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REVIEW ARTICLE

Self-Regulation of Learning within Computer-based Learning Environments: A Critical Analysis

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Abstract Computer-based learning environments (CBLEs) present important opportunities for fostering learning; however, studies have shown that students have difficulty when learning with these environments. Research has identified that students' self-regulatory learning (SRL) processes may mediate the hypothesized positive relations between CBLEs and academic performance. In this review, we identified 33 empirical studies of SRL and CBLEs. We address three research questions: (1) How do learner and task characteristics relate to students' SRL with CBLEs? (2) Can various learning supports or conditions enhance the quality of students' SRL as they learn with CBLEs? (3) What conceptual, theoretical, and methodological issues exist for this growing area of research? We found evidence that specific SRL processes are more often associated with academic success than others and that SRL skills can be supported. We also identified a number of issues that researchers should aim to address in future investigations, including a more comprehensive measurement of facets of SRL and the quality of SRL processes, the seeming disconnect between SRL processes and learning outcomes, and the distinction between self- and other-regulation.

Keywords Self-regulated learning · Computer learning environments

Computer-based learning environments (CBLEs) present important opportunities for fostering learning (Lajoie and Azevedo 2006). However, relatively little focus has been placed on understanding how successful students take advantage of these environments, and research in this area is critical to ensuring that their potential is realized (Mandinach and Cline 2000). It is also the case that many students fail to take full advantage of CBLEs, thus necessitating research into ways of promoting effective use of these powerful but often untapped learning

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environments (Azevedo 2005a; Shapiro and Neiderhauser 2004). This research is particularly important because there have been numerous calls for more considered implementation of technology in education, utilizing pedagogy and content informed by research (e.g., NRC 2003). A number of researchers suggest that one potential mediator between the potential of CBLEs and academic performance is the quality of students' self-regulatory learning (SRL) processes (Azevedo 2005b; Lajoie and Azevedo 2006), and research addressing this relation has flourished in the past 10 years.

With this study, we fill the need for a comprehensive review of the state-of-the-art empirical research investigating the characteristics and conditions that are related to students' SRL with CBLEs. For this review, we identified 33 empirical studies of CBLEs that explicitly investigated SRL as a key construct of interest.

Computer-based Learning Environments (CBLEs)

As the term conveys, CBLEs incorporate various aspects of computer technology to assist individuals in learning for a specific educational purpose (Azevedo 2005a; Chen 1995; Lajoie and Azevedo 2006). The computer technology can afford several different representations of information including text, diagrams, and graphs, among others. CBLEs that use multiple representations of information are a type of multimedia learning environment (Mayer, 2001, 2005). CBLEs that allow for user selection of links between representations or information are called hypermedia environments (Dillon and Jobst 2005), while CBLEs that allow for direct user manipulation of these representations are called simulations or microworlds (Reiber 2005).

Many CBLEs allow for a high degree of learner control and opportunities for self-directed learning (Williams 1996). However, empirical research has shown that students often struggle when using CBLEs (Lajoie and Azevedo 2006). While CBLEs can readily provide multiple representations of information and opportunities to manipulate them, it is often up to learners to determine which representations are most helpful, based on their self-knowledge and beliefs, motivational factors, prior knowledge, task definitions, goals, and strategic knowledge. This careful, considered engagement is indicative of a self-regulated learner (Pintrich 2000; Winne and Hadwin 1998; Zimmerman 2000, 2001). Thus, researchers have turned to SRL models to better understanding what specific SRL processes are associated with learning with CBLEs, how different learner and task characteristics may be related to students' SRL, and how aspects of SRL can be best supported in CBLEs (Azevedo 2005b).

Self-regulated learning models

Both Pintrich (2000) and Zimmerman (2001) have identified common assumptions among the many SRL models in the literature. First, most models assume that learners are active in constructing their own meanings and goals from the various influences in their surrounding environment and their own internal cognitive systems. The second assumption is that individuals are capable of monitoring and controlling the cognitive, motivational, behavioral, and contextual aspects of learning. The third assumption is that this regulation can be constrained or facilitated by intraindividual factors such as biology and development, as well as extraindividual influences such as context. Fourth, SRL models highlight the capability of individuals to set goals for their learning, and it is against these goals that learning is monitored, with control of learning processes influenced by the results of this evaluation. Finally, these models position self-regulated learning as a mediator between personal and contextual influences and actual learning performance.

Zimmerman's (2000, 2001) and Winne and Hadwin's (1998) theoretical models, and Pintrich's (2000) framework of SRL, are often cited in the literature on SRL with CBLEs. These models share important similarities. For example, Pintrich identified four areas or foci of regulatory activity: cognition (e.g., goal-setting, employing and monitoring of cognitive strategies); motivation (e.g., self-efficacy beliefs, value of the task, interest); behavior (e.g., help-seeking, maintenance and monitoring of effort, time use); and context (e.g., evaluation and monitoring of changing task conditions). Zimmerman and Winne and Hadwin also identify these foci, with Zimmerman more focused upon social cognitive factors, and Winne and Hadwin more focused on the cognitive architecture of self-regulation.

All of these theories characterize SRL as a number of phases that follow one another in a loose sequence. The first phase in most models involves planning or forethought, where individuals define the task, set goals, elaborate strategies, and self-motivate. Next, individuals enact their plans and strategies. During this phase individuals self-regulate by engaging in metacognitive monitoring, which can lead to attempts to control the learning process through changes within any of the four foci of self-regulation. For example, an individual may notice that a particular learning strategy (e.g., outlining) does not seem to be leading to retention of the material, and switch to another strategy (e.g., self-questioning). Finally, each of the models includes a self-reflective phase where performance, measured in terms of intrinsic or extrinsic benchmarks, is evaluated, often leading to adaptations to individuals' self-beliefs, beliefs about learning tactics and strategies, and learning contexts. These adaptations may then influence future learning activities. It is also possible that individuals may recycle back through previous stages over the course of learning, particularly when monitoring reveals that the strategies being used are not resulting in understanding or retention. However, this recycling is not likely unless the student has well-developed regulatory skills.

Models of SRL have received a great deal of attention in CBLE research because individuals that can effectively plan, monitor, and control their learning are best positioned to take advantage of the multiple representations and learner control afforded in those environments. Therefore, research has been done regarding how characteristics of the students, task, and learning environment may relate to students' SRL with CBLEs. Research has also focused on ways students' SRL can be supported through prompts, tools, or access to peers or tutors. However, a review of the literature reveals numerous conceptual, theoretical, and methodological concerns that have yet to be resolved.

