Fostering historical knowledge and thinking skills using hypermedia learning environments: The role of self-regulated learning

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ABSTRACT

In this study, we examined how high-school students utilized a hypermedia learning environment (HLE) to acquire declarative knowledge of a historical topic, as well as historical thinking skills. In particular, we were interested in whether self-regulated learning (SRL; Winne & Hadwin, 1998; Zimmerman, 2000) processing was related to the acquisition of declarative knowledge and historical thinking. We found that, using the HLE, participants did learn from pretest to posttest, and that they most often engaged in strategy use SRL processes. However, the frequency of participant use of planning SRL processes, not strategy use, was predictive of learning. This study has implications for how educators use HLEs to foster historical thinking skills, and suggests that scaffolding planning skills may facilitate students’ use of computers as cognitive and metacognitive tools for learning (Azevedo, 2005; Lajoie, 2000).

Keywords:
Teaching/learning strategies
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Multimedia/hypermedia systems

1. Introduction

Despite the proliferation of computer-based learning tools in United States high schools, not enough is known about how students can be best positioned to take advantage of these affordances (Lajoie & Azevedo, 2006). Educators strive to foster conceptual understanding, rather than just declarative knowledge (Schraw, 2006), particularly in subject areas like history, where there is an impetus to foster historical thinking skills, rather than simple historical recall abilities (VanSledright & Limón, 2006). Computers are particularly attractive pedagogical tools because they can present multiple representations of complex content, and allow users more control over how they interact with the material (Jonassen, 1996; Lajoie, 2000). However, research suggests that students do not benefit from the use of computers in classrooms unless they are effective at self-regulating their learning (Azevedo, 2005). This research on self-regulated learning (SRL) and computer use has primarily examined learning in science and mathematics (e.g., Azevedo, Cromley, & Seibert, 2004; Greene & Azevedo, 2009; Kramarski & Gutman, 2006), whereas there is little research on these phenomena in the context of history learning (e.g., Wolters & Pintrich, 1998; Wolters, Yu, & Pintrich, 1996).

In this study, we sought to examine how students utilized a hypermedia learning environment (HLE) to acquire knowledge of a historical topic and historical thinking skills. In particular, we were interested in whether students learned using the HLE, what specific self-regulated learning processes they enacted while using the HLE, and whether self-regulated learning processing was related to the acquisition of historical knowledge and thinking skills. This study has implications for how educators use HLEs to foster historical thinking skills, and the degree to which SRL skills enable students to use computers as cognitive and metacognitive tools for learning (Azevedo, 2005; Lajoie, 2000).

1.1. Historical thinking

The incorporation of the Internet in high school classrooms has sparked a new interest in engaging students in historical thinking. This interest stems from the access the Internet provides to digital libraries. These digital libraries are home to thousands of primary sources. This unprecedented availability of historical documents has prompted teachers to engage students in historical thinking activities and prompted researchers to investigate the process of historical thinking.

Historical thinking is an active and dynamic learning process that calls upon students to engage in historical inquiry, where multiple sources are evaluated in terms of their adequacy, and a historical narrative is created based upon an integration of these multiple sources (Hicks & Doolittle, 2009). Levstik (1996) defined historical thinking as a:
shift from an emphasis on a ‘story well told’ (or, the story as told in the textbook), to an emphasis on ‘sources well scrutinized’...[Where students] pose questions, collect and analyze sources, struggle with issues of significance, and ultimately build their own historical interpretations (p. 394).

This meaning-making process requires teachers and students to interact with primary and secondary historical documents to reconstruct the past. Unfortunately, traditional methods dominate the teaching and learning of history in the K-12 classroom and there has been relatively little research conducted in the area of high-school students’ historical thinking (Baxter, Ferrell, & Wiltz, 1991; Bolick, Hicks, Lee, Molebash, & Doolittle, 2004; Goodlad, 1984; McNeil, 1986; Shaver, Davis, & Helburn, 1979; Wiley & Race, 1977). This void in the literature is due to the depth of historical knowledge and the repertoire of skills one must possess to engage in historical thinking. The existing research demonstrates that historical thinking is often perceived as being too advanced for high-school students (Riley, 1999; VanSledright, 2002; Wineburg, 2001). Levstik and Barton’s (2001) research on historical thinking has led them to call for classrooms in which:

students have to learn what it is to ask and answer historical questions—how to find information, how to evaluate sources, how to reconcile conflicting accounts, how to create an interpretive account. And students certainly must learn what the authentic application of historical knowledge looks like. They must see how history can explain the present and they must see this in the most authentic of ways—through the comparison of conflicting ideas about the nature and significance of the past (p. 14).

HLEs hold the potential to be a powerful means of promoting historical thinking because they are versatile environments in which multiple perspectives and sources of information can be presented in an efficient manner (Jonassen, 1996). HLEs are efficient because they can provide easy access to hundreds or even thousands of sources of information through one portal, the computer browser. However, while HLEs are becoming increasingly popular pedagogical tools (Lajoie & Azevedo, 2006), little is known about the cognitive and metacognitive processes high-school students enact while using history-based HLEs, and how they influence students’ historical thinking (Kingsley & Boone, 2008).

1.2. Hypermedia learning environments

HLEs are computer-based tools where the information is presented as a series of nodes that can be selected by the user (Dillon & Jobst, 2005). These nodes can include a variety of information and means of representing phenomena including animation, video, audio, diagrams, and text (Jonassen, 1996; Scheiter & Gerjets, 2007). These nodes are connected with hyperlinks, allowing the user to determine which representations are selected, and in what order. Jacobson and Archodidou (2000) outlined four ways that hypermedia learning environments benefit students who wish to learn about complex topics. First, students can access information in HLEs in a non-linear manner, allowing them to only attend to representations they find most helpful at a given moment. Second, HLEs allow for a high degree of user control, allowing students to construct their own knowledge by selecting representations they find helpful, and reiterating through representations as needed. Third, hypermedia learning environments are often more intrinsically interesting than traditional teaching techniques because they can include pictures, video, and interactive features in addition to the presentation of content in text or audio format (Jonassen, 1989). Finally, the multiple representations (e.g., text, pictures, videos) in HLEs can be used to present users with a comprehensive treatment of complex systems and ideas that are otherwise hidden from direct observation (Delany & Gilbert, 1991; Mayer, 2005).

Unfortunately, the vast potential of HLEs remains largely unrealized. Most empirical research has found that without proper preparation and support, students learn little from HLEs on their own (Azevedo & Cromley, 2004; Greene & Land, 2000; Shapiro & Niederhauser, 2004). Research has shown that two reasons why students fail to learn with HLEs are cognitive overload and student disorientation (Gerjets, Scheiter, & Schuh, 2008). Cognitive overload occurs because the human mind has a limited working memory in which representations can be manipulated and committed to memory (Baddeley, 2001). HLEs often present a large amount of information to users that can flood working memory, particularly when the user has little prior knowledge of the content (Niederhauser, Reynolds, Salmen, & Skolmoski, 2000). Also, HLEs allow a high degree of user control, meaning the user must make decisions regarding which representations to select. This responsibility for selecting representations can lead to disorientation, including confusion about the means of navigation as well as difficulty defining and following a sensible path through the nodes. Models of learning with HLEs have often focused upon ways of assisting learners with the cognitive demands of utilizing and integrating the vast amount of information spread out across the many nodes (Lajoie, 2000).

