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Challenges in supporting self-regulation in distance education environments

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Abstract This article considers the application of selected components of self-regulated learning (SRL; Zimmerman 2000) to student-content interaction in online learning and distance education (DE). In particular we discuss how, when interacting with electronically enhanced text, students must carefully employ self-regulated learning strategies that include planning, goal setting, self-monitoring processes, and calibration judgments. Because the student is often learning independently in DE courses, and because of the potential for non-linear navigation through online learning materials, we argue that the careful deployment of SRL skills is especially critical for successful outcomes. Consequently we discuss examples of how the demands of student-content interactions put students with self-regulation difficulties at risk of failure. We highlight research on learners who have poor SRL skills, inadequate calibration capabilities, and low executive functions in order to highlight areas of particular difficulty and areas in which support might be most beneficial. We conclude with the recognition that while support strategies can be derived from the research literature, there is a great need for research that addresses questions about student-content interaction in DE course settings specifically, and pertains to the increasingly diverse group of learners who take these courses.

Keywords Self-regulated learning · Calibration · Executive functioning · Instructional design · Distance education

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Introduction

Students are faced with numerous, complex demands when engaged in distance education and on-line learning. Chief among them is the need to be self-directed and regulate one's own learning in pursuit of academically relevant goals. Setting goals, monitoring progress towards these goals, and reflecting on outcomes are hallmarks of effective self-regulation, and these skills have been clearly linked to achievement (e.g., Boekaerts et al. 2000). Some have argued that the demands in distance education settings are greater than those faced by students enrolled in traditional face-to-face courses due to the largely autonomous nature of on-line learning and the lack of on-going, interactive support or scaffolding that a physically present instructor typically provides (Azevedo et al. 2008; Dabbagh and Kitsantas 2004). Therefore, the ability to effectively employ self-regulation skills may be even more critical in distance education environments than in traditional classrooms. In essence, distance education entails multiple episodes of on-line learning and multiple opportunities to engage in self-regulated learning. However, many students find it difficult to manage their learning in distance learning environments (Artino and Stephens 2009). To compound this difficulty, instructors may also lack knowledge of or may inadvertently minimize the importance of self-regulated learning skill (Zohar 1999) in academic achievement. Therefore, they may not design or deliver instruction that supports and promotes self-regulation skills in their students.

Despite its import, scant attention has been focused on the role of self-regulated learning in the design, delivery, and evaluation of the effectiveness of instruction in distance education environments (Abrami et al. 2011). Abrami and his colleagues call for the application of evidence-based approaches, including theories of self-regulation, to guide improvements in the next generation of distance and on-line learning. They contend, "It is possible to create instructional designs with many of the features of self-regulation and to embed these designs as templates into existing tools for distance and on-line learning" (p. 14). The impetus for the current article was to respond to their call by illuminating how self-regulated learning theory and research may inform and improve instructional practices in distance education environments.

Before embarking on this ambitious undertaking, we recognized that discussing every aspect of self regulated learning as it applies to all possible educational tasks or interactions is beyond the scope of this paper. Therefore we narrowed our scope in the following ways. First, we selected student-content interaction rather than other type of interpersonal interactions described in the literature because SRL research can be readily applied to this type of interaction. Second, we concentrated on learning from multimedia environments given our focus on distance education and the increasingly common use of instructional materials which have multimedia and electronically enhanced features. Third, we emphasized Zimmerman's Cyclical Model of Self-regulation (2000), though we acknowledge there are other sound models of self-regulated learning that share common characteristics (e.g., Pintrich 2000; Winne and Hadwin 1998), because its socio-cognitive nature presents both a meaningful framework and specific challenges to instructional designers wishing to promote SRL skills in students. Finally, we incorporated examples from the calibration and executive monitoring literatures to illustrate dysfunctional processes that may impact the effectiveness of instructional design and student learning processes.

Types of interactions

Understanding the types of interactions that occur in educational environments is a useful heuristic for guiding practice as well as research. Anderson (2003) distinguished among the three most common types of interactions addressed in the distance education literature. The first two are interpersonal in nature and include student–teacher and student–student interactions. Examples of student–teacher interaction are receiving and responding to teacher feedback and help-seeking in the form of asking for clarification or direction. Student to student interactions may entail peer review of work, negotiating roles on collaborative tasks, or responding to discussion threads posted by other students. The third type of interaction is intrapersonal. Student-content interaction involves "reading instructional texts for meaning, using study guides, watching instructional videos, interacting with multimedia, participating in simulations, or using cognitive software" (Abrami et al. 2011).

Although the relative importance of the three types of interactions in promoting learning has been hotly debated in the literature, Anderson (2003) argues that some students deliberately select learning environments that minimize the extent of interpersonal interactions. The preference of some students to work independently may lead them to choose distance education options compounding the critical need for effective self-regulation skills in student-content interactions. In the following section we examine student-content interaction from the perspective of Zimmerman's model: interacting with electronically enhanced instructional text, which we take to include informational materials in which multimedia or hypermedia features are embedded.