Research questions

Our review was guided by questions derived from two general directions that research in this area has taken. First, how do learner and task characteristics relate to students' SRL with CBLEs? Second, can various learning supports or conditions enhance the quality of students' SRL as they learn with CBLEs? To situate this article within the larger framework of this special issue, and to identify areas for future research, we address a third research question: What conceptual, theoretical, and methodological issues exist in this burgeoning field of research? In conclusion, we identify issues that researchers should aim to address based on our review of the relevant studies' results, conceptual and theoretical groundings, and methodologies.

Method

To identify studies relevant to this review, we searched the electronic databases PsychInfo and ERIC using key words *self regulat** along with *computer*, *hypermedia*, *multimedia*,

simulation, and *microworld*. Our purpose in this search was to locate studies that self-identified as investigating self-regulated learning. As such, we did not include sub-components of SRL in our search (e.g., planning, goal-setting, metacognition, strategies), with the justification that the term *self regulat** would capture all studies for which self-regulated learning was a main construct of interest. We also examined the reference sections of both theoretical and empirical articles within this literature, and employed a hand search of the tables of contents of: *Computers and Education*, *Journal of Educational Computing Research*, and *Journal of Educational Multimedia and Hypermedia* to identify relevant articles. Our initial search yielded 210 studies.

To cull the articles most appropriate for this review from the 210 we identified as possibilities, we employed the following inclusion criteria: (a) The studies had to be empirical and peer-reviewed (no dissertation studies were included) with a clear description of participants, methods, and results; (b) self-regulation or self-regulated learning had to be a primary focus of the study, as determined by reading the abstract and introduction; (c) the study had to focus on academic learning; and (d) the CBLE had to be the primary instructional modality in the study and had to have affordances beyond what could be offered via traditional instructional means. For example, studies focusing solely upon participants reading word documents online (with no hyperlinks or technology-based supports) were excluded. Through this process we narrowed the corpus to 33 articles.

Results

Our search yielded a wide variety of research studies. The final pool of literature covered a range of developmental levels, from middle school (e.g., Kramarski and Mizrachi 2006a) through graduate level (e.g., Whipp and Chiarelli 2004). The studies were conducted on a range of academic subjects, including art (e.g., De Jong *et al.* 2005), science (e.g., Azevedo *et al.* 2004a), educational technology (e.g., Dabbagh and Kitsantas 2005), mathematics (e.g., Kramarski and Gutman 2005), and psychology (e.g., Van den Boom *et al.* 2004). The studies were conducted in both laboratory and classroom settings, and the time of instruction varied considerably, ranging from a minimum of 5 min (Proske *et al.* 2007) to 3 years (Salovaara 2005). Some of the studies were conducted on students learning individually (e.g., Azevedo *et al.* 2004b), while others were conducted in a collaborative environment (e.g., Winters and Azevedo 2005). The computer-learning environments employed in these studies included computer and web-based learning environments (e.g., Joo *et al.* 2000), multimedia e-learning environments (e.g., Kramarski and Gutman 2005), hypermedia environments (e.g., Schunk and Ertmer 1999), and simulation environments (e.g., De Jong *et al.* 2005). A supplementary table, representing these facets, can be accessed through the journal online. To address the purpose of this review, we organized our results based on our three research questions.

Research question 1: How do learner and task characteristics relate to students' SRL with CBLEs?

Studies that were relevant to this research question addressed the role of different learner characteristics (e.g., prior knowledge; self-efficacy), and task characteristics (e.g., goal structure, level of learner control) and their relation to SRL with a CBLE. As such, we structure our review according to these research foci.

Learner characteristics Studies that have investigated how successful learners have regulated their learning with CBLEs compared to less successful students are pertinent to this section.

Several studies in a line of research by Azevedo and colleagues (Azevedo *et al.* 2004b; Greene and Azevedo 2007; Greene *et al.* 2008) have pursued this inquiry. This body of work has focused on a mixed-methods approach, combining process data in the form of concurrent think-aloud protocols (Ericsson and Simon 1993) with learning outcomes, as students use hypermedia and simulation learning environments. Pintrich's (2000) framework has been used to inform the coding and categorization of process data according to the areas and phases of SRL. These studies by Azevedo and colleagues have shown that the frequency of use of certain SRL processes seem to be consistently associated with learning gains, and therefore they are considered the effective strategies for learning with a hypermedia CBLE (Azevedo 2005b).

For example, Azevedo *et al.* (2004b) compared undergraduate students who made large gains in conceptual understanding during the task to those who made little to no gain and found that a higher proportion of students who made large gains engaged in planning and forethought activities and learning strategies such as summarizing and making inferences. Additionally, students who had smaller gains engaged in more help-seeking and controlling their context than those who were more successful at the learning task. Similarly, Greene and Azevedo (2007) found that middle school students who had large, qualitative shifts in their conceptual understanding from pretest to posttest engaged in active strategic processes such as coordinating informational sources, making inferences, and stating a feeling of knowing, whereas small shift students used more lower-level processes such as controlling the context. Greene *et al.* (2008) found that academically successful, gifted middle school students learned more, on average, from pretest to posttest, than their grade-level counterparts. Further, although they did not differ significantly in behaviors related to planning, monitoring, and interest, gifted level students on average engaged in more effective strategies, such as summarizing and inferring, and did so more often, than did grade-level students.

Whipp and Chiarelli (2004) provide evidence for advanced (graduate-level) students' adaptation of traditional SRL strategies in a web-based course. By analyzing interview transcripts from six graduate students and their instructor, Whipp and Chiarelli determined that these students did indeed use SRL strategies that were adapted to the context, in which students viewed and read hypermedia resources online and participated in asynchronous discussion with their peers and teacher. Further, students expressed beliefs about self-efficacy, goal orientation, and interest during the interviews, which provides support for these key constructs being related to SRL, as explicated in Zimmerman's (2000, 2001) three-phase cyclical model of self-regulated learning model, which the authors used to guide their investigation.