Models of learning with HLEs have traditionally addressed cognitive aspects of learning, however more recent work has focused upon students’ metacognitive and self-regulatory skills (Azevedo, 2005; Lajoie & Azevedo, 2006). Students often need a large repertoire of strategies to manage the complexity of HLEs, but they also need the self-knowledge and skills to appropriately implement those strategies, and monitor their efficacy. There is ample conceptual and empirical research suggesting that students who enact self-regulated learning processes are better able to overcome or avoid the effects of disorientation and cognitive overload, thus improving their chances of learning complex topics, such as historical events and thinking, while using hypermedia (Azevedo, Guthrie, & Seibert, 2004; Greene & Azevedo, 2007).

1.3. Self-regulated learning

SRL theory was forged in the 1970s out of Bandura’s (1986) Social Cognitive Theory work, and it gained prominence in the 1990s as a way of forwarding student autonomy in the learning process (Dinsmore, Alexander, & Loughlin, 2008). While numerous SRL models abound (e.g., Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000), they share a number of common features. First, as Zimmerman (2008) has said, “SRL is viewed as proactive processes that students use to acquire academic skill, such as setting goals, selecting and deploying strategies, and self-monitoring one’s effectiveness, rather than as a reactive event that happens to students due to impersonal forces” (pp. 166–167). Second, students self-regulate their cognition, motivation, behavior, and context to achieve goals. These goals can be
distal (i.e., completing an assignment) and proximal (i.e., learning the definition of a new word). Finally, SRL processes mediate the relations among student characteristics, task characteristics and performance.

Winne and Hadwin (1998) describe the process of SRL as comprising four phases. In the first phase students integrate their knowledge of the task, their prior knowledge, and their beliefs about the context (e.g., teachers, assignments, classroom environment) into a definition of task. This definition then guides the students in the completion of the second phase of SRL – creating goals and planning. Then the students implement strategies to enact the plan and meet their goals. Finally, students evaluate how successful they were in achieving the goals and adapt their beliefs about themselves, the context, and their learning to maximize their likelihood of success in the future. Each of these phases of learning involves metacognitive monitoring and control, where students evaluate their progress toward completing the phase and make adjustments as needed. The metacognitive nature of SRL also allows for students to iterate back through the phases of learning as needed. For example, students having trouble successfully completing the third phase of learning, strategy use, may decide that their task definition is insufficient, and cycle back to the first phase to reread their understanding of the assignment. SRL skills are numerous and varied, but involve students being reflective, intentional, and autonomous learners who take advantage of affordances to overcome difficulties.

Across numerous tasks and settings, research has shown that learners with strong SRL skills outperform those who lack these skills (Azevedo, 2005; Pressley & Ghatala, 1990; Pressley & Harris, 2006; White & Frederiksen, 2005). Unfortunately, the research has also shown that a majority of students are poor regulators of their learning (Paris & Paris, 2001). These findings have spurred a great deal of research into how SRL skills can be taught and prompted in learning environments. While research has shed some light on the issue, it is unclear as to which specific SRL processes best position students to capitalize upon the affordances in HLEs (Biswas, Leelawong, Schwartz, & TAGV, 2005; Greene & Azevedo, 2009; Witherspoon, Azevedo, Greene, Moos, & Baker, 2007).

1.3.1. Empirical research on SRL, hypermedia, and history

Much of the research on SRL and HLEs has been conducted within the science (Azevedo, Moos, Greene, Winters, & Cromley, 2008), mathematics (Camahalan, 2006; Kramarski & Gutman, 2006), and psychology domains (Winters, Greene, & Costich, 2008). In general, empirical research has demonstrated that students who make plans, implement adaptive strategies, and monitor their progress toward goals are more likely to obtain deep, conceptual understanding of complex topics, as opposed to limiting their understanding to shallow, declarative knowledge (cf., Greene & Azevedo, 2007, 2009). As might be expected given the cognitive demands of SRL, students with high prior knowledge of the content are also more likely to engage in adaptive SRL compared to their peers who lack this prior knowledge (Moos & Azevedo, 2008). Thus, students benefit from scaffolds that foster SRL processing because they rarely effectively self-regulate on their own (cf., Azevedo, Cromley, Winters, Moos, & Greene, 2005; Azevedo et al., 2008). These scaffolds can be humans externally regulating the students’ learning, or computer-based tutors modeling student learning and providing adaptive feedback and scaffolding (cf., Azevedo & Jacobson, 2008; Brusilovsky, 2001; Jacobson, 2006).

Unfortunately, there is little research investigating the relations between SRL and learning in history education (see VanSledright & Limón, 2006 for a review). Findings from research on SRL and learning in science (e.g., Azevedo, 2005) may not be transferable to history content because the two domains differ in significant ways. For example, Frederiksen characterized history as an ill-structured domain, whose problems primarily have a clear, single answer that can be obtained through algorithmic methods. On the other hand, Frederiksen classified history as an ill-structured domain, where problems do not have an objectively correct, single answer. Ill-structured domains place more emphasis on evaluations of the adequacy of explanations to determine whether a problem has been sufficiently answered, and experts in these domains recognize that multiple, equally compelling yet contradictory arguments can exist (Torney-Purt, 1994). The ill-structured nature of history requires students to utilize historical thinking skills, and therefore it is unclear whether the kinds of SRL processes associated with successful learning in science (e.g., Greene & Azevedo, 2007, 2009) are also associated with learning in history. Even less is known about how students learn about history and historical thinking when using an HLE. Specifically, it is unclear what specific SRL processes are most helpful for students learning complex topics and skills such as those covered in historical HLEs. Wolters and Pintrich (1998) and Wolters et al. (1996) have shown a relation between self-regulatory strategy use processes and learning in history, but these studies gathered information on student SRL using notoriously unreliable self-report data (Winne & Jamieson-Noel, 2002).

1.3.2. Measuring SRL

While there are numerous ways to capture SRL data, self-report measures remain the dominant method (cf., Duncan & McKeachie, 2005). Indeed, researchers have demonstrated numerous relations between these measures and various academic and social outcomes (Zimmerman, 2008). Unfortunately, there are two concerns with self-report measures of SRL. First, using self-report instruments implies that self-regulation is an aptitude that can be reported independent of context or the students’ progress in terms of completing the learning task (Winne & Perry, 2000). Self-report measures treat SRL as trait-like, and do not appear to be congruent with process or phase models of SRL (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000) that suggest students enact these processes differently depending upon context and progress. Further, Winne and Jamieson-Noel (2002) have shown that students are poor reporters of their SRL activities, leading to concerns regarding the validity of inferences based upon scores from self-report measures. Winters and colleagues (2008) have suggested that empirical research on SRL focuses on the quality of processing as well as direct examinations of the relations between SRL processes and learning, both necessitating a move away from self-report measures.

In an effort both to capture SRL processes more accurately as well as account for their dynamic nature, we have chosen to utilize think-aloud protocols (Ericsson, 2006; Ericsson & Simon, 1993) rather than self-report measures. Think-aloud, or verbal, protocols involve asking students to verbalize their thought processes as they engage in a learning task. In essence, students “turn up the volume” on the voice inside their head, allowing for researchers to examine their verbalizations for evidence of specific SRL processes such as metacognitive monitoring and strategy use. For example, planning processes can be inferred when students say things like “I think I’ll read this section first, then look at the picture, and then see if I can recite all of the details from memory.” In their 1993 book, Ericsson and Simon reviewed numerous studies demonstrating that think-aloud protocols do not interfere with cognitive processes, so long as individuals are asked to report, and not explain, what they are thinking. Ericsson (2006) provided further research supporting this claim, and the work of Bannert and Mengelkamp (2008) also showed that think-aloud protocols, when focused upon verbalization
and not explanation, do not have an effect on learning outcomes as compared to control conditions. This study builds upon the work of Azevedo, Cromley, et al. (2004), Azevedo, Guthrie, et al. (2004), Azevedo and Hadwin (2005), Azevedo and Jacobson (2008), Greene and Azevedo (2007, 2009), who have analyzed think-aloud protocols data to investigate relations between SRL and learning in HLEs.