Zimmerman's SRL model applied to student-content interaction

As noted Zimmerman's cyclical model of self-regulation (see Fig. 1) shares common features with other theoretical models of self-regulated learning found in the literature and supported by empirical findings (e.g., Pintrich 2000; Winne and Hadwin 1998). First and foremost is the dynamic nature of self-regulation where learners cycle through the various phases of learning. It is further assumed that individuals actively manage their learning by monitoring their progress and selecting appropriate cognitive strategies needed to accomplish academic goals. In other words, learning is inherently purposeful. Finally, motivation or self-beliefs influenced by social factors play an important role in each of these models. A brief overview of Zimmerman's model is presented followed by a more detailed discussion of how it is applied to student-content interactions.

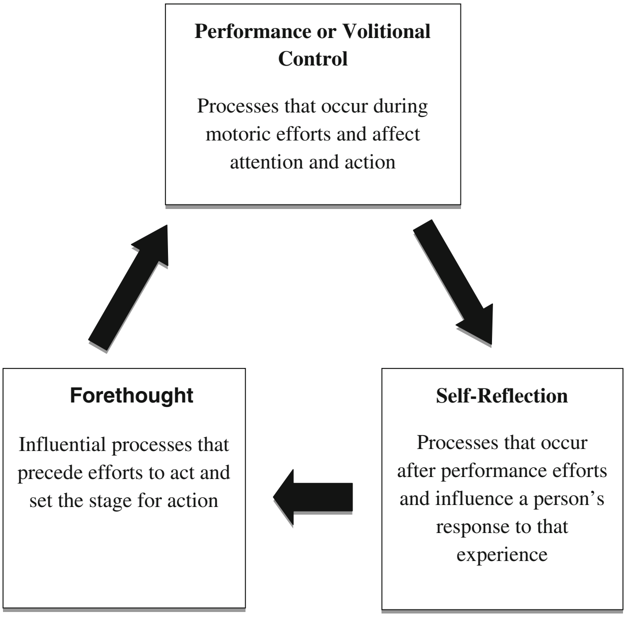

Fig. 1 Zimmerman's (2000) cyclical model of self-regulation

In Zimmerman's (2000) model, self-regulation cycles through three distinct phases. The forethought phase encompasses task analysis that consists of setting goals for a learning episode as well strategically planning the deployment of personal and motoric strategies required for achieving these goals. Continuous adjustment of goal setting and task analysis occurs as learners progress or alternatively, fail to progress, when prerequisite skills are needed or context and demands vary. However, goal setting and task analysis depend on motivational beliefs. "Self-regulatory skills are of little value if a person cannot motivate themselves to use them" (p. 16). The self-motivational components of forethought include beliefs about self-efficacy, outcome expectations, intrinsic interest or value, and goal orientation. The second phase is performance or volitional control and is categorized into self-control and self-observation processes. Self control optimizes a learner's effort and involves the processes of self-instruction, imagery, attention focusing, and task strategies. Self-observation processes consist of both self-recording and self-experimentation. Learners monitor different aspects of their performance in conjunction with the conditions influencing it and its outcomes. This may lead to self-experimentation when attempting to diagnose the success or failure of their efforts and what conditions may lead to improvement. The third and final phase in this cyclical model is self-reflection that occurs at the conclusion of a learning episode. A natural consequence of self-observation is self-judgment and self-reaction. Learners evaluate their performance which can trigger causal attributions that explain performance. These explanations can be adaptive (e.g., poor performance due to lack of effort) or maladaptive (e.g., poor performance due to lack of ability) affecting the likelihood of persistence or continued effort and ultimately successful mastery of a learning task. Self-reactions can incur positive self-satisfaction leading to adaptive responses (e.g., selecting more effective cognitive strategies) or more defensive self-evaluations leading to self-handicapping behaviors (e.g., procrastination, task avoidance, and cognitive disengagement).

Zimmerman's social cognitive model relies on environmental, social, and self-influences that have clear implications for instructional design. In addition, by situating our discussion within this model we recognize several important ideas. First, the model reinforces that all students possess self-regulatory capacities, but that the quantity and quality of these capacities, the degree of success with which these capacities can be executed, and the adaptive or maladaptive nature of the goals that they serve, differs between students. Underlying this idea is the assumption that self-regulated learning capacities are well-characterized as a skill set that is subject to individual, contextual and subject matter-related influences on its execution. From an instructional design perspective this means that SRL skills can be moderated through the student's experience of instruction. The challenge for instructional designers of distance education materials in particular is to support self-regulated learning through means that are not dependent on synchronous interaction between the teacher and student, or among students. Within the social cognitive framework, SRL skills are learned through progressive internalization following the observation of expert models. Thus, windows of opportunity exist for presenting, scaffolding, supporting, and also releasing responsibility for SRL processes. Once again, although synchronous interactions are becoming more prevalent, the predominantly asynchronous nature of learning in DE settings means that the provision of such scaffolding and support is challenging. This is especially true because although in an ideal situation students would engage in proactive regulation and would seek goals which promote knowledge and skill development, in many situations students self-regulate in a reactive manner and implement strategies only in the face of feedback which informs them that their performance is deficient. Thus, just as it is important for distance education research to acknowledge and explore social-cognitive mechanisms for the acquisition and improvement of SRL skills, it is also important that DE students have the tools they need in order to accurately monitor and calibrate their level of performance. In particular, as we discuss, planning and self-monitoring appear to be critical mediating factors when interacting with material in computer based learning environments. Exercises in the consideration of support for these processes are therefore not inconsequential.