Prior knowledge is a learner characteristic that has been investigated in several studies because of its potential to play a critical role in the forethought or planning phase of SRL (Pintrich 2000). Indeed, Moos and Azevedo (2008b) found that undergraduate students with high prior domain knowledge used significantly more planning and monitoring behaviors than those with low prior knowledge, whereas those with low prior knowledge used more strategies. By analyzing the process data, Moos and Azevedo demonstrated that low prior knowledge students used only a few, specific strategies such as summarizing and notetaking, and they did not often engage in other active strategies such as making inferences or elaborating on their knowledge. MacGregor (1999) found that middle school students who had higher prior knowledge tended to have an internal locus of control (indicating higher self-regulation), connect more concepts as they navigated in a hypermedia environment, have a higher need for cognition, and have higher scores on the learning measure than those with lower prior knowledge.

Two studies used a social-cognitive lens to investigate students' self-efficacy for SRL. In accordance with Zimmerman *et al.* (1992), Joo *et al.* (2000) defined self-efficacy for self-

regulated learning as middle school students' perceptions of their ability to self-monitor, self-evaluate, set goals and plan, self-consequence, and restructure the environment. Similar to past research conducted in non-CBLE settings, Joo *et al.* (2000) found that self-efficacy for self-regulated learning was positively related to academic self-efficacy, self-reported strategy use, and internet efficacy in web-based instruction. In turn, academic self-efficacy predicted academic performance. However, this finding might be moderated by parental education level. Using a questionnaire developed in part from Bandura's (1989) Multi-dimensional Self-Efficacy Scales, Williams and Hellman (2004) found that compared to first-generation college students, second-generation college students reported statistically significantly greater self-efficacy for SRL skills related to internet learning.

Students' goal orientation has also been a topic of interest in SRL and CBLE research. Using a CBLE called gStudy, Nesbit *et al.* (2006) used trace data to investigate undergraduate students' metacognitive monitoring (e.g., notetaking and highlighting activities) in relation to their goal orientations (mastery or performance approach or avoidance; Elliot and McGregor 2001). Both avoidance and approach mastery goal orientations were negatively correlated with highlighting behaviors, while mastery approach was positively correlated with the number of words in elaborative notes, indicating that a mastery goal orientation was related to SRL strategies.

Task characteristics A number of studies have focused on the role that task or instructional characteristics, such as goal structure, learner control, and collaboration, play in students' SRL with CBLEs. Moos and Azevedo (2006) manipulated the type of learning goal (mastery, performance-approach, and performance-avoidance; Elliot and McGregor 2001) provided to undergraduate students to determine what effect this might have on their learning, task value, extrinsic motivation, intrinsic motivation, and SRL processes. No significant differences were found on the motivational variables, as measured via the MSLQ (Pintrich *et al.* 1993), or on the learning measure. In terms of SRL processes, however, those who were provided with a performance-avoidance goal engaged in a greater number of planning processes relative to the students given other learning goals. For this task, planning processes consisted of activating prior knowledge and recycling goals in working memory. There were no statistically significant differences between groups' monitoring, strategy use or management of task difficulty and demands.

Schunk and Ertmer (1999) also found no statistically significant differences in learning outcomes between undergraduate students given either a process goal aimed at learning, or a product goal aimed at performance. However, they did find that process goals led to higher self-efficacy scores, higher self-judged learning progress, and more self-regulatory competence and strategy use than product goals. Comparatively, Stahl *et al's.* (2006) results indicated that when task complexity changes, undergraduate students self-reported changing their plans and goals accordingly while learning with a hypermedia environment. Further, students with more sophisticated epistemological beliefs reported better monitoring of task difficulty and more appropriate control of goal-setting and planning.

Several studies investigated the relation between levels of learner control in a CBLE and students' SRL. Young (1996) and Eom and Reiser (2000) found that middle school students who were classified as having low self-regulated learning skills performed better on a learning outcome measure when they were in a program control condition compared to a learner control condition. In the learner control condition, students classified as having high self-regulatory skills scored better than those classified as having low self-regulatory skills. Similarly, McManus's (2000) found that linear hypermedia environments, with few choices, were a hindrance to highly self-regulating undergraduate learners, whereas nonlinear environments were a hindrance to those who are not as highly self-regulating.

Tasks and instructional methods involving collaborative learning have been an area of investigation in the literature. For instance, Winters and Azevedo (2005) found that high prior-knowledge high school students working collaboratively with low prior-knowledge students did not make significant learning gains during the task, although the low prior-knowledge students did make significant gains from pretest to posttest. Low prior-knowledge students relied on their partners for cognitive and metacognitive support, and in response, the high prior-knowledge students spent time providing this support to their peers, at the possible detriment to their own learning. In another collaborative-learning study, Azevedo *et al.* (2004c) investigated low-achieving high school students' SRL as they worked in dyads. They found that while students did make statistically significant gains from pretest to posttest, the gains were small. Analysis of student discourse revealed that students spent much of their time on a few low-level strategies, such as following procedural tasks and searching the environment, rather than planning, monitoring, or engaging in higher-level strategies.

In a qualitative study looking at the processes of self-regulation for students using a computer-supported collaborative learning (CSCL) environment, De Jong *et al.* (2005) analyzed middle school student discussions for evidence of self-regulatory processes. They found that student dyads (online and in person) regulated each other's learning predominantly by maintaining common ground and using cognitive strategies, but little monitoring or planning occurred. In contrast, Jarvela and Salovaara (2004) and Salovaara (2005) focused on high-school students in a 3-year longitudinal study that compared the use of cognitive learning strategies of students engaged in computer-supported collaborative learning (CSCL) to those in a traditional classroom. These researchers used process data in the form of interviews regarding students' beliefs about self and the learning environment, motivational interpretations on goals, and interpretations about cognitive strategies. Focusing just on the information gleaned about cognitive strategies, Salovaara (2005) found that students engaged in the CSCL used some cognitive strategies associated with deeper processing (i.e., monitoring, creating representations, and sharing information collaboratively) to a greater degree than the group in a non-CSCL (traditional) classroom. But, the comparison group used one surface level strategy (memorization) and one deeper-processing strategy (content evaluation) to a greater degree than the CSCL group. Looking at the data longitudinally demonstrated that students in both conditions increased their reported use of planning, monitoring, selecting information, revising and seeking information, each year.