1.3.3. Azevedo and colleagues’ model of SRL

Azevedo and colleagues’ (2008) model of SRL integrates the work of Pintrich (2000), Winne and Hadwin (1998), and Zimmerman (2000) into a scheme that can be used to assess students’ SRL process use while learning. A major contribution of this model is the clear connection made between observable SRL cognitive and metacognitive processes that students enact while learning and conceptual models of the phases and areas of self-regulation (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). For example, Winne and Hadwin describe how students enact different cognitive operations (e.g., strategies) depending upon where they are in their learning process. As such, students who are defining the task might activate their prior knowledge regarding the content studied whereas students who are in the process of learning the material might make inferences that are derived from two or more pieces of information. Across all four phases of learning, Azevedo and colleagues’ model identifies over 30 SRL processes, including those addressing the areas of cognition, motivation, behavior, and context. For example, the model outlines processes that are often used for recognizing and managing the large demand placed upon working memory while using HLEs (Gerjets et al., 2008): students might identify when their working memory is being taxed through a judgment of learning (see Appendix A), and utilize a cognitive strategy (e.g., taking notes) to offload some of the content onto an external store. These cognitive and metacognitive processes are identified using a coding scheme that defines how SRL process data can be inferred from think-aloud protocols.

The coding scheme developed by Azevedo and colleagues (2008) focuses upon what Greene and Azevedo (2009) call the micro- and macro-level SRL processes that students enact when learning. Micro-level SRL processes include such cognitive and metacognitive processes as setting sub-goals, judging the adequacy of learning, and using strategies such as drawing or taking notes. Azevedo and colleagues have attempted to create a micro-level SRL code for each cognitive and metacognitive process participants engage in while learning with an HLE, regardless of the relative efficacy of those processes. The goal of the coding scheme is to accurately capture the entirety of participants’ relevant SRL processing, including cognitive and metacognitive processes. Each of these micro-level SRL codes can also be characterized as an instance of a macro-level SRL codes (see Appendix A for a complete list of micro- and macro-level SRL codes). In Azevedo and colleagues’ model there are five macro-level SRL codes or processes: planning, monitoring, strategy use, handling task difficulty and demands, and displaying interest. These macro-level SRL codes align well with the processes that are outlined in conceptual models of SRL, yet often measured using self-report instruments (e.g., Bembenutty, 2007; Bendixen & Hartley, 2003; Kramarski & Gutman, 2006; Sperling, Howard, Staley, & DuBois, 2004). The benefit of using Azevedo and colleagues’ model is that micro- and macro-level SRL processes can be measured in a more objective manner (i.e., think-aloud protocols) than using self-report data, and these processes can then be used as indicators of macro-level SRL processes that have been shown to be predictive of learning performance.

Micro-level SRL processing data give a sense of what specific activities participants engage in while learning with the HLE. Research into micro-level SRL processes can be useful in determining which SRL activities are utilized by participants who show learning gains, and which are used by participants who fail to learn (cf., Greene & Azevedo, 2007; Greene, Moos, Azevedo, & Winters, 2008). These analyses can indicate which micro-level SRL processes are effective in HLEs, and which are not. However, once the effective and non-effective micro-level SRL processes are identified, it can be illuminating to examine how macro-level SRL processing relates to learning gains with HLEs.

An advantage of examining SRL at the macro-level is that it allows for inter-individual differences regarding how students engage in SRL processing. At a practical level, what matters most is that students regulate their learning in ways that benefit them. Focusing on the specific effective micro-level SRL processes chosen might obfuscate relations between SRL and performance because there are most likely idiosyncratic differences regarding which strategies learners find helpful. For example, one student might learn best by memorizing definitions and then coordinating information sources to develop a concept map of a complex system. Another student might learn equally well through the use of drawing and activating prior knowledge. Trying to predict student performance using these micro-level SRL processes might lead to equivocal findings, as no one micro-level SRL process would be a reliable predictor of learning across individuals. However, by counting each of these micro-level SRL processes as an instance of the macro-level SRL process strategy use, relations between the amount of strategy use and learning may be identified. Overall, Greene and Azevedo operationalize macro-level SRL processing as the summation of the effective micro-level SRL processes within each macro-level SRL code (see Appendix A).

Greene and Azevedo’s (2009) model and methodology have not been used in a history context. The little research that exists on SRL in history contexts (e.g., Wolters et al., 1996) focused solely upon macro-level measures of SRL strategy use, captured using self-report measures. Greene and Azevedo’s methodology allows for a much more in-depth analysis of planning, monitoring, and strategy use at both the macro- and micro-levels of SRL processing. Their methodology also utilizes coding of think-aloud protocols, which is more objective than relying upon scores from self-report measures. Thus, given the lack of information regarding how students self-regulate while using an HLE to learn about history, we chose to examine both micro- and macro-level SRL processing, but focus our analyses on the macro-level SRL codes.

1.4. Overview of the current study

In this study, we sought to address the gap in the literature regarding how high-school students use HLEs to learn history content and historical thinking. Given that HLEs and other computer-based learning environments are more and more frequently incorporated in high-school curricula, we felt it important to understand how students used them to learn. There is a lack of research on HLEs and history, particularly in terms of how they affect participants’ acquisition of historical thinking skills. Finally, findings by Azevedo (2005) and others (e.g., Greene & Azevedo, 2009) would suggest that frequent use of SRL processes within an HLE should be a predictor of academic performance. Our specific research questions were as follows:
Research Question 1: Did participants gain knowledge of the Regulator Movement and historical thinking skills while learning with the Documenting the American South hypermedia environment?

First, we wished to examine whether participants gained declarative and conceptual knowledge of the history content, as well as historical thinking skills, while using the HLE. To determine this, we compared the participants’ pretest and posttest scores on measures of both history knowledge and thinking skills. Evidence of learning during the HLE would then allow us to examine potential explanations for this learning, such as participants’ SRL processing.

Research Question 2: What types of micro- and macro-level SRL processes do participants exhibit when learning about history using the HLE Documenting the American South? Given the lack of empirical research utilizing think-aloud protocols to capture participants’ self-regulation while working with an HLE based in history, we first sought to examine what kinds of SRL processes participants used. This information was then used to identify relevant processes to examine in research question 3.

Research Question 3: What are the relations among participants’ prior knowledge (as measured by the pretest), SRL process use, and performance on measures of historical knowledge and thinking (as measured by the posttest)? Having identified relevant SRL processes, with this research question we wished to examine their utility as predictors of participant learning, above and beyond prior knowledge, as measured by the pretest. For this research question we focused upon macro-level SRL processes as a way to summarize participant processing and make the analysis practically feasible. With little prior research to guide us, we did not make a priori hypotheses regarding which processes would be predictive, or the nature of relations among our variables of interest.