In the sections that follow, we first emphasize how executing metacognitive processes during these activities represents phases of self-regulated learning and that students must effectively regulate their own learning in order to profitably interact with the material. Second, we identify areas in which instructional design features are, or could be, utilized to support learners during learning episodes. To do this we draw from research which has tried to take into account the effect of individual difference variables in learners' SRL skills and areas of weakness, as well as features of the task itself. We highlight the role of self-monitoring through the concept of calibration and the constructs of executive functions, and conclude with a call for research into the effectiveness of support mechanisms for diverse groups of learners.

Learning from electronically enhanced text

Students in DE courses are often required to read and learn from a substantial amount of informational text. This text can range from viewing a PDF file on a screen to interacting with hypermedia text in which links to further content are embedded, or viewing a combination of informational text and graphics, animations, or movie files. We use the term electronically enhanced text to mean screen-presented text which may or may not include a combination of hyperlinks and embedded graphics, animations and other digital multimedia objects. The potential for learning that these media offer is great. But the critical role of self-regulated learning techniques when learning from electronically enhanced text has also been recognized. According to Greene and Azevedo (2009) "hypermedia environments, with their flexibility in presenting multiple representations, have been suggested as ideal learning tools for fostering sophisticated mental models of complex systems." However, they go on to say that

> Students must possess effective SRL skills to benefit from such environments because navigating and learning from multiple representations requires large amounts of learner control…students who do not regulate their learning often become overwhelmed by the many options presented to them in hypermedia environments, thus making the presence of relevant information in multiple representations a hindrance rather than an advantage (p. 19).

Theoretical accounts of self-regulated learning predate the research that specifically deals with learning from electronically enhanced text. Many of these studies investigated SRL in the context of learning from various forms of informational text presented in paper form. Through these studies, researchers identified particular self-regulated learning strategies that were important factors in predicting learning outcomes (Pressley 2000; Pressley and Ghatala 1990). For example, when interacting with informational text, skilled readers were found to be more likely to engage in metacognitive strategies such as goal setting (Pearson and Fielding 1991; Pressley 2000). A purpose for and desired outcome of reading allows the reader to engage in more effective self-monitoring. Skilled readers also consider what they already know about a topic prior to reading. During reading they monitor their progress, and activate strategies designed to promote comprehension of the information in the text as well as integration of information with background knowledge. At the conclusion of a learning episode, skilled readers may reflect on the effectiveness of their learning as well as the effectiveness of the strategies and procedures used. In short, effective learning from informational text involves goal setting, prior knowledge activation, comprehension monitoring, task- and subject-specific strategy selection, and reflection on both outcome and process.

With the exception of certain task and medium features which incur unique learning-related behaviors, such as the hyperlink functionality that introduces decisions about clicking to view additional content, research pertaining to learning from traditional forms of informational text and converges with research on learning from electronically enhanced material, in the sense that similar SRL behaviors characterize successful students in both settings. The work of Azevedo and colleagues (e.g. Azevedo et al. 2004) has revealed that students with effective self-regulated learning skills are more likely to experience gains in the content and complexity of their knowledge structures than students with poor self-regulated learning skills. Importantly, these gains are not simply due to differences in prior knowledge or the use of micro-level strategies such as note-taking or re-reading areas of the material (Greene et al. 2010). Rather, gains are in large part due to differences in the macro-level metacognitive processes such as planning and self-monitoring that characterize the first two phases of Zimmerman's SRL model. Specifically, according to Azevedo et al. (2004), the most effective students spend a higher proportion of their time engaging in tasks relating to planning, self-monitoring, and cognitive strategy use. They create sub-goals during the learning task, retrieve relevant prior knowledge, and monitor their progress towards goals. They are effective in planning their time, which is a critical factor when learning episodes are of a fixed length.

The role of self-monitoring during the second, task performance phase of SRL has received detailed attention. More successful students tend to spend proportionately more time and effort monitoring the relationship between new and prior knowledge, rather than simply trying to understand the new information without this consideration. This finding is related to the both the purpose and the content of thoughts that can be categorized as serving self-monitoring processes. For example, Greene and Azevedo (2009) found that the presence of self-monitoring activities such as self-questioning and judgments of learning were more powerful predictors of knowledge growth from pre-test to posttest than planning or activities related to managing task difficulty (such as help-seeking). The precursors to these self-questioning activities also seem to be important. From close examination, Greene and Azevedo (2007) identified several behaviors which differentiated more from less successful students as they interact with electronically enhanced text. These included management of the process of meaning construction, such as when drawing inferences from the text or coordinating between sources of information (e.g. between graphics and text); management of the interaction between oneself and the material, such as when monitoring the adequacy of current understanding in order to rate the adequacy and utility of the information being provided; and management of one's own knowledge state, such as when establishing judgments of learning and monitoring the feeling of knowing.