Summary

The results of these studies indicate that students adapted their SRL processes to web-based learning (Whipp and Chiarelli 2004), and that learner and task characteristics influenced these processes. In particular, high-prior knowledge students tended to engage in greater instances of planning and monitoring than low-prior knowledge students, who in turn tended to use more of just a few select strategies (MacGregor 1999; Moos and Azevedo 2008b). Students who were more academically successful, or who showed higher learning gains during a task tended to use more active learning strategies as compared to students who did not demonstrate as much success learning (e.g., Greene *et al.* 2008). Students working collaboratively supported each other in a regulatory manner (De Jong *et al.* 2005; Winters and Azevedo 2005), but the success of the collaboration depended in part on the ability and prior knowledge levels of the collaborating students (Azevedo *et al.* 2004c).

Patterns in motivation have also been reported. For instance, students' self-efficacy for SRL has been shown to relate positively to other beliefs critical to academic success when using CBLEs (Joo *et al.* 2000). However, it appears that these motivational outcomes may be

influenced by individual differences, such as parental education level (Williams and Hellman 2004). Goal orientation has been shown to be related to specific SRL behaviors, such as notetaking (Nesbit *et al.* 2006), while manipulation of students' goal structure has resulted in the differential use of SRL behaviors. In particular, performance-avoidance goals resulted in more emphasis on planning and forethought activities, such as activating prior knowledge and recycling goals in working memory (Moos and Azevedo 2006), whereas process goals were related to greater self-efficacy and SRL competence (Schunk and Ertmer 1999). Further, students adapted their individual goals and plans in accordance with changes in task complexity (Stahl *et al.* 2006). However, in the two studies we reviewed, differences in goal structure did not influence students' learning outcomes. The level of learner control also appears to be related to students' SRL, with highly self-regulating students having learned more successfully than lower self-regulating students in learner-controlled CBLEs (Eom and Reiser 2000; McManus 2000; Young 1996).

Research Question 2: Can various learning supports or conditions enhance the quality of students' SRL as they learn with CBLEs?

The studies that addressed the second research question investigated the influence of support tools, conceptual supports, and metacognitive supports on students' SRL processes. Support tools are affordances within a CBLE that allow learners to engage and manipulate resources and ideas in the CBLE (e.g., creation, communication, note-taking, and highlighting tools; Hannafin *et al.* 1999). Conceptual supports consist of aids inside or outside of the CBLE that guide students' understanding of content (e.g., static and adaptive scaffolding for conceptual understanding). Metacognitive supports guide students' ways of thinking and reflecting on their task (e.g., training and prompts for self-monitoring and reflection) (Hannafin *et al.* 1999). The justification for this line of research has been to determine what supports can help students learn more effectively with CBLEs. As such, the studies employed specific supports, often tailored to a particular CBLE or task, with little similarity between them.

Support tools Dabbagh and Kitsantas (2005) asked students in an undergraduate distributed learning course to rate how well particular web-based pedagogical tools supported SRL processes that are contained in Zimmerman's model of SRL. Consistent with previous research (Kitsantas and Dabbagh 2004), the authors found that students thought content delivery and creation tools supported goal setting, help-seeking, self-evaluation, and task strategies; collaborative and communication tools supported goal-setting, time planning and management, and help-seeking; administrative tools supported self-monitoring, self-evaluation, time planning and management, and help-seeking; and assessment tools supported task strategies, self-monitoring, and self-evaluation. However, no observational data were included to provide evidence for students' actual use of these tools in relation to their SRL.

In contrast, Narciss *et al.* (2007) and Proske *et al.* (2007) used trace data to investigate how undergraduate students used support tools for SRL in an optional, self-directed, web-based learning environment called Studierplatz. There were active learning tools (e.g., notetaking and dossier-building tools), and strategic monitoring and evaluation tools, in the form of progress and task report features and informative tutoring feedback. They found that total time on tasks predicted performance on the tasks. However, students spent most of their time reading and studying the texts presented in the environment, and only used a few of the tools such as the highlighter and glossary. Students rarely used the notetaking or monitoring tools. Despite the infrequent use of the notetaking and monitoring tools, Proske *et al.* (2007) found

a statistically significant positive correlation between the number of learning tasks correctly completed and the use of notetaking and monitoring tools.

Combining self-report and trace data, Winne and Jamieson-Noel (2002) investigated undergraduate students' calibration of study tactics and achievement while using a multimedia CBLE that provided notetaking and highlighting capabilities to the user. Winne and Jamieson-Noel evaluated students' calibration of study tactics by comparing students' self-reported claims of SRL activity to their actual performance (e.g., instances of planning, setting objectives, highlighting, etc.). They found that students were inaccurate in self-reports compared to their actual behavior. In some cases, students reported using effective tactics such as creating analogies, when in fact they did not. Winne and Jamieson-Noel contend that deficient calibration skills may be one reason why some students are poor self-regulators, and thus ineffective learners, as students who do not closely monitor what they do and how it works will be unlikely to effectively adapt their learning strategies.

Conceptual support Moos and Azevedo (2008a) investigated the influence of static conceptual scaffolds on undergraduates' self-efficacy before, during, and after the task, and on SRL behavior at three points during the task. Students provided with the static conceptual scaffold engaged in greater amounts of planning relative to those with no scaffolds. There were no statistically significant differences in monitoring or strategy use. Over the course of the 40-min task, students in both conditions generally decreased their use of SRL behaviors as they learned, and their self-efficacy diminished as well.

Azevedo *et al.* (2004a) supported undergraduate students' SRL and conceptual understanding via a human tutor that adaptively scaffolded students' learning. Compared to a condition in which students received static scaffolding in the form of subgoals, and a condition in which students received no scaffolding, on average the students who had adaptive scaffolding had statistically significantly larger learning gains from pretest to posttest, and their use of SRL processes differed as well. Specifically, compared to those who did not receive the scaffolding, students in the adaptive scaffolding condition used more of the planning, monitoring, and strategy processes that previous research has shown to be linked to more positive learning outcomes (Azevedo 2005b).

Metacognitive support Research by Kramarski and colleagues has found that SRL guidance in the form of metacognitive self-questioning training has helped foster self-regulated learning skills for mathematics problem-solving using CBLEs (Kramarski and Gutman 2005; Kramarski and Hirsch 2003; Kramarski and Mizrachi 2006a; Kramarski and Mizrachi 2006b). As their method of metacognitive guidance, the researchers used a mathematics instructional method called IMPROVE, which involves giving students self-questioning training focused on comprehending the problem, connecting with prior knowledge, using appropriate strategies, and reflecting on the process.

