11

This chapter explores the role of self-regulation in learning with computer-based learning environments, and how it can be assessed and fostered.

Self-Regulation of Learning with Computer-Based Learning Environments

Jeffrey A. Greene, Daniel C. Moos, Roger Azevedo

In general, students who self-regulate their learning tend to perform better than students who do not (Schunk and Zimmerman, 2006). *Self-regulation* refers to students' ability to monitor and control their cognition, motivation, behavior, context, and emotion in a dynamic manner over the course of learning (Zimmerman, 2000). Self-regulated learning (SRL) skills are enacted dynamically over the course of learning tasks, and the frequency and quality of their use can fluctuate dramatically (Moos and Azevedo, 2008b). Further, students' SRL skills can vary from one academic domain to another and even from one task to another within a single domain. Thus, while SRL skills are essential for effective learning, they can look quite different depending on the content to be learned, the context of learning, and even the characteristics of the students themselves (Zimmerman, 2000).

Increasingly, computer-based learning environments (CBLEs) are being introduced to the college classroom context, but their value-added depends critically on students' ability to take advantage of CBLEs' capabilities (Azevedo and Witherspoon, 2009). CBLEs are most powerful when students can effectively self-regulate. In this chapter, we explore the various types of CBLEs, the challenges students face in using them to learn about complex topics, and their potential as cognitive and metacognitive tools to support learning. Then we discuss how SRL skills are a key requirement for the successful use of CBLEs and how students' SRL skills can be scaffolded. Finally, we discuss the educational implications of catalyzing the potential

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of CBLEs through the effective implementation of SRL scaffolds and training.

What Are the Various Types of Computer-Based Learning Environments?

The growing number of classroom applications for CBLEs can be attributed, in part, to the ability of CBLEs to display multiple representations of complex topics and the ease with which instructional designs can be modified to meet individual student needs (Niederhauser, 2008). Distinct types of CBLEs include multimedia, hypertext, and hypermedia environments as well as intelligent and adaptive hypermedia systems. *Multimedia* environments offer students access to information in a variety of formats, including text, still images, animation, video, and audio presentations. Stimulating multimedia presentations effectively can meet a myriad of educational goals, including engaging the learner and facilitating learning through the presentation of information in multiple formats (Mayer, 2009). However, multimedia environments do not offer the interactivity that many students have come to expect from CBLEs.

Hypertext environments present text on a computer screen, with parts of the text connected through links. Unlike multimedia, hypertext environments allow students to make decisions about their instructional path by selecting which links to follow (Shapiro and Niederhauser, 2004). Effective learning with these environments requires a high degree of student control because of the hyperlinks (Shapiro, 2008). However, hypertext environments do not provide multiple representations (e.g., pictures or video), limiting the potential of these CBLEs. *Hypermedia* environments, however, offer multiple representations of information that are linked, allowing for student control of these representations. The ever-evolving landscape of technology has produced a variety of forums that have characteristics consistent with the defining traits of hypermedia. Environments such as computer-based encyclopedias (e.g., Encarta), the Internet, and Blackboard have emerged as popular hypermedia environments in the classroom. Hypermedia's combination of the advantages found in multimedia and hypertext offers students a powerful context in which to learn (Jacobson, 2008).

Recent advancements have produced CBLEs that can model, prompt, support, and/or foster students' cognitive, metacognitive, motivational, and/or affective SRL processes. For example, *intelligent and adaptive hypermedia systems*, such as MetaTutor (Azevedo and others, 2008) can keep track of how student deploy, or fail to deploy, SRL processes during learning and then use this information to provide individualized SRL instruction and scaffolding. These intelligent and adaptive hypermedia systems were designed to address a critical issue concerning the use of CBLEs in classrooms: students who do not self-initiate SRL processing often fail to benefit from what CBLEs afford, particularly when attempting to learn about complex topics (Azevedo and Witherspoon, 2009).

Challenges of Learning Complex Topics with Computer-Based Learning Environments

Complex topics, such as the water cycle in physical geology or the human circulatory system in biology, pose challenges to learners because they contain multiple layers of information that often interact in abstract, counter-intuitive, and unobservable ways (Hmelo-Silver and Azevedo, 2006). When designed and used effectively, CBLEs can be powerful tools for learning complex topics by presenting multiple representations of this information that can be manipulated by users in a dynamic manner to further their understanding (Jacobson and Wilensky, 2006). However, CBLEs also present challenges that can stymie even the best learners (Lajoie and Azevedo, 2006).

The many capabilities of CBLEs bring with them an equal number of challenges.