In summary, it seems that individual differences in the tendency to engage in macro-level planning and self-monitoring activities account for differences in performance outcomes following interactions with electronically enhanced text. One important question that follows is how to best support students' self-monitoring behaviors, particularly in DE courses where learner-teacher interaction is likely to be asynchronous. As a matter of further relevance to this issue, we consider students who have difficulties with the self-regulation, and how these difficulties may influence interactions with instructional content.

Support for self-regulatory processes

In this section we consider for whom SRL support might be beneficial, and the nature of the support that could be provided. We also consider more generally, ways in which support for SRL processes could be incorporated into DE courses.

Students with weak self-regulated learning skills

Students with weak SRL skills are an obvious priority for targeted support. In particular, since metacognitive planning and self-monitoring behaviors are associated with knowledge gains, one approach might be to focus support on these processes explicitly. Students with weak SRL skills, according to Greene and Azevedo (2007, 2009) are unlikely to spend time planning their learning and more likely to simply recycle the goals they do adopt in working memory. Thus, they may benefit from prompts to engage in planning and to consider the goal of their learning episode. Prompting a written or typed record of this goal may relieve working memory burden and reduce overall cognitive load. Similarly, these students are likely to spend more time focusing on the meaning of the instructional text and less time comparing and monitoring the status of their prior knowledge in relation to the meaning of the text. Prompt questions that encourage students to reflect on the congruence of the new information with prior knowledge, or which require an answer that integrates the new information into existing frameworks that have been previously covered in the course, may facilitate more meaningful reflection.

As would be predicted by Zimmerman's social-cognitive perspective on the formation of SRL strategies and habits, in addition to supporting these processes through prompts within the instructional sequence, it may be possible to intervene and successfully train students to use specific self-regulatory strategies (Azevedo and Cromley 2004). While at first glance it may seem that a training study would not be relevant to DE settings, this study can be used as an illustration of the potential benefits following even a short intervention. Here, the training employed consisted of a brief 30 min instructional period in which each participant received a detailed explanation of the phases of self-regulated learning with examples from the hypermedia environment they were going to use. This guidance was provided by an instructor prior to the experimental learning episode. Even with such a brief intervention, students in the intervention condition were more likely to plan their learning using the more effective strategy of activating prior knowledge rather than the less effective behavior of recycling the goal in working memory. Differences were also apparent in self-monitoring. Students in the intervention condition were more likely to monitor their comprehension using feeling of knowing (FOK) and judgment of learning (JOL) processes than students in the control condition, who did not receive any training in SRL. These students were instead more likely to use information adequacy judgments, in which relative emphasis was given to the suitability of the information in terms of serving the learning goal, rather than the relationship between the new information and prior knowledge. Students in the intervention condition were also more likely to use effective generative strategies during their learning episode, and were found to engage in note-taking, summarizing, and coordinating informational sources. This was in contrast to students in the control condition were more likely to engage in informational searches.

This study raises the possibility that older students taking DE courses may benefit from even a brief overview of self-regulated learning and examples of ways in which they can use metacognitive strategies to facilitate their interactions with electronically enhanced text. The conclusion is made, however, with the caveat that the typical length of experimental learning episode is short (1 h or less) and limited to one interaction with the material. Further research is needed to see whether or not the effects of this type of short intervention would persist over time, whether or not students of younger ages would gain any benefit from it, and whether or not this brief intervention has efficacy in DE settings.

Students with poor calibration skills

Students may be weaker in particular areas of self-regulated learning compared to others and may need further targeted support aimed at improving these skills. One such area is calibration. Calibration is defined generally as the degree to which a person's perception of performance corresponds with his or her actual performance (Keren 1991). The degree of correspondence is determined by a person's judgment of his or her performance compared against an objectively determined measure of that performance (Hacker et al. 2008b). Thus, calibration is considered to be metacognitive monitoring process. Monitoring provides information at the metacognitive level about the status of one's knowledge or strategies at a cognitive level (Nelson 1996). Based on this information, metacognitive control can be exerted to regulate one's knowledge or strategies. In Zimmerman's model (2000), self-evaluation "refers to comparing self-monitored information with a standard or goal" (p. 21). In numerous studies, calibration accuracy is measured by comparing students' judgments of their performance on an exam or individual item with their actual performance (e.g., Bol and Hacker 2001; Bol et al. 2005; Maki et al. 2005). These kinds of judgment may be prospective (predictions), aligning with the forethought phase or retrospective (postdictions), aligning with the reflection phase. Calibration is also important in the performance or volitional phase when a learner continuously monitors and adjusts his focus contingent on feelings of knowing (FOK's) or judgments of learning (JOL's). Therefore, it may be argued that effective self-regulated learning is enhanced by accurate calibration in each of the cyclical phases.