Using this method, Kramarski and Mizrachi (2006a, b) found that middle school students who were provided the IMPROVE-based support as they worked on algebra problems in an online discussion forum outperformed control groups on math literacy, self-reported strategy use, and interest in learning online. Using both product data, in the form of a test of algebraic thinking, and process data, in the form of think-aloud protocols and a self-report metacognitive questionnaire, Kramarski and Hirsch (2003) found that students using the IMPROVE method during collaborative algebra problem-solving with a computer algebra system (CAS) had higher scores on two aspects of algebraic thinking and metacognitive knowledge afterward than did the control group. Process data indicated that the experimental group also employed more metacognitive behavior while learning than the control group.

Similarly, Kramarski and Gutman (2005) found that students provided with IMPROVE support in a mathematics e-learning environment outperformed students in the control group on procedural problem-solving tasks, on providing mathematical explanations and arguments, and on self-reported self-monitoring strategies.

Azevedo and Cromley (2004) tested whether specifically training undergraduate students to engage in the different phases and areas of SRL prior to the task affected learning and process data. They found that students who received training on effective behaviors in the different areas and phases of Pintrich's (2000) framework of SRL had significantly greater conceptual learning gains from pretest to posttest, and they enacted the those strategies more frequently than those who were not trained. In contrast, a study by Kauffman (2004) found that a web-based environment with self-monitoring prompts did not influence undergraduate students' self-reported metacognitive awareness, even though these students had higher scores on a learning outcome measure than those in a control group. Quite the reverse, Van den Boom *et al.* (2004) found that undergraduate students who were provided with metacognitive reflection prompts and tutor feedback did not differ in learning outcomes compared to those without support, but the addition of a tutor in both the prompt and control condition resulted in higher scores on ratings of self and external regulation.

Summary

The studies in this section demonstrated that while students may have viewed support tools as aiding their SRL (Dabbagh and Kitsantas 2005), they did not always use tools and supports available to them (Narciss *et al.* 2007; Proske *et al.* 2007). Students' poor calibration between what they think they do and what they actually do when learning with a CBLE may provide one explanation for this contradiction (Winne and Jamieson-Noel 2002). Further, static conceptual learning supports in these studies increased planning behaviors (Moos and Azevedo 2008a), while adaptive scaffolding for conceptual understanding as well as SRL increased planning, monitoring, and effective strategy use in concert with improved learning outcomes (Azevedo *et al.* 2004a). In addition, for metacognitive support, the IMPROVE method by Kramarski and colleagues fostered several self-reported aspects of SRL, including self-monitoring, strategy use, and interest, as well as led to positive learning outcomes for middle school students. Finally, Azevedo and Cromley (2004) provided evidence that students can be trained to use particular SRL processes that are considered effective for a given task.

Research Question 3: What conceptual, theoretical, and methodological issues exist in this growing field of research?

The results of the reviewed literature provided evidence for a variety of learner and task characteristics that are related to how students regulate their learning with CBLEs, as well as evidence that some SRL processes can be supported as students learn with CBLEs. However, in the process of developing this review, we identified a number of conceptual, theoretical, and methodological issues present in this body of literature that should be considered as research in this area moves forward.

In most cases, the reviewed articles discussed SRL generally with statements about students actively directing their cognition, motivation, and behavior. However, only 23 of the 33 reviewed articles contain an explanation or recognition of the specific theoretical model or framework used to inform the investigation of SRL. Among these 23 studies, Zimmerman's (2000, 2001) three-phase social-cognitive model, Winne and Hadwin's (1998) information-

processing model, and Pintrich's (2000) framework predominate (see supplementary Table 1). Ten of the 33 reviewed studies appear to treat SRL as a construct without theoretical distinctions by not specifying a particular model, theory, or framework that guided the research. SRL does have theoretical distinctions, largely organized around various cognitive and social-cognitive theories of learning. A lack of theoretical focus can produce a lack of clarity about terminology and definitions in the literature. For example, the terms metacognition and SRL were used interchangeably by Kramaski and colleagues, and MacGregor operationally defined self-regulation as *perception of locus of control*. While this lack of clarity is quite common in the literature associated with SRL more generally (Dinsmore *et al.*, this issue), these varied definitions make building a cohesive body of evidence for SRL with CBLEs very challenging.

Even among studies that employed similar theoretical underpinnings, different aspects of a particular model or theory were addressed. For example, Whipp and Chiarelli (2004) found evidence of students enacting processes from all three phases of Zimmerman's social-cognitive model of SRL during an online course, while Dabbagh and Kitsantas's (2005) research addressed only certain aspects of Zimmerman's model, including goal-setting, self-monitoring, and self-evaluation; they did not address aspects related to motivation, most notably self-efficacy and interest, and how these may have been supported by the various web-based pedagogical tools. On the other hand, Joo *et al.* (2000) placed an emphasis on self-efficacy, but there was less emphasis on other aspects of SRL, such as self-monitoring. These differences in emphasis on various facets of SRL present a challenge to determining how all of them may be interrelated and how they may provide evidence for a particular theory or model of SRL.

Similarly, the focus of many of the reviewed studies—guided by theory or not—was often on just one area of SRL despite language in the study suggesting the variable of interest was the construct of SRL itself. For example, several studies analyzed trace data on just a few specific learning strategies (e.g., Narciss *et al.* 2007; Nesbit *et al.* 2006), failing to capture SRL in its entirety. Because most theories and models define SRL as a recursive and recycling process between different phases, pulling apart individual pieces for scrutiny may not provide an accurate picture of the role the pieces play in the larger construct of SRL. On the other hand, capturing all of SRL within one study may prove exceptionally challenging, if not impossible.

The way in which SRL was measured in a number of these studies may be a limitation to gleaning information about SRL with CBLEs. The majority of studies in this review used a self-report measure to assess SRL. Students' reported use of strategies is not always as accurate as observational techniques (Winne and Jamieson-Noel 2002), and there is some controversy surrounding the validity of scores from common instruments used to measure SRL (e.g., MSLQ; Dinsmore *et al.*, this issue). The incorporation of multiple data sources, in the form of trace data and self-report (Nesbit *et al.* 2006; Winne and Jamieson-Noel 2002), provides a more accurate measure of students' activities than single data source methodologies. For example, Whipp and Chiarelli (2004) relied on self-report, but by including an interview with the students' instructor, they did provide a combination of data sources to provide a more accurate assessment of the effectiveness of students' SRL. As such, they found that one student who self-reported seeking help during the task, which is usually considered an effective strategy, was in turn characterized by the instructor as highly dependent on others, rather than self-regulatory. The self-report data alone would not have provided as accurate a picture of these students.