2. Method

2.1. Participants

During the 2008–2009 academic year, 40 students at a high school in the southeastern United States participated in this study. The students’ mean age was 16.33 years (SD = .526) and 21 (52.5%) of them were female. Pretest scores confirmed that the majority of the participants had minimal knowledge of the history content, with 85 percent of them receiving the lowest score in terms of their conceptual understanding of the Regulator Movement.

2.2. Measures

Several documents were used to gather information about the participants, including a parental consent form, participant assent form, participant questionnaire, pretest, and posttest.

2.2.1. Participant questionnaire

Each participant was asked to complete a questionnaire gathering basic demographic information (e.g., gender, age, year in school). Additionally, it included items concerning the current history course in which the participant was enrolled and his or her current history course grade.

2.2.2. Pretest and posttest

The paper-and-pencil pretest and posttest used to capture a participant’s prior and gained knowledge of the Regulator Movement were similar to measures successfully used in several previous studies (Azevedo, Cromley, et al., 2004; Azevedo et al., 2005; Greene & Azevedo, 2007; Moos & Azevedo, 2008). The pretests and posttests were identical and included two sections: (a) a multiple-choice/true–false task that required the participant to answer four multiple-choice questions and three true–false questions; and (b) an open-ended essay, asking each participant to, “Please write down everything you can about the Regulator Movement. Be sure to include who was active in the Movement, the actions the participants took, the purpose behind their actions, the results of their actions, and the significance of their actions. Discuss their role in history by providing contextual information about what was happening during their activities.” The first task was intended to measure participants’ declarative knowledge of the Regulator Movement, while the second task captured their conceptual understanding and historical thinking skills.

2.3. Hypermedia learning environment

The participants were asked to learn about the Regulator Movement using a specially-designed subset of a hypermedia learning environment called Documenting the American South. The Regulator Movement took place in North Carolina during the 1860s and 1870s. It was a citizen uprising against public officials. Documenting the American South is one of the earliest and best-known digital libraries. Developed by the University of North Carolina at Chapel Hill University Library, Documenting the American South (http://docsouth.unc.edu) is a collection of more than 1000 texts, images, and audio files related to southern history, literature, and culture. The specially-designed HLE consisted of nine hypermedia pages (five text document pages and four image pages) related to the Regulator Movement, taken from the larger Documenting the American South digital library. A title page with links to each hypermedia page was created to allow for easy access to each document and image.

The text documents used in this study consisted of 528,604 words divided into 42 sections. These documents included primary and secondary sources. The primary sources were first hand accounts from individuals who experienced the Regulator Movement. The secondary source was a historian’s report on the event. Each image contained a picture and a short caption. The images included historical drawings and photographs of historical sites. The participants navigated within the documents and images using a standard search option (ctrl + F), as well as hyperlinked titles for each document. Participants were told they could navigate to any part of the HLE they wished, but that they could not access the internet. Participants were limited to working with the selected documents and images, and could not access the rest of the Documenting the American South HLE.
2.4. Procedure

We used a procedure similar to that used by Azevedo and Cromley (2004), Azevedo, Guthrie, et al. (2004), and Greene and Azevedo (2009). The first author trained four graduate students (including the third author), one undergraduate student, and the second author in the experimental procedures. Each session took place in a room with one participant and one or two researchers present. Participants were run individually. First, the participant submitted his or her signed parental consent form. He or she was then informed of the time commitment and told that he or she could opt out at any time without penalty. Once the participant agreed to participate, he or she read and signed an assent form. Then the participant was given as much time as needed to complete the participant questionnaire.

Next, the participant was given 15 min to complete the pretest. The researcher informed the participant to complete each page of the test in the order in which it was provided, without skipping or returning to a previous section. The participant did not have access to any instructional materials during the pretest. Participants were aware that there would be a posttest, but they were given no information about it. In particular, participants did not know that the posttest was identical to the pretest.

Once the pretest was complete, the participant received instructions about the learning task and goal, and was given a tour of the HLE. The participant was told that the learning task involved using the HLE to learn as much as possible about the Regulator Movement in 25 min focusing on this learning goal, which was presented in written form and read aloud to the participant: “Make sure you learn about who the Regulators were, when the Regulation Movement occurred, and the significance of the Regulation Movement.” The learning task instructions and goal remained visible to the participants throughout the 25 min learning session. Next, the researcher introduced the participant to the navigation functions, the articles, and the images available.

Next, the think-aloud process was described in detail to the participant. This included instructing the participant to verbalize all thoughts and reading while navigating through the HLE (Ericsson & Simon, 1993). We were careful to ensure that participants did not explain their thinking, as such verbalizations have been shown to influence cognitive processing (Ericsson, 2006). To ensure the participant was comfortable with think-aloud, the participant practiced the process using a document unrelated to the Regulator Movement and received feedback from the researcher. Participants were asked to think-aloud with the practice document. The researcher provided direct feedback to participants on their thinking-aloud, if necessary. For example, participants who forgot to verbalize their thoughts, and those who failed to verbalize anything beyond the reading of text, were reminded of the purpose of the think-aloud protocol, and asked to continue practicing until the researcher determined they were able to execute the protocol.

Once the participant was reminded of the learning task and all final questions were answered, the 25 min learning session began. During this time the participant was both audio and video taped. The participant was allowed to take notes, although not all did so. If the participant was silent for more than two seconds, the researcher prompted the participant to verbalize his or her thoughts. Verbal time prompts were given to the participant when there were 15, 8, and 2 min remaining. After 25 min all recording was terminated, the participant’s notes (if any) were removed from the testing area, and the HLE was closed.

Finally, the participant was given 15 min to complete the posttest. The participant did not have access to any instructional materials or notes during this time. After the posttest was complete, the participant was debriefed and asked not to share the details of the procedure with other potential participants. The components of the procedure followed in the order described and did not last longer than 90 min.

2.5. Coding and scoring

In this section, we describe the processes of scoring the participants’ declarative measures and conceptual understanding and historical thinking skills essays, as well as the process of segmenting and coding of the participants’ verbalizations. We also discuss the coding scheme used to analyze participant self-regulation.

2.5.1. Declarative measure

The multiple-choice/true–false portion of each participant’s pretest and posttest were scored for accuracy. The scores on these sections of the tests reflect the number of correct answers provided by the participant. Each matching pretest and posttest was scored by a trained graduate or undergraduate student.

2.5.2. Conceptual knowledge and historical thinking skills measure

We adapted Azevedo and colleagues’ (Azevedo & Cromley, 2004; Azevedo, Cromley, et al., 2004; Azevedo, Guthrie, et al., 2004; Azevedo et al., 2005, 2007, Azevedo et al., 2008; Greene & Azevedo, 2009) method for evaluating science content to history as a means of scoring participants’ conceptual understanding and historical thinking skills pretest and posttest essays. We identified 10 different degrees of learning that progressed from no understanding of the Regulator Movement to the most complete understanding. The 10 degrees of learning were: (1) no understanding, (2) mention of people involved, (3) mention of people involved, where the movement took place, and the time period in which the movement occurred, (4) general grievances of the Regulators, (5) mention of one specific grievance, (6) mention of more than one specific grievance, (7) mention of more than one specific grievance and one or more basic purpose or result of the movement, (8) mention of more than one specific grievance and one advanced purpose or result of the movement, (9) 1–8 above and historical context, and (10) 1–9 above and significance of movement (see Appendix B). To score within one of the highest four degrees of learning, participants had to have enacted historical thinking skills, including evaluating multiple sources within the HLE and coming to an understanding of how the historical narrative included multiple perspectives upon the Regulator Movement.