The poor calibration skills of the lowest achieving students have been well documented in literature (Bol and Hacker 2001; Bol et al. 2010; Hacker et al. 2008b; Juslin et al. 2000; Maki et al. 2005). Typically, students with poor calibration skills are inaccurate and overconfident when compared to their higher achieving peers who are much more accurate and often underconfident (Hacker et al. 2000, 2008a, b). Lower-achieving students seem to anchor their calibration judgments on optimistic yet inaccurate beliefs about their own abilities. Students who are overconfident may have a false sense of how well they have mastered the material. They may believe they are prepared when in fact they are at risk for failure. Or students could intentionally inflate their overconfidence during a learning episode as a self-handicapping strategy, excusing or attributing their poor performance to external causes (Winne 2004; Zimmerman 2000). Underconfidence also can be detrimental to academic performance because students may fail to disengage from studying and misallocate study time if they assume the material is not yet mastered. Students with poor calibration skills may not take the remedial steps necessary to improve their efforts (Hacker et al. 2008a, b).

The detrimental effects of poor calibration skills beg the question of whether and how they can be improved. Attempts to improve calibration accuracy in classroom settings have been met with mixed success. Contrary to expectations, repeated calibration practice does not seem to enhance accuracy. In one illustrative experiment (Bol et al. 2005), students in traditional and distance course formats, took a series of five on-line quizzes. In the practice condition, students were required to predict and postdict their quiz scores. Taking the quizzes on-line provided students with immediate feedback on their scores and calibration accuracy. Students in the control condition did not predict or postdict their performance on the quizzes. The dependent variables were calibration accuracy and scores on the final exam for both groups. The results revealed that calibration practice on the quizzes neither enhanced calibration accuracy or exam performance. Calibration tends to be stable, suggesting that feedback and practice alone are insufficient for improving calibration accuracy. The findings that reflection and instruction on monitoring and calibration were found to be effective were more promising (Nietfield et al. 2006). In this experiment, weekly reflection coupled with feedback improved calibration accuracy and performance on exams and the course project. Another study showed that external rewards or incentives for more accurate calibration enhanced postdiction accuracy among lower-achieving students. More recently, group calibration practice and the provision of guidelines have been shown to improve calibration accuracy and achievement among high school students (Bol et al. 2010). The study by Azevedo and Cromley (2004) described earlier provided at least indirect support for the effectiveness of SRL training for improving calibration. They found that students in the intervention condition were more likely to monitor their comprehension using feeling of knowing and judgment of learning, processes underlying calibration, than students in the control condition, who did not receive any training in SRL.

Students with executive function deficits

Distance education courses by their nature attract a diverse group of learners and have historically attracted students who may be non-traditional in terms of their age and learning histories; some may have literacy difficulties or learning disabilities and others may be re-entering formal education after a decade or more. Few studies have specifically examined learning with hypermedia and electronically enhanced learning materials in these populations, so this is an area in which future research will enhance our understanding of how a potentially significant proportion of these students learn using these materials. For now, we focus on executive function difficulties, in part because of their under-represented nature in this literature but also because of the relevance of executive function constructs to reading comprehension (Locascio et al. 2010) and self-regulated learning processes (Garner 2009; Manganello 1995; Peterson et al. 2006).

The term "executive functions" refers to a fairly broad group of neurocognitive processes that support higher level cognitive and metacognitive functions. These include planning, organization, self-monitoring and goal-directed behavior (Eslinger 1996). At the neurocognitive level, executive functions give rise to control over attention and working memory, and facilitate freedom from distractibility (Locascio et al. 2010). Executive functions can be conceptualized on a continuum in much the same way as other cognitive processes; that is to say, it is where some individuals have strengths and others weaknesses. Individuals with effective executive functions are likely to operate with broadly effective self-regulatory processes in all areas of life, flexibly regulate goal-directed actions, and organize pieces of information as well as their interaction with that information. Individuals with executive function difficulties struggle with planning, self-organization and self-monitoring, and may find it hard to screen out or otherwise not respond to distracting stimuli. Deficits in executive functions are associated with a number of risk factors including mild to moderate traumatic brain injury and a position on the autism and Asperger's spectrum, but for many individuals the source of weaknesses in planning, organizational skills and attentional control may not be identifiable. Like working memory capacity or cognitive ability, a range of executive function performance exists even in the typical population (Garner and Tocker 2011). Yet, while the deficit remains at the subclinical level the difficulties can nonetheless interfere with everyday life (Garner and Tocker 2011; Manganello 1995; Peterson et al. 2006; Wilson et al. 1996).

Executive functions have been widely investigated in the clinical psychological literature, in part because neuropsychological and organic disorders tend to have an obvious executive dysfunction component. More recently, however, educational researchers have started to consider the prevalence and potential consequences of subtle variations in executive functions on the cognitive, metacognitive and interpersonal regulatory processes in which students engage (McCloskey et al. 2009; Metzler 2007; Garner 2009, Garner and Bol 2011; Peterson et al. 2006). An executive functions-related component of attention deficit disorder and reading disabilities have been revealed by recent research studies, but even in typical and unimpaired samples there is evidence to suggest that variation in executive functions has consequences for self-regulated learning processes and academic achievement. Specifically, Garner (2009) found that executive functions accounted for variance in metacognitive, cognitive and affective aspects of SRL, and both Peterson et al. (2006) and Garner and Tocker (2011) found that college students with sub-clinical risk factors for executive dysfunction were at risk of poor self-regulatory processes and academic distress.