Azevedo and colleagues have relied on process data in the form of think-aloud protocols (conducted according to Ericsson and Simon 1993) or discourse analysis for identification of SRL processes students use as they are learning, instead of questionnaire or other self-report

methods. These methods have the advantage of capturing students' SRL processes as they occur, and with potentially more accuracy. The next step in using think-aloud protocols may be to examine the quality of the SRL processes that students use. For example, summarizing is usually considered an effective learning strategy. However, the quality of a summarization relative to the goal of the task (e.g., when it is used, how it is conducted, or choice of topic) is as important as simply engaging in the strategy. Azevedo and colleagues may be starting to address this issue, as Moos and Azevedo (2008b) presented qualitative analyses regarding the quality of SRL process use. Further, while think-aloud protocol methodology has been demonstrated to effectively capture cognitive processes, it is not clear how effective it is at tapping motivational processes. Moos and Azevedo (2006, 2008a) included self-report measures on different motivational variables, as well as analyzed think-aloud data, and it is this type of triangulation that will be necessary to see a full spectrum of SRL processes. Further, research in this line is also starting to take into account the dynamic and changing nature of SRL over the course of a task (e.g., Moos and Azevedo 2008a) that no other studies addressed.

Another notable finding from this review is that nearly one third of the reviewed studies did not include any type of measure of student learning. Inherent in the definition of SRL is learning, and claims about particular SRL processes being advantageous in different instructional contexts or for different types of learners of people must include evidence of a relationship with learning outcomes. Similarly, several studies that did include learning outcomes did not find significant differences between experimental groups on those outcomes (e.g., Moos and Azevedo 2006). What conclusions about SRL can be drawn from studies in which students differ in their SRL processes, but these differences appear unrelated to learning outcomes? This is a curious finding given that theoretical models posit a strong relationship between SRL and learning outcomes. The presence of statistically non-significant learning results in experimental studies, and/or the absence of a measure of learning in other studies, makes clear application and generalization of the results of these studies difficult.

Finally, we reviewed a number of studies that employed some type of SRL scaffolding through peers (De Jong *et al.* 2005; Winters and Azevedo 2005; Azevedo *et al.* 2004c); tools embedded in the environment (Narciss *et al.* 2007; Proske *et al.* 2007); or tutors (Azevedo *et al.* 2004a). The scaffolding's impact on students' self-regulated learning was then investigated; however, the question remains as to how much of this regulation was *self-initiated*. If these supports aid students' SRL, the processes students engage in may more accurately be described as *other* rather than *self-* regulated. Support for self-regulation may be necessary in the development of SRL (Fox and Riconscente, this issue), but at what point should these supports be removed or faded (Puntambekar and Hubscher 2005)? Supports that remain present may be providing *other-* as opposed to *self*-regulation (Dinsmore *et al.*, this issue).

Conclusion and Future Directions

The 33 studies in this review provided evidence that different learner and task characteristics (e.g., prior knowledge, goal orientation, learner control) and types of learner support are related to students' SRL when using CBLEs. However, the studies reviewed do not constitute a large body of evidence from which to draw set conclusions about these relationships. Consequently, future research is needed to bolster the trends and relations we have identified in this review. In particular, we found evidence that students who are more academically successful tend to use more effective strategies when learning with a CBLE, and that students with high prior knowledge tend to engage in greater instances of planning and monitoring than those with

lower prior knowledge. Other learner characteristics such as goal orientation also seem to affect students' SRL, but not learning outcomes in the studies we reviewed.

We also ascertained that particular task characteristics may be related to SRL. In particular, providing students a high amount of learner control works well for students who are highly self-regulated and not so well for those who are not. We also found evidence that students may provide regulation for each other as they learn collaboratively, but this may be tempered by factors such as the students' prior knowledge. Moreover, when SRL is supported through tools, students often do not avail themselves of such support, although they tend to perceive themselves as using the supports more often than they actually do. We found evidence that adaptive scaffolding in the form of a tutor appears to support many areas of students' SRL as they learn with a CBLE, as does training students to utilize particular processes and strategies before they engage in a task.

In concert with these trends, our review also identified a number of challenges that remain for researchers pursuing this line of inquiry. First, the majority of studies failed to measure SRL in all its diversity. SRL research encompasses many aspects of learning that have traditionally been investigated in isolation, and this trend appears to continue. By definition, SRL is a cyclical, recursive, and active process encompassing motivation, behavior, and context, and as such, very challenging to capture in its entirety. Zimmerman and Tsikalas (2005) have argued that research on self-regulation in CBLEs has focused on aspects of the forethought and performance phases, specifically metacognitive scaffolding, but has paid little attention to motivation and self-reactions, the more social cognitive aspects of SRL. This issue is further complicated by researchers' failure to align with a particular model or theory of SRL. This creates confusion among definitions and terminology, with constructs such as metacognition being used interchangeably with SRL (Dinsmore *et al.*, this issue). Future research should strive to capture SRL in it entirety.

Second, future research should find ways to supplement or replace self-report measures for SRL. We reviewed several studies that used trace data to supplement or in place of self-report measures. However, trace data collection methods are limited to actions taken with the CBLE environment, and may not capture motivation or interest. Think-aloud methodology also provides a potentially more accurate approach than questionnaire or interview methods. However, it is important to use think-aloud protocols in the way Ericsson and Simon (1993) recommend. Ericsson and Simon have shown that simply asking students to verbalize their thoughts does not interfere with cognitive processing or make participants more reflective; however, asking them to *explain* their cognitions does. Therefore, researchers who utilize think-aloud methodology need to be careful about how they gather think-aloud data, as asking students to say why they are engaging in a certain process may actually influence what kind of self-regulation students enact.