(1) The nonlinear nature of hypermedia environments requires learners to actively manage the multiple representations available to them and determine which representations are helpful given their prior knowledge while simultaneously monitoring the structure of the environment (Scott and Schwartz, 2007). This coordination process, when coupled with the challenge of learning how to navigate within the hypermedia environment, can quickly overwhelm students' working memory, leading to cognitive overload and disorientation, which hinder knowledge acquisition (Gerjets, Scheiter, and Schuh, 2008). Metacognitive processes, such as monitoring emerging understanding and relevancy of content, are required to facilitate this balancing of content comprehension and effective navigation during learning with CBLEs.

(2) The high degree of control in many CBLEs, as afforded by linked multiple representations, requires decisions concerning instructional goals. Setting appropriate subgoals and coordinating informational sources are critical skills that allow students to make effective plans regarding how to spend their time in the CBLE.

(3) CBLEs often necessitate decisions regarding contextual issues (e.g., determining how much support is needed from contextual resources, locating both human and computerized contextual resources, and determining the utility and value of contextual resources). Conceptual research suggests, and empirical research confirms, that effective monitoring, planning, and strategy use skills are necessary to overcome the challenges of hypermedia environments and take advantage of their capabilities (Azevedo, 2005a; Azevedo, Johnson, Chauncey, and Burkett, 2010).

Importance of Self-Regulation When Using Computer-Based Learning Environments

Azevedo and colleagues (Azevedo, 2005a; Greene and Azevedo, 2009; Moos and Azevedo, 2008a) have expanded conceptual models of SRL (e.g., Zimmerman, 2000) to explore the relations between students' SRL processing and learning with CBLEs. Through analyses of students' verbalized thoughts, Azevedo and colleagues have cataloged over thirty specific microlevel SRL processes that students enact while learning with CBLEs (Greene and Azevedo, 2009). For example, some students take notes as a strategy for learning, whereas others summarize and make inferences. For any particular learning task and any particular student, certain microlevel SRL processes may be effective while others may be ineffective. The use of these effective microlevel SRL processes has been shown to be predictive of students' conceptual understanding of complex topics such as the circulatory system (Azevedo, 2005b; Greene and Azevedo, 2007). Using ineffective microlevel SRL processes seems to impede learning.

Each of the microlevel SRL processes can be considered an instance of one kind of macrolevel SRL processing, such as planning, strategy use, or monitoring (Greene and Azevedo, 2009). For example, there are many ways that students might evaluate the efficacy of their studying (e.g., judging their understanding, assessing their progress toward a goal), and each of these microlevel SRL processes can be considered an instance of the macrolevel SRL process known as monitoring. Numerous studies have shown that the frequency of student engagement of macrolevel SRL processing is predictive of learning (Azevedo, Moos, Greene, Winters, and Cromley, 2008; Greene and Azevedo, 2009; Greene, Bolick, and Robertson, 2010; Moos and Azevedo, 2008a). Thus, by operationalizing macrolevel SRL processes, such as planning, into specific, measureable microlevel SRL processes, the work of Azevedo and colleagues has provided a way of studying how SRL processing, in all its forms, influences learning. Taken together, the findings of Azevedo and colleagues have two important implications.

1. Students who are able to self-regulate their learning effectively with CBLEs are likely to acquire a conceptual understanding of complex topics, whereas those who are not effectively self-regulating are not likely to learn.
2. Students who do not self-initiate effective SRL processes should be taught how to discover the microlevel SRL processes that are most effective for them and then utilize them frequently to engage in the macrolevel SRL processes of planning, strategy use, and monitoring.

This second point leads to two important considerations for educators: (1) What are the student characteristics that predict whether students will effectively self-regulate their learning? (2) How can SRL be fostered in students who would otherwise not enact these processes on their own?

Student Characteristics that Influence How Students Self-Regulate Their Learning with Hypermedia

Why do some students self-regulate their learning with CBLEs while others do not? SRL researchers have posited that student characteristics, including motivation and prior knowledge, can have an influence on SRL processing (Zimmerman, 2000). Therefore, it is important for instructors to consider these factors when helping students develop the SRL skills needed to successfully take advantage of the opportunities of CBLEs and learn about complex topics.

Self-efficacy—students' self-perception of their ability to meet the situational demands of the learning task (Bandura, 1997)—is of particular importance when considering how students use CBLEs because it predicts the extent to which they engage in SRL (Moos and Azevedo, 2009a, 2009b). Using complex cognitive and metacognitive processes related to SRL is effortful, and students may engage in these processes only if those students have sufficient self-efficacy (Moos and Azevedo, 2009b). However, research also has suggested that even efficacious students may experience decreases in their self-efficacy as they learn with CBLEs, if the environment proves too challenging to use (Moos and Azevedo, 2008b). In addition to self-efficacy, research also has considered the relationship between students' extrinsic/intrinsic motivation and SRL with CBLEs. The extent to which a student engages in behavior due to pleasure, interest, enjoyment, and/or challenge (intrinsic motivation) and/or external incentives, such as money, grades, and praise (extrinsic motivation; Berlyne, 1960), predicts the quantity and quality of their SRL with CBLEs, particularly in terms of their note taking (Moos, 2009). Therefore, educators must diagnose specific aspects of students' motivation, such as their self-efficacy and extrinsic/intrinsic motivation, and be prepared to support students who lack one or both of these qualities.