Thus, in conceptualizing the relations between executive functions and self-regulated learning, we position executive functions as neurocognitive processes that promote self-regulation at both the basic cognitive (e.g. attentional control) and metacognitive (e.g. planning and self-monitoring) levels. Because of their foundational role in cognitive and metacognitive regulation, difficulties with executive functions may impact the SRL cycle as it is employed during interactions with electronically enhanced text. These difficulties may manifest themselves in three ways. The first is at the macro-level of self-regulated learning processes, in terms of the choices the learner makes when opportunities for strategic behavior arise. The second is through reading comprehension processes, and the third is through navigation behavior.

As previously noted, macro-level SRL processes include planning, self-monitoring and self-evaluation. Poor executive functions may result in difficulties recognizing the need for goal setting and strategic planning. Cognitive rigidity and cognitive impulsivity—both included under the umbrella term of executive dysfunction (Wilson et al. 1996)—may result in a learner beginning an interaction with the learning materials without a clear goal in mind and being unable to switch strategies when changes to the learning process are called for. Without specific prompting and support, self-evaluation may not result in the necessary improvements to SRL behaviors.

Also as noted previously, a large proportion of student-content interaction involving electronically enhanced text entails reading. Before considering the specific issue inherent to the presence of electronic enhancements such as hyperlinks, it is worth considering that individuals with executive function difficulties can exhibit difficulties with comprehension processes that are separable from other specific reading disabilities (Locascio et al. 2010; Sesma et al. 2009). That is, in spite of fluent word recognition processes, learners with executive function difficulties can have difficulty constructing an overall understanding of the 'big picture' concepts contained within the material. Whether this difficulty arises from a lack of control over attention and working memory processes, a failure to organize importance pieces of information, or some other difficulty is not known. Yet, the implications are that these learners may benefit from explicit support in constructing a global representation of the text.

To further complicate matters, electronically enhanced text contains features such as hyperlinks and search functions which make non-linear navigation not only easy to do but visually and cognitively appealing. However, when reading materials that contain hyperlinks, global reading comprehension processes can be negatively impacted by the over utilization of these embedded links. This is the case even in typical learners who do not have documented difficulties with either reading comprehension or attentional control (Greene and Azevedo 2007). The use of hyperlinks have also been questioned as a factor in making it more difficult for the reader to build coherent representations of text (Zumbach 2006) and Greene and Azevedo (2007) noted that excessive movement between areas within electronically enhanced learning materials was associated with poor learning outcomes. Thus, students must be more engaged in using reading strategies than when reading traditional text (Schrader et al. 2008), but they must also be engaged in the exercise of restraint in following links and navigating in a manner that does not suit the overall goal of the learning episode. To do this requires impulse control, which is a broadly recognized executive function (Spinella 2005). However, since impulse control, control over attention and working memory, and the maintenance of freedom from the influence of distracting stimuli (both intrinsic and external to the learning material) are problematic for students with executive function difficulties, it may be hard for them to inhibit the desire to click on hyperlinks and other "hot" areas of graphics or to not view other pages on a website simply because they are listed in the page outline. Since broad organization of a large number of pieces of information is also a challenge for these students, comprehension outcomes may ultimately be quite poor.

Supports for student learning with electronically enhanced material

When considering how to support learners' interaction with electronically enhanced text from the perspective of executive functions and metacognitive aspects of self-regulated learning, it may be helpful to think about students' needs in terms of the four types of scaffolds identified by Azevedo et al. (2004). Azevedo and colleagues identified conceptual scaffolds, which support the learner in selecting relevant knowledge and information; metacognitive scaffolds, which facilitate students' management and self-regulation of task accomplishment; procedural scaffolds, which support students' completion of tasks or use of learning resources; and strategic scaffolds, which help students to be aware of strategic choices and alternatives for successfully completing different learning tasks. Of these, strategic and metacognitive scaffolds appear to offer the most relevance for learners with regulation difficulties.

Students with weak executive function and self-regulated learning skills have difficulties with planning, self-monitoring, self-reflection and organization of material. Hence, metacognitive and strategic scaffolds may be of particular benefit. Examples include Meyer et al.'s (2010) ePEARL online electronic portfolio system. This unique software platform integrates electronic storage of work products with features that prompt the creation of goals at the beginning of a work cycle, and the ability to view and integrate feedback into subsequent versions of the work product. Students can therefore retain and easily access concrete representations of their SRL processes. The system has been found to improve middle school students' metacognitive management of their learning, but the potential as an intervention tool for students with specific self-regulatory and executive difficulties has not been examined, and it is not clear how ePEARL could support the wide-scale presentation of instructional material for students in DE courses.

Strategic scaffolds may be of particular use to students with self-regulated learning and executive function difficulties because of the difficulty that these students may have in selecting appropriate and alternative strategies when problems are encountered. For example, if learning materials were to be presented through the medium of an electronic learning platform, and if that platform could support flexible problem solving behaviors by presenting a sequence of steps through which students can navigate in order to consider more and less likely solutions to a problem, then students may be able to interact more effectively and strategically with the information even while they are relative novices in the subject area. For instance, students who are learning within a scientific domain where the process of hypothesis generation is key (e.g. medicine), prompts for the consideration of multiple instead of singular pieces of information, and several rather than one potential diagnosis, might be helpful (Lajoie et al. 1998).