One trained graduate student and one trained undergraduate student individually scored each essay by assigning one of the 10 values (inter–rater agreement was .988; agreement on 79/80 essays). The first author resolved the one disagreement.

2.5.3. SRL coding

All participant sessions were transcribed and coded using a version of Azevedo and colleagues’ (Azevedo & Cromley, 2004; Azevedo et al., 2005) SRL coding scheme that we adapted for this study. The scheme includes 35 micro-level self-regulatory processes used by learners to regulate their learning of historical topics with hypermedia (see Azevedo et al., 2005, pp. 394–397). Each of the micro-level codes is further categorized into one of five macro-level processes: planning (e.g., activating prior knowledge), monitoring activities (e.g., judgment of
learning), strategy use (e.g., drawing, coordinating informational sources, knowledge elaboration), handling task difficulty and demands (e.g., help-seeking behavior), and interest to learn the content or complete the task (see Appendix A). Differences between the Azevedo and colleagues’ (2005) coding scheme and the one used in this study include minor changes to the definitions of some codes, the inclusion of plus and minus variations of some codes, and the addition of four new codes, described later.

The coding scheme described above was used to group participants’ think-aloud verbalizations into segments. To qualify as a codeable segment, a word or group of words had to represent one of the 35 micro-level SRL processes. For example, if a participant said, “Okay, so it went from like North Carolina to some islands... it was almost like triangle trade,” the statement would be divided into two segments, each of which would be considered a different SRL process. “Okay, so it went from like North Carolina to some islands” would be the first segment and would be coded as a summarization of the passage just read (SUM, i.e., the participant verbally restated what was just read or inspected in the hypermedia environment; see Appendix A for a list of codes and explanations) whereas the second segment “it was almost like triangle trade” would be coded as knowledge elaboration (KE, i.e., the participant elaborated on what was just read or seen with prior knowledge). None of the hypermedia text reading was coded, unless the participant re-read a section of five or more words. Some text segments could not be coded as indicative of any of the micro-level SRL processes, and these were labeled as “not codeable” and ignored in the analysis.

Audio tape of each participants’ think-aloud processing was transcribed by trained graduate and undergraduate students. Every utterance, spoken both by the participant and the experimenter, was included in the transcript. Italics were used for sections of the transcript where the participant read directly from the learning environment, so as to easily identify the participant’s codeable thoughts. The audio tapes for two of the participants were inaudible; therefore we did not transcribe the audio data nor were any SRL data gathered for these participants.

Each transcript was coded using both the transcription and the video recording, to ensure accuracy. A total of 950 min (15.83 h) of audio tape was transcribed and coded. The first author trained a group of graduate and undergraduate researchers to code the data. Two researchers coded each transcript, independently, and then came together to compare their coding. Differences were resolved through discussion between the two coders. The total number of codeable segments for all participants was 3539 ($M = 93.13$ per participant).

2.5.4. Inter-rater agreement

As noted above, all transcriptions were coded twice. Two trained researchers independently coded each transcript and then compared their coding. The researchers discussed and resolved all coding differences. If the researchers could not come to agreement on a particular segment, the first author was consulted to make the final decision. Of the total 3539 codeable segments, the first author was consulted on less than 10 occasions. Using this process of coding, there is no need to calculate inter-rater reliability because every codeable segment was evaluated by two separate researchers, with any differences resolved through discussion.

2.6. Missing data

The only missing data in this analysis consisted of SRL process data for two participants, whose audiotapes were too difficult to transcribe due to volume problems. Given that the reason for missing data was technical, we treated these missing data as missing completely at random (Little & Rubin, 2002) and used full information maximum likelihood (FIML) estimation in analyses involving the SRL data (i.e., Research Question 3). FIML, which allows for the inclusion of cases with partial missing data into the analysis, has been shown to be superior to other means of handling missing data such as case-wise or list-wise deletion, or mean imputation (see Enders, 2001).

2.7. Data preparation

The declarative and conceptual knowledge scores were treated as continuous variables. To create macro-level SRL variables, we summed the frequency of each participant’s relevant micro-level SRL processes. However, past research using Azevedo and colleagues’ (2008) coding scheme has shown that certain micro-level SRL processes are not associated with learning and should not be included in the summation (see Azevedo et al. 2008, Greene & Azevedo 2007, 2009 for more information). Further, the results of our examination of the frequency of use of micro-level SRL processes in this study, described in the results section of this article, informed our computation of the macro-level SRL variables. Specifically, for the planning macro-level SRL process variable, we summed the micro-level SRL processes planning and sub-goal, but not recycle goal in working memory. For the monitoring macro-level SRL process variable, we summed all micro-level SRL process variables listed in Appendix A except time monitoring and task difficulty. For the strategy use macro-level SRL process variable, we summed all of the micro-level SRL process variables listed in Appendix A except selecting a new informational source. Overall, past research and theory suggest that these omitted micro-level SRL processes (i.e., recycle goal in working memory, time monitoring, task difficulty, and selecting a new information source) are not indicative of adaptive self-regulation, nor are they associated with learning (Greene & Azevedo, 2007, 2009). For this study we did not use data on participant interest or task difficulty and demands processing.

3. Results

Descriptive statistics were computed using SPSS 16.0. All other analyses were performed using Mplus 5.2 (Muthén & Muthén, 2008).

3.1. Descriptive statistics

Examination of the descriptive statistics for both pretest and posttest shows that, on average, participants’ mean scores increased on both sections of the test – multiple-choice/true–false and conceptual understanding and historical thinking skills essay (see Table 1). The descriptive statistics for the macro-level SRL variables reveal that, on average, participants engaged in strategy use more so than any other macro-level SRL variable ($M = 46.000$). Strategy use also had the largest standard deviation ($SD = 21.206$) and range (Range = 89),
indicating that the frequency of strategy use micro-level self-regulation processes varied greatly among participants. The next most frequently used macro-level SRL process was monitoring ($M = 17.553$). Finally, researcher prompts for participants to think-aloud (i.e., “Please say what you are thinking”) had a mean of 1.50 and a standard deviation of 2.65. A majority of participants were prompted zero times, and the highest total number of prompts given to any participant was 12. Overall, these data suggest that participants did not have trouble following the think-aloud protocol.

### 3.2. Research Question 1: Did participants gain declarative knowledge of the Regulator Movement and historical thinking skills while learning with the Documenting the American South hypermedia environment?

Given the non-normal nature of the declarative knowledge multiple choice and conceptual understanding and historical thinking skills essay data, we used the Wilcoxon Signed Ranks Test to determine if participants learned from pretest to posttest. On average, participants scored statistically significantly higher on the posttest than the pretest on both the multiple choice ($z(40) = -5.339, p < .001$) and essay ($z(40) = -5.390, p < .001$) measures. In terms of practical significance, on the multiple choice tests all participants increased their scores except three, two of whom had equal scores on both the pretest and posttest and one whose posttest score was lower than the pretest score. On the essay, all participants had higher scores at posttest than pretest except for two, whose scores were the same on both tests.

### 3.3. Research Question 2: What types of micro- and macro-level SRL processes do participants exhibit when learning about history using the HLE Documenting the American South?