Third, there was a lack of focus on the quality of SRL processes used, and future research should strive to address this. Current research carries an implicit assumption that evidence for a particular behavior occurring is also indicative of the behavior being effective and appropriately applied. Few of the reviewed studies accounted for qualitative differences in behaviors between individuals as well as contexts, in part because this type of investigation is time-consuming and somewhat subjective. Nevertheless, an assessment of quality of SRL process use is critical to furthering our understanding.

Fourth, not all studies linked SRL process use with learning outcomes. This is despite the fact that SRL theories arose to explain differences in learning outcomes, and all models of SRL posit a relationship between learning outcomes and SRL processes. It is our contention that learning outcomes should be addressed in studies investigating SRL; and, if SRL processes are

found to differ between groups despite non-significant learning differences, this should be investigated and explained.

Fifth, many of the studies provided support for different aspects of SRL, either through various tools, through access to tutors or feedback, through prompts, and through peers. Yet, all discussed the processes students used within these contexts as self-regulated learning. If these supports are intended to foster SRL, they should be removed, or faded once independent use is reached. Without the key aspect of fading, it is not clear whether what is supported is truly *self*-regulated learning or what Puntambekar and Hübscher (2005) would call *other*-regulated learning. Another difficulty that researchers face is knowing when and how to fade scaffolding for SRL. Appropriately fading scaffolding is often challenging for even an experienced teacher, let alone a computer. Creating computer-based agents that can diagnose learners' understanding and provide or fade scaffolding appropriately is an extremely difficult task (see Hmelo-Silver and Azevedo 2006; Lajoie and Azevedo 2006 for more detailed reviews of these challenges).

Finally, there is a need to identify whether the efficacy of particular SRL processes varies according to the type of CBLE used (e.g., multimedia, hypermedia, simulation, ITS; Chen 1995). Many of the reviewed studies identified strategies and other processes that were particular to certain CBLE environments. Systematic, sustained research with particular CBLE types, similar to the research being conducted by Azevedo and colleagues with hypermedia, is necessary to tease apart potential differences in SRL that may be affected by context.

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References

Azevedo, R. (2005a). Computer environments as metacognitive tools for enhancing learning. *Educational Psychologist*, *40*, 193–197.

Azevedo, R. (2005b). Using hypermedia as a metacognitive tool for enhancing student learning? The role of self-regulated learning. *Educational Psychologist*, *40*(4), 199–209.

Azevedo, R., & Cromley, J. G. (2004). Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology*, *96*, 523–535.

Azevedo, R., Cromley, J. G., & Seibert, D. (2004a). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology*, *29*, 344–370.

Azevedo, R., Guthrie, J. T., & Seibert, D. (2004b). The role of self-regulated learning in fostering students' conceptual understanding of complex systems with hypermedia. *Journal of Educational Computing Research*, *30*, 87–111.

Azevedo, R., Winters, F. I., & Moos, D. C. (2004c). Can students collaboratively use hypermedia to learn science? The dynamics of self-and other-regulatory processes in an ecology classroom. *Journal of Educational Computing Research*, *31*(3), 215–245.

Bandura, A. (1989). The multidimensional self-efficacy scales. Unpublished test, Stanford University, Stanford, CA.

Chen, M. (1995). A methodology for characterizing computer-based learning environments. *Instructional Science*, *23*, 183–220.

Dabbagh, N., & Kitsantas, A. (2005). Using web-based pedagogical tools as scaffolds for self-regulated learning. *Instructional Science*, *33*(5), 513–540.

De Jong, F., Kollöffel, B., van der Meijden, H., Staarman, J. K., & Janssen, J. (2005). Regulative processes in individual, 3D and computer supported cooperative learning contexts. *Computers in Human Behavior*, *21*(4), 645–670.

Dillon, A., & Jobst, J. (2005). Multimedia learning with hypermedia. In R. E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp. 569–588). New York, NY: Cambridge University Press.

Dinsmore, D. L., Alexander, P. A., & Loughlin, S. M. (2008). Focusing the conceptual lens on metacognition, self-regulation, and self-regulated learning. *Educational Psychology Review* (this issue).

Elliot, A. J., & McGregor, H. A. (2001). A 2 × 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*(3), 501–519.

Eom, W., & Reiser, R. A. (2000). The effects of self-regulation and instructional control on performance and motivation in computer-based instruction. *International Journal of Instructional Media*, *27*(3), 247–260.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data*. Cambridge, MA: MIT.

Fox, E., & Riconscente, M. M. (2008). Metacognition and self-regulation within the theories of James, Vygotsky, and Piaget. *Educational Psychology Review* (this issue).

Greene, J. A., & Azevedo, R. (2007). Adolescents' use of self-regulatory processes and their relation to qualitative mental model shifts while using hypermedia. *Journal of Educational Computing Research*, *36*(2), 125–148.

Greene, J. A., Moos, D. C., Azevedo, R., & Winters, F. I. (2008). Exploring differences between gifted and grade-level students' use of self-regulatory learning processes with hypermedia. *Computers and Education*, *50*, 1069–1083.

Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: foundation, methods, and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory, Vol. II* (pp. 115–140). Mahwah, NJ, US: Lawrence Erlbaum.

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: some core challenges. *The Journal of the Learning Sciences*, *15*(1), 53–61.

Järvelä, S., & Salovaara, H. (2004). The interplay of motivational goals and cognitive strategies in a new pedagogical culture: a context-oriented and qualitative approach. *European Psychologist*, *9*(4), 232–244.

Joo, Y. J., Bong, M., & Choi, H. J. (2000). Self-efficacy for self-regulated learning, academic self-efficacy and internet self-efficacy in web-based instruction. *Educational Technology Research and Development*, *48*(2), 5–17.

Kauffman, D. F. (2004). Self-regulated learning in web-based environments: instructional tools designed to facilitate cognitive strategy use, metacognitive processing, and motivational beliefs. *Journal of Educational Computing Research*, *30*(1&2), 139–161.

Kitsantas, A., & Dabbagh, N. (2004). Promoting self-regulation in distributed learning environments with web-based pedagogical tools: An exploratory study. *Journal of Excellence in College Teaching*, *15*(1–2), 119–142.

Kramarski, B., & Hirsch, C. (2003). Using computer algebra systems in mathematical classrooms. *Journal of Computer Assisted Learning*, *19*(1), 35–45.

Kramarski, B., & Gutman, M. (2005). How can self-regulated learning be supported in mathematical e-learning environments? *Journal of Computer Assisted Learning*, *22*(1), 24–33.

