Using Hypermedia to Learn about Complex Systems: A Self-Regulation Model

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INTRODUCTION

Understanding complex systems is a critical part of learning science and necessary for solving real-world problems. However, these systems have many characteristics that make them difficult to understand [1]. For example, in order to have a coherent understanding of the circulatory system, an intricate system of relations must be understood not only locally but system-wide as well [2,3]. Understanding system complexity is sometimes difficult because their properties are not available for direct perception [4]. As such, some educators and researchers have turned to multimedia and hypermedia environments as a potential solution for enhancing students understandings of these complex systems.

This has led to an increased use of hypermedia and multimedia environments for learning and teaching. There is, however, a continuing debate about the effectiveness of such technologies for learning. As such, several cognitive and educational researchers [5,6,7] have recently begun to empirically test the effectiveness of multimedia and hypermedia environments on students learning. This research has begun to address several cognitive issues related to learning, including the role of basic cognitive structures (e.g., multi-modal short-term memory stores), functioning (e.g., mental animation), and multiple representations (text, diagrams, video). In contrast, computer scientists and AI researchers have been addressing issues related to making hypermedia adaptive by experimenting with various existing student modeling techniques [e.g., 8].

However, there are several outstanding issues related to learning and the use of adaptive hypermedia systems designed to foster self-regulated learning (SRL). The *purpose of this paper* is to outline a theoretically-based and empirically-driven research agenda which examines the role of self-regulation in college students learning with hypermedia environments, designed to foster mental model progression of complex systems (e.g., circulatory system). The objectives of this workshop paper and talk are to:

(1) present a theoretical overview of self-regulated learning (SRL),

(2) present empirical research conducted by our team on the role of self-regulation during learning with hypermedia environments (e.g., goal-setting conditions that facilitate and interfere with a learner s ability to self-regulate their learning, shifts in mental models based on several instructional conditions, a model of SRL, dynamics of SRL variables during learning with hypermedia), and

(3) discuss issues and challenges related to designing adaptive hypermedia systems based on our model of SRL (e.g., student modeling, instructional planner, interpretation of help-seeking behavior, etc.).

THEORETICAL FRAMEWORK COGNITIVE-CONSTRUCTIVIST MODEL OF SELF-REGULATION

Self-regulated learners are generally characterized as active learners who efficiently manage their own learning in many different ways [9,10,11]. Self-regulated learning is an active constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior [12]. Models of self-regulation [e.g., 10,12,13] describe a recursive cycle of cognitive activities central to learning and knowledge construction activities (e.g., using a hypermedia environment to learn about the circulatory system). Most of these models propose four phases of self-regulated learning [e.g., 12]. The first phase includes planning and goal setting, activation of perceptions and knowledge of the task and context, and the self in relationship to the task. The second phase includes various monitoring processes that represent metacognitive awareness of different aspects of the self, task and context. Phase three involves efforts to control and regulate different aspects of the self, task, and context. Lastly, phase four represents various kinds of reactions and reflections on the self and the task and/or context.

Even though these SRL models propose different constructs and conceptualizations [for a review see 14], they all share some general assumptions about learning and regulation. There are four assumptions that are included in nearly all models (1) active constructive, (2) potential for control, (3) goal, criterion, or standard, and (4) mediators. First, the *active, constructive assumption* is based on the cognitive perspective that views learners as active, constructive participants in the learning process. It assumes that learners actively construct their own meanings, goals, and strategies from the information available in the external world (e.g., hypermedia environment) as well as information in their own minds (internal environment). Second, the *potential for control assumption* states that learners can potentially monitor, control, and regulate certain aspects of their own cognition, motivation, and behavior as well as features of the environments. According to [12], this does not mean that learners will or can monitor and control their cognition, motivation and behavior at all times. There are biological, developmental, contextual, and individual differences that can interfere with learners ability to regulate. The third assumption, *goal, criterion, standard* assumes that there is some type of criterion or standard against which comparisons are made in order to assess whether the process should continue as is or if some type of change is necessary. As such, it assumes that learners can set standards or goals to strive for in their learning, monitor their progress towards these goals, and then adapt and regulate their cognition, motivation, and behavior to reach their goals. The fourth assumption states that self-regulated activities are *mediators* between personal and contextual characteristics and actual achievement or performance. Our research on learners SRL provides a critical but yet unexplored issue related to learning with adaptive hypermedia systems.