Table 2 indicates the average frequency of use of each micro-level SRL process across the entire sample. The most frequent SRL process used was SNIS, which involves the participant clicking on hyperlinks (see Appendix A). This is a common but not very illustrative process in

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptive statistics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Mean</td>
</tr>
<tr>
<td>Declarative knowledge pretest</td>
<td>2.120</td>
</tr>
<tr>
<td>Declarative knowledge posttest</td>
<td>5.850</td>
</tr>
<tr>
<td>Conceptual knowledge pretest</td>
<td>2.150</td>
</tr>
<tr>
<td>Conceptual knowledge posttest</td>
<td>6.380</td>
</tr>
<tr>
<td>Planning</td>
<td>1.711</td>
</tr>
<tr>
<td>Monitoring</td>
<td>17.553</td>
</tr>
<tr>
<td>Strategy use</td>
<td>46.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Frequency of micro-level SRL process use across entire sample.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro-level SRL process</td>
<td>Micro-level SRL process</td>
</tr>
<tr>
<td>Planning</td>
<td>Planning (Plan)</td>
</tr>
<tr>
<td></td>
<td>Sub-goal (SG)</td>
</tr>
<tr>
<td></td>
<td>Recycle goal in working memory (RGWM)</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Content evaluation plus (CE+)</td>
</tr>
<tr>
<td></td>
<td>Content evaluation minus (CE−)</td>
</tr>
<tr>
<td></td>
<td>Expectation of adequacy of content plus (EAC+)</td>
</tr>
<tr>
<td></td>
<td>Expectation of adequacy of content minus (EAC−)</td>
</tr>
<tr>
<td></td>
<td>Emotion monitoring (EM)</td>
</tr>
<tr>
<td></td>
<td>Feeling of knowing plus (FOK+)</td>
</tr>
<tr>
<td></td>
<td>Feeling of knowing minus (FOK−)</td>
</tr>
<tr>
<td></td>
<td>Judgment of learning plus (JOL+)</td>
</tr>
<tr>
<td></td>
<td>Judgment of learning minus (JOL−)</td>
</tr>
<tr>
<td></td>
<td>Monitor progress toward goals (MPG)</td>
</tr>
<tr>
<td></td>
<td>Monitor use of strategies (MUS)</td>
</tr>
<tr>
<td></td>
<td>Self-questioning (SQ)</td>
</tr>
<tr>
<td></td>
<td>Time monitoring (TM)</td>
</tr>
<tr>
<td></td>
<td>Task difficulty (TD)</td>
</tr>
<tr>
<td>Strategy use</td>
<td>Coordinating informational sources (COIS)</td>
</tr>
<tr>
<td></td>
<td>Draw (DRAW)</td>
</tr>
<tr>
<td></td>
<td>Emotion regulation (ER)</td>
</tr>
<tr>
<td></td>
<td>Inferences (INF)</td>
</tr>
<tr>
<td></td>
<td>Knowledge elaboration (KE)</td>
</tr>
<tr>
<td></td>
<td>Memorization (MEM)</td>
</tr>
<tr>
<td></td>
<td>Prior knowledge activation (PKA)</td>
</tr>
<tr>
<td></td>
<td>Read notes (RN)</td>
</tr>
<tr>
<td></td>
<td>Re-reading (RR)</td>
</tr>
<tr>
<td></td>
<td>Search (SEARCH)</td>
</tr>
<tr>
<td></td>
<td>Selecting a new informational source (SNIS)</td>
</tr>
<tr>
<td></td>
<td>Self-knowledge activation (SKA)</td>
</tr>
<tr>
<td></td>
<td>Summarization (SUM)</td>
</tr>
<tr>
<td></td>
<td>Taking notes (TN)</td>
</tr>
</tbody>
</table>
terms of how participants approached the content. Far more interesting was the participants’ use of summarization and taking notes strategies. In past research (e.g., Greene & Azevedo, 2007) these processes have not been associated with learning. On the other hand, in this study participants engaged in relatively little knowledge elaboration and made few inferences, two processes that have been associated with learning. There are at least two possibilities for the discrepancies between this study and the previous one by Greene and Azevedo. It may be that the history content required different strategies to learn than those required in the science-based HLE used in Greene and Azevedo’s study. It may also be the case that the participants were not as successful learning this content as participants in previous studies. In support of the latter possibility, the average multiple choice and essay scores were toward the middle of their respective ranges, suggesting that participants did not learn as much as what might be hoped. Participants engaged in less monitoring and planning than strategy use, overall.

The most frequent monitoring activities enacted were those involving the determination that content was not helpful (CE−) and the realization that the participant had not sufficiently understood previously encountered content (JOL−). These processes are participants’ subjective understandings of what is important and what level of understanding is necessary to successfully complete the task. It is encouraging to see participants engaging in these processes, but the question remains as to whether the participants actually used the results of these monitoring activities to inform their subsequent learning.

Overall, participants failed to engage in many planning SRL activities. This is not surprising given that in another domain, mathematics, Schoenfeld (1985) found that students engaged in far less planning than is typically required, and that students who did take more time to plan outperformed their peers who took less time. The lack of planning amongst participants in this sample suggests that it may be beneficial to prompt high-school students to plan before using HLEs.

Finally, using Friedman’s non-parametric test for related samples, we found statistically significant differences among the participants’ use of the three macro-level SRL processes: planning, monitoring, and strategy use [χ²(2, N = 38) = 67.722, p < .001]. Follow-up Wilcoxon Signed Ranks Test pairwise comparisons showed that on average participants engaged in more strategy use than planning [z(38) = −5.236, p < .001] or monitoring [z(38) = −5.374, p < .001], and that they also engaged in more monitoring than planning [z(38) = −5.033, p < .001].

3.4. Research Question 3: What are the relations among participants’ prior knowledge (as measured by the pretest), SRL process use, and performance on measures of historical knowledge and thinking (as measured by the posttest)?

We wished to examine whether macro-level SRL process use mediated the relations between pretest (i.e., prior knowledge) and posttest declarative and conceptual knowledge measures. To do this, we performed a path analysis using Mplus 5.2. All variables were treated as measured, and the MLR estimator was used to account for non-normality. Both the multiple choice and essay posttest scores were regressed onto the three macro-level SRL variables (i.e., planning, monitoring, and strategy use) as well as the pretest scores. The three macro-level SRL variables were also regressed onto the pretest scores. The residual variances of the posttest variables were correlated, as were the pretest variables.

The chi-square test of model fit was statistically non-significant [χ²(3, N = 40) = 6.952, p = n.s.] indicating that model had good fit to the data and the estimates of the regression coefficients could be interpreted. Table 3 shows the results of statistical tests for all paths in the analysis. As can be seen, participants’ posttest scores on the declarative knowledge measure were statistically significantly related to their use of planning SRL processes, with those who planned more often having higher predicted posttest scores than those who planned less. No other predictors had a statistically significantly relationship with declarative knowledge posttest score.