Further, individual differences in SRL with CBLEs can be explained by prior domain knowledge. Students with low prior domain knowledge typically rely on strategies during learning with CBLEs (Moos and Azevedo, 2008c). They rarely rely on monitoring processes, such as assessing the relevancy of the content, because they simply do not have the necessary knowledge to engage in these processes. Those with higher prior domain knowledge, however, have the cognitive resources to engage in monitoring during learning with hypermedia. Again, teachers who use formative assessments gain valuable information about their students that can determine whether they are likely to self-initiate effective SRL processes or whether they are likely in need of support from the teacher to do so.

Thus, when students fail to benefit from CBLEs, it is most often due to a lack of SRL skill, knowledge, or motivation. Educators should consider formative assessments of these student characteristics before implementing CBLEs, to determine whether students are likely to be able to take advantage of what CBLEs offer. When such formative assessments reveal that students are unlikely to be able to enact effective SRL processing on their own, educators must consider scaffolding these processes. Student SRL with CBLEs can be fostered through both adaptive human and computerized scaffolding.

Scaffolding Self-Regulated Learning in Computer-Based Learning Environments

Over the last decade and across several universities, researchers have examined the role of cognitive, metacognitive, and motivational self-regulated learning processes during learning with multimedia, hypermedia, and intelligent and adaptive hypermedia learning systems (see Azevedo, 2008; Azevedo and Witherspoon, 2009; Greene and Azevedo, 2007; Moos and Azevedo, 2009b). In general, empirical results show that learning challenging topics with CBLEs can be facilitated if students are provided with adaptive human or computerized scaffolding that addresses both the content of the domain and the processes of SRL (Azevedo, Cromley, and Seibert, 2004; Azevedo, Cromley, Winters, Moos, and Greene, 2005; Azevedo, Greene, and Moos, 2007; Azevedo and Jacobson, 2008). Critically, in adaptive human or computerized scaffolding, the tutor must continuously assess the students' understanding and provide specific, relevant support related to both content and the cognitive and metacognitive processes students use to understand this content. As students gain more familiarity with the content, the CBLE, and their own learning processes, scaffolding can be faded to foster true SRL.

Research has shown that adaptive scaffolding is effective in facilitating learning on several measures of declarative, procedural, and inferential knowledge and mental models. In contrast, providing students either with no scaffolding or with fixed scaffolds, such as a list of domain-specific subgoals, tends to lead to negligible improvements in their mental models and only small gains in declarative knowledge (Azevedo, 2008; Azevedo and others, 2007; Azevedo and others, 2008). This line of research makes clear that when scaffolding students' use of CBLEs, the tutor, whether human or computerized, must diagnose and guide the students' evolving understanding in a manner targeted to the individual learner (Azevedo and others, 2010). Impersonal, fixed scaffolds to "read carefully" or "thinking about what you are learning" are unlikely to lead to gains in knowledge. Instead, teachers are encouraged to think critically about the content, model how they might self-regulate their learning with the material, and encourage students to try out various microlevel SRL processes to see which are most effective for them.

Conclusion

Because CBLEs will continue to proliferate in college classrooms, students must be positioned to take full advantage of these powerful learning contexts. Students who are effective at self-regulating their learning will continue to capitalize on the opportunities of CBLEs while those who lack this ability will find themselves at a serious disadvantage. Educators would do well to consider preliminary and formative assessments of their students' SRL skills, knowledge, and motivation while using CBLEs and then design scaffolding interventions accordingly. Direct instruction from a human may continue to be the gold standard of SRL training for some time, but adaptive, computerized scaffolding tools exist and will continue to develop and be refined over time. Future research should focus on the efficacy of various types and methods of scaffolding in terms of fostering students' *self*-regulated learning and conceptual understanding. Educators and researchers would do well to keep each other abreast of developments and needs in both areas, to maximize students' ability to use CBLEs as cognitive and metacognitive tools.

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JEFFREY A. GREENE is an assistant professor in the Educational Psychology, Measurement, and Evaluation Program in the School of Education at the University of North Carolina at Chapel Hill. His research interests focus on how students' beliefs interact with their self-regulation while learning with computers.

DANIEL C. MOOS is an assistant professor in the Education Department at Gustavus Adolphus College, St. Peter, Minnesota. Most recently, his research focuses on the complex relationship between various motivation constructs and student learning with technology.

ROGER AZEVEDO is a professor in the Department of Educational and Counselling Psychology at McGill University, Montreal, Canada. His research interests include self-regulated learning with computer-based learning environments in complex domains.