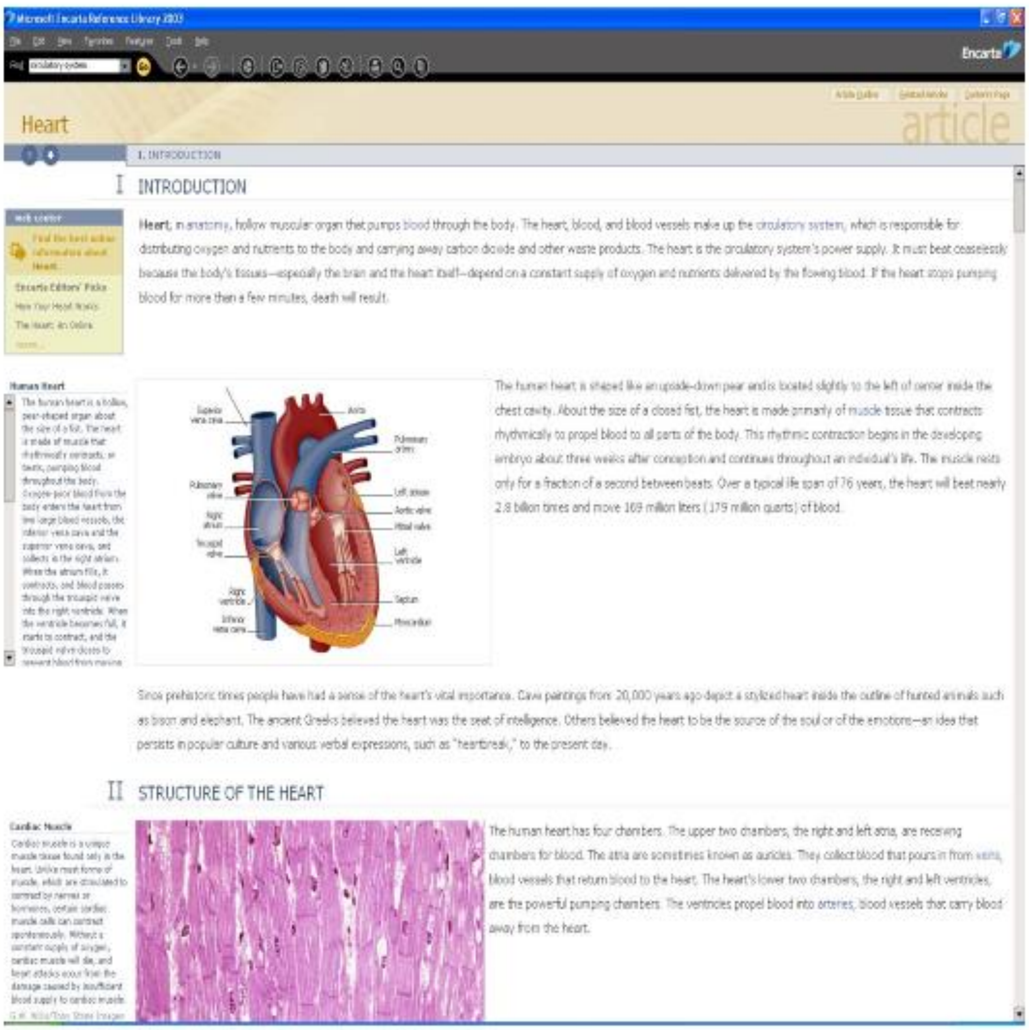
Q.26. "Is there anything you would do differently on this particular test if you were given another chance to study the material? Please explain."

______________________________________________________

OK, great. The last thing I need you to do is to complete this short survey.

***Thank student for participating and escort back to their classroom.***

# APPENDIX E: SCREEN SHOT OF ENCARTA$^{TM}$ (2003) HYPERMEDIA LEARNING ENVIRONMENT



## APPENDIX F: INFORMED CHILD CONSENT AGREEMENT

**What type of thinking processes do adolescent students use in a computer environment as they learn about science?**

**INFORMED ASSENT FORM: for Minor**

**RESEARCH STEPS**

We are going to see how you plan your work, study, and reflect when you learn about a complex science topic from a computer. If you agree to be a part of our study, you will be asked to take a pre and post-test, answer a couple of questions as you use a computer program, and take a questionnaire. The research will take place after regular school hours at Thoreau Middle School and it will not interrupt any class activities. We expect you will spend no more than one hour participating in this study. With your permission, some of your answers will be taped to make sure we are accurate. Some of your answers may be used in scholarly or educational journals.

**RISKS**

There are no risks for being a part of our study.