Students with poor calibration skills may particularly benefit from metacognitive scaffolds and other supports that might be incorporated into on-line learning environments. More specifically, Winne (2004) identified four strategies to promote calibration of knowledge and learning processes in software design. The first strategy was to guide learners to delay metacognitive monitoring. This strategy is based on a phenomenon labeled the delayed JOL effect (Thiede and Dunlosky 1994) that shows improved judgments after a learning delay similar to improved achievement associated with distributed sessions over time. For example, learners might be first asked to highlight a text and at a later time evaluate the highlighted content relative to how well it is understood, how easily is can be retrieved, and how it relates to the learning objective. A second strategy is the provision of forms and timed alerts that guide students to summarize content. Thiede and Anderson (2003) found that summarizing information after a delay improved calibration accuracy. Furthermore, other research (Wood et al. 1995) suggests that the summaries were more effective when forms and guidelines were provided. "Adding such forms as software tools and pairing them with delay effect Thiede and Anderson reported should enhance calibration and improve a skill for learning" (Winne 2004, p. 481). It is likely that this finding was a byproduct of increased knowledge due to the summarize technique. As students gain more knowledge their calibration accuracy improves (Krugar and Dunning 1999). Helping learners review the "right" information is the third strategy. Students have a tendency to select "almost learned" (high JOL) or more interesting content for restudy. If students were to rate test items on JOL and interest they could be provided feedback indicating that selection of content for restudy based on interest and minimal challenge may not be the best choices. Finally, the development of more effective practice tests would provide students with records of their performance on past tests as well as items (or tasks) on those tests. This longitudinal data may improve students' calibration over time, shifting the basis of calibration judgments from past judgments to actual performance. Calibration tends to be largely inaccurate and biased towards overconfidence among lower achieving students because they anchor their judgments on past predictions in an effort to protect their self-worth (Bol et al. 2005; Hacker et al. 2008a, b). Overall, Winne (2004) argued for the development of electronically enhanced learner interfaces which not only present learning material but which but also store information which students have indicated is important and prompt more effective calibration judgments as an essential component of self-regulated learning.

In addition to the Winne's (2004) sound suggestions for enhancing calibration skills in software design, the studies described earlier might also bear promise in fostering calibration accuracy. Calibration practice coupled with reflection could be efficiently built into course design. Although some studies did not reveal metacognitive benefits associated with practice tests and feedback alone (Bol and Hacker 2001; Bol et al. 2005), Nietfield et al. (2006) findings suggested that requiring students to make calibration judgments coupled with reflections on their accuracy about their accuracy and how performance might be improved was effective in enhancing accuracy and performance. The intervention consisted of exercises that asked students to assess their learning for the current session as well as their study preparation, respond to and provide confidence ratings on review items and reflect on the accuracy of their confidence ratings. In addition to weekly feedback, the students were given feedback and interpretation of their calibration accuracy the week following exams. Similarly, the findings by Hacker et al. (2008a, b) revealed that providing students with information about their calibration accuracy, having them reflect on this accuracy, and suggesting ways in which it could be improved increased calibration accuracy for lower achieving students but only when incentives (extra credit points) for increased calibration accuracy were awarded. More recently, a study with high school students suggested that providing students with guidelines designed to improve their predictions for their exam performance improved calibration accuracy and test performance. This was particularly true when calibration was practiced in group settings (Bol et al. 2010a, b). In the forethought phase, instructional designers might prompt students to make predictions for particular topic areas or skills, feedback might be ongoing as students engage in a learning episode, and strengths and weaknesses identified. Guidelines for reflection (either individually or perhaps in group contexts through discussion boards) could spark a revision in goals or plans to guide further study. After a learning task students might receive feedback on performance and calibration, engage in further reflection and perhaps, be rewarded for increasing the accuracy of metacognitive judgments anchored on past performance. The computer software facilitates this record keeping as well as the provision of delayed calibration prompts, guidelines for reflection, rewards, and options for group calibration and study.

At a more basic but equally important level from an instructional design perspective, individuals with executive function difficulties can often have trouble with working memory and attentional control, (McCabe et al. 2010; Scope et al. 2010). Attentional focusing is imperative during the performance or volitional stage of SRL (Zimmerman 2000). Thus, since it is known that individuals with poor selective attention capabilities pay attention to information that is more intense or visually appealing than other aspects of information, and that as such it is more difficult for them to maintain a goal in working memory, careful use of hyperlinks and other visual aspects of electronically enhanced text must take place in order to reduce the chances of becoming distracted, off-task or losing track of recently assimilated information (Radosh and Gittelman 1981). To date, very little research has been conducted with samples of students with self-regulated learning and executive function difficulties to examine the specific features of hypermedia and electronically enhanced learning materials on students' navigation and reading practices, judgments of learning, and actual learning outcomes.