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Predictor</th>
<th>Estimatea (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declarative knowledge posttest</td>
<td>Declarative knowledge pretest</td>
<td>−.031 (.184)</td>
</tr>
<tr>
<td></td>
<td>Conceptual knowledge pretest</td>
<td>.248 (.151)</td>
</tr>
<tr>
<td></td>
<td>Planning macro-level SRL process use</td>
<td>.374 (.114)***</td>
</tr>
<tr>
<td></td>
<td>Monitoring macro-level SRL process use</td>
<td>.017 (.170)</td>
</tr>
<tr>
<td></td>
<td>Strategy use macro-level SRL process use</td>
<td>.190 (.118)</td>
</tr>
<tr>
<td>Conceptual knowledge posttest</td>
<td>Declarative knowledge pretest</td>
<td>−.133 (.178)</td>
</tr>
<tr>
<td></td>
<td>Conceptual knowledge pretest</td>
<td>.459 (.162)***</td>
</tr>
<tr>
<td></td>
<td>Planning macro-level SRL process use</td>
<td>.228 (.181)</td>
</tr>
<tr>
<td></td>
<td>Monitoring macro-level SRL process use</td>
<td>−.011 (.157)</td>
</tr>
<tr>
<td></td>
<td>Strategy use macro-level SRL process use</td>
<td>.070 (.166)</td>
</tr>
<tr>
<td>Planning macro-level SRL process use</td>
<td>Declarative knowledge pretest</td>
<td>−.236 (.268)</td>
</tr>
<tr>
<td></td>
<td>Conceptual knowledge pretest</td>
<td>.111 (.148)</td>
</tr>
<tr>
<td>Monitoring macro-level SRL process use</td>
<td>Declarative knowledge pretest</td>
<td>−.047 (.209)</td>
</tr>
<tr>
<td></td>
<td>Conceptual knowledge pretest</td>
<td>.059 (.189)</td>
</tr>
<tr>
<td>Strategy use macro-level SRL process use</td>
<td>Declarative knowledge pretest</td>
<td>−.055 (.244)</td>
</tr>
<tr>
<td></td>
<td>Conceptual knowledge pretest</td>
<td>−.047 (.218)</td>
</tr>
<tr>
<td>Declarative knowledge pretest</td>
<td>Conceptual knowledge pretestb</td>
<td>.636 (0.082)***</td>
</tr>
<tr>
<td>Declarative knowledge posttest</td>
<td>Conceptual knowledge posttestc</td>
<td>.266 (.037)***</td>
</tr>
</tbody>
</table>

a  All estimates are standardized coefficients.

b  This estimate is the correlation between both pretest measures.

c  This estimate is the correlation between the residual variances of these measures.

p < .05.

**  p < .01.

***  p < .001.
Participants’ scores on the conceptual knowledge and historical thinking posttest measures were statistically significantly predicted by their pretest scores. No other predictors were statistically significant predictors of posttest score. However, there was a sizable but statistically non-significant effect \( (b = .228, p = .209) \) that showed planning SRL processes related to conceptual knowledge and historical thinking posttest scores. The small sample size in this exploratory study may be a reason why this effect failed to achieve statistical significance. The r-squared value for the declarative knowledge posttest measure was .221, and for the conceptual knowledge and historical thinking posttest measure was .206, both medium effects according to Cohen’s (1992) standards.

4. Discussion

HLEs have the potential to foster complex understandings of history content and the development of historical thinking skills, but past research would suggest that only those students who are effective at self-regulating their learning are capable of truly benefiting from computer-based learning environments. Our findings in this study support the use of HLEs to foster historical knowledge and thinking skills, as evidenced by high school students’ gains from pretest to posttest after using a computer to learn about the Regulators. We also gained an understanding of what SRL cognitive and metacognitive processes were enacted during college students’ learning, with strategies used much more often than planning or monitoring activities. Our findings suggest that it may be helpful to encourage students to engage in SRL processing beyond strategy use, as illustrated by the fact that planning activities were a statistically significant predictor of learning at posttest, above and beyond prior knowledge. However, the relatively mediocre posttest scores for the sample suggest that these high-school students could have and perhaps should have done more to self-regulate their learning, which hopefully would have resulted in improvement of their historical knowledge and thinking skills. Within the limitations of this study, these findings support the use of HLEs to foster historical thinking and understanding, and provide further evidence for the importance of students’ acquisition and use of effective SRL processes such as planning.

4.1. Limitations

The primary limitation of this study is that it utilizes a non-experimental design. As such, no claims of causality can be made. This study is further limited by the HLE itself, as these findings may not generalize to other computer-based learning environments. In addition, the sample size for this study was relatively small, which may be a reason why certain relations (i.e., planning SRL processes and conceptual knowledge posttest scores) failed to achieve statistical significance. Likewise, the sample was from a single high school, and more research is needed with larger and more diverse samples before definitive claims can be made regarding how historical thinking can be fostered using HLEs.

One threat to the internal validity of our claims is that we used the same measure at pretest and posttest. Given the lack of accepted measures of historical thinking skills and conceptual understanding, specifically in the context of the Regulator Movement, we felt that it would be difficult to justify two different instruments as equivalent measures of these phenomena. In the future researchers should focus on developing item banks that can be used to create non-parallel pretest and posttest measures that are equitable measures of these phenomena. Finally, we analyzed these data using a thoroughly researched coding scheme, but it may be that other methods of measuring SRL would elicit informative findings as well.

4.2. Future directions

Clearly, more research is needed that examines historical thinking, SRL, and HLEs with diverse samples. Causal relations between these phenomena can be examined by instituting scaffolding conditions where some participants learn SRL skills and then comparing those students’ processing and historical thinking to a control group (cf., Azevedo & Cromley, 2004). Likewise, the HLE used in this study was static, but there is a great deal of research to suggest that student learning can be fostered by using adaptive computer environments that diagnose understanding and then scaffold accordingly (cf., Azevedo & Hadwin, 2005; Biswas et al., 2005; Graesser, McNamara, & VanLehn, 2005). For example, an adaptive HLE designed to foster historical thinking could prompt users to make a plan, evaluate sources, locate conflicting evidence, and construct narratives that detail not only the declarative knowledge relevant to the content, but also the motivations of the principals involved. Studies such as this one can inform the design of adaptive HLEs that directly target relevant SRL processes. Finally, studies are needed to determine whether the skills learned using HLEs transfer to other learning tasks not involving computers.

5. Conclusions

In this study we found that high-school students did acquire knowledge about a history topic and historical thinking skills using an HLE, and that participants engaged in many different kinds of SRL processing. This processing was related to learning from pretest to posttest, and a descriptive examination of participants’ SRL indicated that they engaged in strategy use far more than other processes such as planning or monitoring. Interestingly, planning activities were associated with learning, suggesting that more research is needed into how students can be encouraged to plan appropriately when using an HLE to learn about history and historical thinking. Future directions for research based upon this study include examining whether historical thinking skills may be more easily fostered using adaptive HLEs that prompt students’ SRL. Our findings also suggest that interventions designed to bolster SRL skills may have subsequent benefits in terms of learning outcomes.

Acknowledgements

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research was supported by grants from the University of North Carolina at Chapel Hill (Lezley and Jeff Hoffman Seed Grant Research Award; University Research Council Research Grant) awarded to the first and second authors.

Appendix A

See Appendix Table A1.