**BENEFITS**

There are no direct benefits to students for participating in this study.

**CONFIDENTIALITY**

The data in this study will be kept private and your name will not be linked with your responses in any future publications of this research. All tests and tapes will be kept in a locked cabinet.

**PARTICIPATION**

You do not have to participate in this study. You may leave from the study at any time and for any reason. If you decide not to participate or if you leave the study, you will not be punished. There are no costs to you or any other party.

**ALTERNATIVES TO PARTICIPATION**

If you choose not to participate in the study you will participate in normal after school activities.

**CONTACT**

This research is being done by Dr. Anastasia Kitsantas at George Mason University. She may be reached at (703) 993-2688 for questions. You may contact the George Mason University at 703-993-4121 if you have questions. This research has been reviewed by George Mason University.

**CONSENT**

Please check the appropriate boxes and then sign and date this form. Thank you.

☐ I agree to participate in this study.
☐ I agree to be recorded in this study.

______________________________
Name

______________________________
Date of Signature

## APPENDIX G: INFORMED PARENT CONSENT AGREEMENT

**What type of thinking processes do adolescents use in a computer environment as they learn about science?**

**INFORMED CONSENT FORM: Parent(s) or Legally Authorized Representative**

**RESEARCH PROCEDURES**

The goal of this study will be to answer the question "What thinking processes do adolesent students use in a computer environment as they learn about a complex science topic? If you allow your child to take part, they will be asked to complete a pre and post test, explore a computer task on the circulatory system, and then answer a questionnaire. The interviews will be approximately one hour in length, take place after regular school hours at Thoreau Middle School, and will not interrupt any class activities. With your permission, responses will be audio taped. Some of your child's answers may be used in scholarly and educational journals.

**RISKS**

There are no foreseeable risks to your child for participating in this research.

**BENEFITS**

There are no benefits to your child as a participant other than to further research in determining the types of thinking processes they use in a computer environment as they learn about a complex science topic.

**CONFIDENTIALITY**

Each student will be identified by their first and last name which will be placed at the top of each document. All documents will be placed in a locked folder until all data has been organized and analyzed at which point it will be destroyed. Your child's name will not be linked with their responses in any future publications of this research. We will erase the tapes once we have completed data analysis.

**PARTICIPATION**

Your child's participation is voluntary, and you may withdraw him or her from the study at any time and for any reason. There are no costs to you or any other party.

**ALTERNATIVES TO PARTICIPATION**

Students that are not participating in the study will participate in their normal after school activities.

**CONTACT**

This research is being conducted by Dr. Anastasia Kitsantas at George Mason University and she may be reached at (703) 993-2688 for questions. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your rights as a participant in this research.

**CONSENT**

Please check the appropriate boxes and then sign and date this form. Thank you.

☐ I agree to allow my child to participate in this study.

☐ I agree to allow my child to be recorded in this study.

______________________________

Name

______________________________

Date of Signature

# APPENDIX H: GEORGE MASON UNIVERSITY INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

GEORGE MASON UNIVERSITY

Office of Research Integrity and Assurance
Research Hall
4400 University Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-4121; Fax: 703-993-9590

TO: Anastasia Kitsantas, College of Education and Human Development

FROM: Aurali Dade
Assistant Vice President, Research Compliance

PROTOCOL NO.: 8447 Research Category: Doctoral Dissertation

PROPOSAL NO.: N/A

TITLE: Self-Regulated Learning Processes used in a Hypermedia Environment learning about Science

DATE: November 30, 2012

Cc: Brian Mandell

On 11/30/2012, the George Mason University Institutional Review Board (GMU IRB) reviewed and approved the above-cited protocol following expedited review procedures.

Please note the following:

1. Copies of the final approved consent documents are attached. You must use these copies with the IRB stamp of approval for your research. Please keep copies of the signed consent forms used for this research for three years after the completion of the research.
2. **Any modification to your research (including the protocol, consent, advertisements, instruments, funding, etc.) must be submitted to the Office of Research Integrity & Assurance (ORIA) for review and approval prior to implementation.**
3. Any adverse events or unanticipated problems involving risks to subjects including problems involving confidentiality of the data identifying the participants must be reported to the ORIA and reviewed by the IRB.

The anniversary date of this study is 11/29/2013. **You may not collect data beyond that date without GMU IRB approval.** A continuing review form must be completed and submitted to the ORIA 30 days prior to the anniversary date or upon completion of the project. In addition, prior to that date, the ORIA will send you a reminder regarding continuing review procedures.

If you have any questions, please do not hesitate to contact me at 703-993-5381.

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