Tentative recommendations can be drawn from considering the needs of learners with cognitive disabilities that include individuals with attention and executive function-related difficulties. For example, Mariger (2006) explains that learners who have difficulty with attention and working memory control benefit from limited hyperlinks and an uncluttered visual display. Kanta (2001) presents a list of modifications to web pages that can assist the learning who has a disability, including providing auditory feedback, presenting the key information at the beginning of the page, and using screen layouts which provide the option to view only one area at a time. While intuitively significant, the recommendations do not appear to be drawn from empirical studies and arguably these very general principles would aid those without disabilities as well. In contrast, Zentall (2005) provides an excellent summary of recommendations for the design of instructional materials for individuals with attention-related difficulties. From his survey of empirically based resources, we relate several key findings which have direct consequences for the design of electronically enhanced learning materials and which relate well to the processes of attentional focusing and self-instruction which fall under the performance phase of Zimmerman's model of self-regulated learning. The first category of modification relates to the removal of extraneous or unnecessary visual stimulation from the task, what Zentall called "irrelevant cues." This principle, which is also aligned with multimedia principles of learning (Mayer 2001), calls for the removal of details not central to the concept being conveyed by the materials and the removal of colored or visual stimuli on the screen which alert the reader to this non-essential information. Secondly, Zentall recommends the addition of features such as color to highlight essential information or elements. The caveat in this area of course, is one familiar to instructional designers: the provision of a sufficient number of cues and signals for important information without the creation of visual distractions. The third area of recommendation concerns the promotion of students' self-instruction skills. Self-instruction according to Zimmerman (2000) involves overt or covert self-articulation of the steps involved in achieving an academic goal. Miranda et al. (2002) found that for younger students with attentional difficulties, teaching specific self-instruction for task completion (e.g. "I need to follow my plan") improved performance. Related work by Reid et al. (2005) showed that the performance of children with attentional difficulties could be improved by the provision of cue to self-monitor progress. Thus in a manner similar to Winne's (2004) call for the inclusion of progress monitoring steps for all students within computer based learning environments, it seems that a broad range of students could be helped by support for basic self-regulated learning process such as planning, goal setting, self-monitoring and self-reflection.

Summary and conclusions

This paper highlights challenges in supporting self-regulation in on-line or DE contexts. We responded to Abrami's et al.'s (2011) call to apply self-regulation theory and research to help guide improvements in the next generation of distance and on-line learning. Using Zimmerman's cyclical model of self-regulation (2000), we focused on selected design strategies that have shown promise in fostering more effective self-regulation skills among learners. However, given the breadth of our charge, a more narrow scope was required. Therefore, we primarily focused on the role of self-regulation in student-content interactions and identified specific areas of difficulty for students working with electronically enhanced text. Furthermore, we identified populations for whom SRL support might be particularly beneficial and suggested ways to support SRL processes for these learners. Students with weak general SRL skills, poor calibration skills, and executive function deficits might be particularly at risk in DE courses that are largely autonomous or self-directed in nature. One common support found in the literature is the use of scaffolds to support self-regulated learning in on-line learning environments (Azevedo et al. 2004). Scaffolds may be employed coupled with electronic portfolios to guide planning, self-monitoring, self-reflection, and organization (e.g., ePEARL developed by Meyer et al. (2010). As techniques to improve calibration skills in particular and self-regulation more generally, Winne (2004) suggests a delay between the learning episode and metacognitive monitoring, the provision of timed alerts and forms that guide content summarization, directing students to review appropriate information based on past performance, and the development of more effective practice tests followed by performance feedback. A review of calibration studies conducted in classroom contexts points to the use of sustained, guided, and in-depth reflection across trials, perhaps in conjunction with incentives and group practice, to promote more accurate calibration, SRL skill and performance (Hacker et al. 2008a, b; Nietfield et al. 2006; Bol et al. 2010a, b), Students with attention deficits linked to executive dysfunction may profit from the removal of extraneous, unnecessary visual stimulation, the provision of features to highlight essential information, and the promotion of self-instruction skills involving self-articulation of the steps needed to accomplish academic goals (Zentall 2005).

Incorporating evidence-based approaches like self-regulation theory into distance education may help meet the challenge of improving student learning and satisfaction in these contexts. Nevertheless, researchers need to bolster the evidence base to evaluate and tailor these approaches to meet the needs of their students. This line of inquiry should be expanded to include a broader range of students, particularly students with poor SRL skills or nontraditional students who enroll in DE courses. Researchers also need to account for potential interactions that may occur when students are strong domain experts but have weak SRL skills or vice versa. Extending episodes of learning beyond short-term experimental studies would further advance our understanding. More in-depth, longer term studies might focus on a protracted course of study and how students effectively employ SRL in the face of multiple distractions and demands on their time. Furthermore, research is sparse on studies investigating the role of SRL in other types of interaction that occur in on-line and distance education settings. Exploring ways to best integrate SRL into student–teacher and student–student interactions has been emphasized less than in student-content interactions. All three types of interaction are important and demand effective use of SRL. Anglin et al. (2010) contend that high reliability interventions must be applied to distance education, with practice following research. We strongly concur and recognize that though initial research to understand SRL in distance education contexts has been promising, much more work remains.

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