RESEARCH OBJECTIVES

My colleagues and I have recently begun to investigate the effects of goal-setting conditions (e.g., learner-generated versus experimenter-set), on learners ability to self-regulate their learning with hypermedia [15,16, 17]. So far, our research addresses three specific research questions, including: (1) Do different goal-setting conditions influence students ability to shift to a more sophisticated mental model of the circulatory system? (2) How do goal-setting conditions influence students regulation in a hypermedia environment? (3) What are the qualitative differences in students self-regulatory learning in the three goal-setting conditions?

Methods

Our studies combine true-experimental designs (e.g., students randomly assigned to one of three instructional conditions learner-generated sub-goals, bottom-up and top-down) with a think-aloud protocol methodology, where participants are asked to verbalize their thinking processes while they use a hypermedia environment to learn about the circulatory system. The use of a mixed methodological strategy allows us to determine the effects of various instructional interventions on SRL and to examine the dynamic nature of SRL variables during learning with hypermedia. Other relevant methodological aspects will be discussed during the presentation.

Results

It should be noted that our results present an initial research-based study aimed at investigating the nature of self-regulated learning (SRL) with hypermedia. During the workshop presentation, I will discuss the relevant details of our research, including: (1) shifts in mental models (of the circulatory system) from pretest to posttest, (2) role of multiple representations during learning with hypermedia, (3) coding scheme developed to analyze learners self-regulatory behavior, (4) model of SRL with hypermedia, and (5) dynamics of SRL variables during learning.

Shifts in Mental Models Based on Goal-Setting Conditions. Our results indicate that students in the learner-generated sub-goals condition developed (from pretest to posttest) more sophisticated mental models than those in the top-down and bottom-up conditions (88% versus 63% and 63%, respectively). In addition, the learner-generated sub-goals condition led to the highest mean jump or improvement in students mental models (e.g., participant S1 jumped from a model 5 on the pretest to a model 12 on the posttest). On average, students in the learner-generated sub-goals condition jumped an average of 4.3 mental models (SD =2.9) from pretest to posttest, while students in the top-down and bottom-up condition jumped considerably less far (M = 1.6, SD = 2.4 and M = 1.4, SD = 2.7, respectively). A Sign test revealed that the shifts from pretest to posttest, across conditions, were significant (p = .007).

How do Goal-Setting Conditions Influence Students Ability to Self-Regulate Their Learning with Hypermedia. We used the think aloud protocols to develop a coding scheme to analyze students self-regulated learning. Five clusters of SRL variables were extracted and used to examine learners SRL while using a hypermedia environment to learn about the circulatory system. The clusters include:

1. *Planning* (planning, sub-goaling, prior knowledge activation, and recycling a goal in working memory),
2. *Monitoring* (judgement of learning, feeling of knowing, self-questioning, content evaluation, and identifying the adequacy of information available in the hypermedia environment),
3. *Strategy use* (selecting a new informational source, searching, summarization, copying information, re-reading, making inferences, hypothesizing, knowledge elaboration, and evaluating the content as the answer to a question),
4. *Task difficulty and demands* (time and effort planning, help-seeking behavior, task difficulty, control of context, and expectation of adequacy of information), and
5. *Interest statement* (the learner s level of interest in the task/topic/domain).

Chi-Square analyses were performed and revealed significant differences in the distribution of students use of SRL variables related to planning, monitoring, strategy use, and task difficulty and demands, across the three goal-setting conditions. The focus of this subsection is to highlight the learners who participated in the learner-generated condition the high self-regulated learners. The percentages in brackets denote the proportion of variable use (by all the learners in the learner-generated sub-goals condition) based on the total number of coded think aloud protocol segments. Overall, the students in the learner-generated sub-goals condition *planned* their learning of the circulatory system by creating sub-goals, activating their prior knowledge, and planning (16%, 6%, and 3%, respectively). They *monitored* their learning by identifying the adequacy of information, evaluating the content, and self-questioning (5%, 4%, and 3%, respectively). They *controlled* their learning by using the following *strategies* re-reading, selecting a new informational source, summarizing, and elaborating their knowledge (13%, 12%, 6%, and 6%, respectively). These students handled *task difficulty and demands* by seldom using a combination of the five variables belonging to this category (2%, 3%, 2%, 1%, and 2%, respectively). The results of the other two conditions will be contrasted during the paper presentation. Lastly, a process model illustrating the dynamics of self-regulated learning variables will also be presented at the conference.