Kramarski, B., & Mizrachi, N. (2006a). Online discussion and self-regulated learning: effects of instructional methods on mathematical literacy. *Journal of Educational Research*, *99*(4), 218–230.

Kramarski, B., & Mizrachi, N. (2006b). Online interactions in a mathematical classroom. *Educational Media International*, *43*(1), 43.

Lajoie, S. P., & Azevedo, R. (2006). Teaching and learning in technology-rich environments. In P. A. Alexander, & P. H. Winne (Eds.), *Handbook of educational psychology, 2nd ed* (pp. 803–821). Mahwah, NJ: Erlbaum.

MacGregor, S. K. (1999). Hypermedia navigation profiles: cognitive characteristics and information processing strategies. *Journal of Educational Computing Research*, *20*(2), 189–206.

Mandinach, E. B., & Cline, H. F. (2000). It won't happen soon: practical, curricular, and methodological problems in implementing technology-based constructivist approaches in classrooms. In S. Derry, & S. Lajoie (Eds.), *Computers as cognitive tools* (pp. 377–398). Hillsdale, NJ: Lawrence Erlbaum.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. New York: Cambridge University Press.

McManus, T. F. (2000). Individualizing instruction in a web-based hypermedia learning environment: nonlinearity, advance organizers, and self-regulated learners. *Journal of Interactive Learning Research*, *11*(3), 219–251.

Moos, D. C., & Azevedo, R. (2006). The role of goal structure in undergraduates' use of self-regulatory processes in two hypermedia learning tasks. *Journal of Educational Multimedia and Hypermedia*, *15*(2), 49–86.

Moos, D. C., & Azevedo, R. (2008a). Monitoring, planning, and self-efficacy during learning with hypermedia: the impact of conceptual scaffolds. *Computers in Human Behavior*, *24*(4), 1686–1706.

Moos, D. C., & Azevedo, R. (2008b). Self-regulated learning with hypermedia: the role of prior domain knowledge. *Contemporary Educational Psychology*, *33*(2), 270–298.

Narciss, S., Proske, A., & Koerndle, H. (2007). Promoting self-regulated learning in web-based learning environments. *Computers in Human Behavior*, *23*(3), 1126–1144.

National Research Council (2003). Planning for two transformations in education and learning technology: report of a workshop. Committee on Improving Learning with Information Technology. In R. Pea, W. A. Wulf, S. W. Elliott, & M. A. Darling (Eds.), *Center for Education and Board on Behavioral, Cognitive, and Sensory Sciences, Division of Behavioral and Social Sciences and Education and Computer Science and Telecommunications Board, Division on Engineering and Physical Sciences*. Washington, DC: The National Academies.

Nesbit, J. C., Winne, P. H., Jamieson-Noel, D., Code, J., Zhou, M., MacAllister, K., *et al.* (2006). Using cognitive tools in gStudy to investigate how study activities covary with achievement goals. *Journal of Educational Computing Research*, *35*(4), 339–358.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451–502). San Diego, CA: Academic.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement*, *53*(3), 801–813.

Proske, A., Narciss, S., & Korndle, H. (2007). Interactivity and learners' achievement in web-based learning. *Journal of Interactive Learning Research*, *18*(4), 511–531.

Puntambekar, S., & Hübscher, R. (2005). Tools for scaffolding students in a complex learning environment: what have we gained and what have we missed? *Educational Psychologist*, *40*(1), 1–12.

Reiber, L. P. (2005). Multimedia learning in games, simulations, and microworlds. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 549–568). New York, NY: Cambridge University Press.

Salovaara, H. (2005). An exploration of students' strategy use in inquiry-based computer-supported collaborative learning. *Journal of Computer Assisted Learning*, *21*(1), 39–52.

Schunk, D. H., & Ertmer, P. A. (1999). Self-regulatory processes during computer skill acquisition: goal and self-evaluative influences. *Journal of Educational Psychology*, *91*(2), 251–260.

Shapiro, A., & Niederhauser, D. (2004). Learning from hypertext: research issues and findings. In D. H. Jonassen (Ed.), *Handbook of research for education communications and technology, 2nd ed*. Mahwah, NJ: Erlbaum.

Stahl, E., Pieschl, S., & Bromme, R. (2006). Task complexity, epistemological beliefs, and metacognitive calibration: an exploratory study. *Journal of Educational Computing Research*, *35*(4), 319–338.

Van den Boom, G., Paas, F., van Merriënboer, J. J. G., & van Gog, T. (2004). Reflection prompts and tutor feedback in a web-based learning environment: effects on students' self-regulated learning competence. *Computers in Human Behavior*, *20*(4), 551–567.

Whipp, J. L., & Chiarelli, S. (2004). Self-regulation in a web-based course: a case study. *Educational Technology Research and Development*, *52*(4), 5–22.

Williams, M. D. (1996). Learner-control and instructional technologies. In D. H. Jonassen (Ed.), *Handbook of research of educational communications and technology* (pp. 957–983). New York: Macmillan.

Williams, P. E., & Hellman, C. M. (2004). Differences in self-regulation for online learning between first- and second-generation college students. *Research in Higher Education*, *45*(1), 71–82.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Hillsdale, NJ: Erlbaum.

Winne, P. H., & Jamieson-Noel, D. (2002). Exploring students' calibration of self reports about study tactics and achievement. *Contemporary Educational Psychology*, *27*(4), 51–572.

Winters, F. I., & Azevedo, R. (2005). High-school students' regulation of learning during computer-based science inquiry. *Journal of Educational Computing Research*, *33*(2), 189–217.

Young, J. D. (1996). The effect of self-regulated learning strategies on performance in learner-controlled computer-based instruction. *Educational Technology Research & Development*, *44*(2), 17–27.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). San Diego, CA: Academic.

Zimmerman, B. J. (2001). Theories of self-regulated learning and academic achievement: an overview and analysis. In B. J. Zimmerman, & D. E. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 1–37). Mahwah, NJ: Erlbaum.

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment. *American Educational Research Journal*, *31*, 845–862.

Zimmerman, B. J., & Tsikalas, K. E. (2005). Can computer-based learning environments (CBLEs) be used as self-regulatory tools to enhance learning? *Educational Psychologist*, *40*(4), 267–271.