Table A1

<table>
<thead>
<tr>
<th>Micro-level processes</th>
<th>Description*</th>
<th>Student example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macro-level process: planning</strong></td>
<td>Stating two or more sub-goals simultaneously or stating a sub-goal and combining it with a time requirement. Learner articulates a specific sub-goal that is relevant to the experiment provided overall goal. Must verbalize the goal immediately before taking action.</td>
<td>“First I’ll look around to see the structure of environment and then I’ll go to specific sections of the Regulator Movement”</td>
</tr>
<tr>
<td><strong>Recycle goal in working memory (RGWM)</strong></td>
<td>Restating the goal (e.g., question or parts of a question) in working memory</td>
<td>“… who the Regulators were when the movement occurred, and the significance of the movement”</td>
</tr>
<tr>
<td><strong>Macro-level process: monitoring</strong></td>
<td>Monitoring content relative to goals. Learner states content is or is not useful toward reaching the goal. Expecting that a certain type of representation will prove either adequate or inadequate given the current goal</td>
<td>“The Regulators were in Hillsborough, I need to know that.”</td>
</tr>
<tr>
<td><strong>Feeling of knowing (plus and minus) (FK+/-)</strong></td>
<td>Learner is aware of having read something in the past and having some understanding of it, but not being able to recall it on demand or learner states this is information not seen before</td>
<td>“… I recognize that from the pretest…” or “Governor Tryon - I never heard of him before.”</td>
</tr>
<tr>
<td><strong>Judgment of learning (plus and minus) (JOL+/-)</strong></td>
<td>Learner makes a statement that they understand what they’ve read or becomes aware that they don’t know or understand everything they read</td>
<td>“I get it” or “I don’t know this stuff, it’s difficult for me”</td>
</tr>
<tr>
<td><strong>Monitor progress toward goals (MPG)</strong></td>
<td>Assessing whether previously-set goal has been met</td>
<td>“Those were our goals, we accomplished them”</td>
</tr>
<tr>
<td><strong>Monitor use of strategies (MUS)</strong></td>
<td>Participant comments on how useful a strategy was</td>
<td>“Yeah, taking notes really helped me understand the grievances of the Regulators”</td>
</tr>
<tr>
<td><strong>Self-questioning (SQ)</strong></td>
<td>The learner asks a question relevant to the task, but does not articulate a specific plan to investigate the answer. Indicates that the learner has recognized a gap in understanding</td>
<td>“Was Governor Tryon for or against the Regulators?”</td>
</tr>
<tr>
<td><strong>Time monitoring (TM)</strong></td>
<td>Participant refers to the number of minutes remaining</td>
<td>“I only have 3 min left”</td>
</tr>
<tr>
<td><strong>Task difficulty (TD)</strong></td>
<td>Learner indicates the task is hard or easy</td>
<td>“This is harder than reading a book.”</td>
</tr>
<tr>
<td><strong>Macro-level process: strategy use</strong></td>
<td>Coordinating multiple representations, e.g., drawing and notes</td>
<td>“I’m going to put that [text] with the image”</td>
</tr>
<tr>
<td><strong>Draw (DRAW)</strong></td>
<td>Making a drawing or diagram to assist in learning</td>
<td>“…I’m trying to imitate the image as best as possible”</td>
</tr>
<tr>
<td><strong>Emotion regulation (ER)</strong></td>
<td>Learner actively attempts to control emotional response to some aspect of the learning task</td>
<td>“Okay, I’m going to count to ten to calm down.”</td>
</tr>
<tr>
<td><strong>Inferences (INF)</strong></td>
<td>Making inferences based on what was read, seen, or heard in the hypermedia environment</td>
<td>“I see in this image some people who look poor. Since the Regulators had issue with unfair taxes, maybe they’re the Regulators.”</td>
</tr>
<tr>
<td><strong>Knowledge elaboration (KE)</strong></td>
<td>ELaborating on what was just read, seen, or heard with prior knowledge</td>
<td>[Learner sees the image of Governor Tryon and the Regulators] and states “So I gather from this picture that…”</td>
</tr>
<tr>
<td><strong>Memorization (MEM)</strong></td>
<td>Learner tries to memorize text, diagram, etc.</td>
<td>“I’m going to try to memorize this picture”</td>
</tr>
<tr>
<td><strong>Prior knowledge activation (PKA)</strong></td>
<td>Searching memory for relevant prior knowledge either before beginning performance of a task or during task performance</td>
<td>“It’s hard for me to understand, but I vaguely remember learning about the role of the Regulation Movement in 10th grade”</td>
</tr>
<tr>
<td><strong>Read notes (RN)</strong></td>
<td>Reviewing learner’s notes. Re-reading or revisiting a section of the hypermedia environment</td>
<td>“Grievances of the Regulators were unfair taxes – unfair taxes.”</td>
</tr>
<tr>
<td><strong>Search (SEARCH)</strong></td>
<td>Searching the hypermedia environment with or without the Encarta search feature</td>
<td>“I’m reading this again.”</td>
</tr>
<tr>
<td><strong>Selecting a new informational source (SINS)</strong></td>
<td>The selection and use of various cognitive strategies for memory, learning, reasoning, problem solving, and thinking. May include selecting a new representation, coordinating multiple representations, etc.</td>
<td>“I’m going to type grievances in the search box”</td>
</tr>
<tr>
<td><strong>Self-knowledge activation (SKA)</strong></td>
<td>The learner verbalizes that he or she is (or is not) going to invoke a strategy because it is helpful (or not helpful) to him/her personally</td>
<td>“I’m gonna take notes because that helps me remember things better.”</td>
</tr>
<tr>
<td><strong>Summarization (SUM)</strong></td>
<td>Summarizing what was just read, inspected, or heard in the hypermedia environment</td>
<td>“So James Moore was against the Regulators.”</td>
</tr>
<tr>
<td><strong>Taking notes (TN)</strong></td>
<td>Copying text from the hypermedia environment</td>
<td>“I’m going to write that under grievances”</td>
</tr>
<tr>
<td><strong>Macro-level process: handling task difficulty and demands</strong></td>
<td>Learner seeks assistance regarding either the adequateness of their answer or their instructional behavior</td>
<td>“Do you want me to give you a more detailed answer?”</td>
</tr>
</tbody>
</table>
Appendix B

Necessary features for each level of conceptual understanding and historical thinking skills (based on Azevedo and Cromley, 2004)

1. No understanding.
2. Lists one of the following:
   - NC colonists.
   - Herman Husband.
   - Governor Tryon.
   - Orange and/or surrounding counties.
   - Late 1760–1771s (pre-Revolutionary War).
3. Lists more than one of the following:
   - NC colonists.
   - Herman Husband.
   - Governor Tryon.
   - Orange and/or surrounding counties.
   - Late 1760–1771s (pre-Revolutionary War).
4. Grievances of Regulators – general:
   - 1–3 above.
   - Lists that the Regulators had some kind of grievance or issue.
5. Grievances of Regulators – one specific:
   - 1–4 above.
   - Lists one specific grievance of the Regulators:
     - Excessive taxes (or extortionate fees).
     - Dishonest sheriffs.
     - Wanted better economic conditions.
     - Wanted a system that did not benefit only colonial officials.
     - Wanted to make the colony’s political process more equal.
6. Grievances of Regulators – more than one specific:
   - 1–5 above.
   - Lists more than one specific grievance of the Regulators:
     - Excessive taxes (or extortionate fees).
     - Dishonest sheriffs.
     - Wanted better economic conditions.
     - Wanted a system that did not benefit only colonial officials.
     - Wanted to make the colony’s political process more equal.
7. Grievances of Regulators, purpose of movement, and results of movement (basic):
   - 1–6 above.
   - Lists one of the following:
     - Movement itself was considered to be unsuccessful.
     - Some (approximately 6–7) of the Regulators were hanged; majority pardoned in exchange for their allegiance to the crown.
8. Grievances of Regulators, purpose of movement, and results of movement (advanced):
   - 1–7 above.
   - Lists more than one of the following:
     - Movement itself was considered to be unsuccessful.
     - Some (approximately 6–7) of the Regulators were hanged; majority pardoned in exchange for their allegiance to the crown.
References