IMPLICATIONS OF SRL RESEARCH FOR THE DESIGN OF ADAPTIVE HYPERMEDIA ENVIRONMENTS ISSUES AND CHALLENGES

The focus of this paper will be to examine how the results of our research can be applied to the design of hypermedia environments aimed at detecting, modeling, monitoring, and fostering learners self-regulated learning. The following issues will serve as the basis for discussion during the workshop presentation.

- The theoretical and empirical importance of our research in addressing issues relevant to the AI-ED community (e.g., adaptivity, adaptive hypermedia environments, student modeling, instructional planning, self-regulated learning, help-seeking behavior, etc.).

- What are the critical SRL variables used by high self-regulated learners (e.g., planning, sub-goaling, prior knowledge activation, self-questioning, coordination of multiple representations, re-reading, knowledge elaboration, intentional control of time on task, strategic use of tools embedded in hypermedia environments to enhance learning, and motivational aspects related to the learner s interest in the topic)? What techniques can we use to detect, monitor, and model these variables?

- How can we use our model of SRL to inform the design of adaptive hypermedia environments (AHS) designed to detect, monitor, model, and foster learners understanding of complex systems?

- What are the implications of our SRL model in designing the student model, instructional planner, motivational planner, and other system components which may be needed for the system to detect, trace, monitor, model, and foster self-regulated learning? For example, do we need to build an SRL palette (like a help system) which allows learners to indicate that they don t know how to plan their learning of the cardiovascular system? In this case, should the AHS present a student with a planning net that displays a sequence of possible sub-goals that he/she should pursue?

- What if the student indicates low motivation (e.g., low interest in the task/topic/domain)? How can the AHS detect low motivation? Should it ask the student explicitly about his/her motivational state [18,19] on a regular basis or should the student be aware that there is an on-line motivational palette (part of the SRL pallete), which he/she can access and use to modify his/her current motivational level during learning? And even if the AHS is successful in detecting the learner s motivational level, then how should the instructional planner and student model react? Should the student be challenged? How do these decisions affect subsequent learning (including the recursive nature of SRL)?

- What types and levels of scaffolding methods should be designed for low self-regulating learners? According to our research results, these students typically do not plan their learning activities, fail to set appropriate learning goals, fail to monitor their learning, use ineffective learning strategies, and mange their learning by engaging in lots of help-seeking behavior since they have difficulty judging task difficulty, and fail to integrate new information with existing prior knowledge. So, how do we expand the AHS s components (e.g., student model, instructional model, interface, etc.) to determine if a learner is a low or high self-regulator and what effects will this determination have on the detection, monitoring, and fostering of learners overall self-regulation? How do we make our SRL model visible to the learners and flexible enough to allow learners to explore advanced topics related to the circulatory system, including its content and structure. So, how does the environment adapt and exhibit flexibility during learning?

- How can we design ways of detecting, monitoring, and fostering shifts in learners mental models of the circulatory system? Can we have students create concepts maps and/or drawings which can be used to dynamically assess their existing mental model and which will interact with the other system components? For example, what kind of instructional decisions should be made in the case where the AHS has determined that a student has a sophisticated mental model of the circulatory system but has expressed low interest in the task, versus a learner who has a less-sophisticated mental model but has indicated to be highly interested in the topic, but lacks the ability to plan his/her learning and is using ineffective strategies (e.g., blindly searching the hypermedia environment without any goals)? Would making the learner construct an external visual representation of his/her emerging mental model of the domain allow them to self-regulate their learning? Can this information provide the system with another variable with which to make informed instructional decisions? Also, would this external representation, which is visible, and accessible, allow the user and others (e.g., peers, teachers) to share, inspect, critique, modify, and assess the learner s understanding of a complex system?

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