Self-Regulated Learning in Digital Environments: Theory, Research, Praxis

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A B S T R A C T

From a metacognitive perspective, self-regulated learning (SRL) refers to the cyclical processes of understanding the required task, developing a plan and implementing strategies to satisfy task requirements and monitoring the effectiveness of those strategies in achieving the desired outcome. A considerable volume of research establishes that the instructional tools available in digital learning environments are particularly useful in supporting SRL. This paper reviews current theoretical models and recent empirical investigations germane to applications of digital technology to promote SRL. SRL is promoted by teachers who provide instruction architecture that encourages students to ensure that the task is fully understood, select and execute effective plans and strategies and monitor personal progress toward task completion. Such instructional architecture is more readily applied in digital, as opposed to traditional, learning environments. Based upon such review of theoretical and applied research, a comprehensive instructional framework of SRL in digital environments is presented. This framework functions to inform those who design and teach in digital environments to reflect and explicitly address the degree to which their learners have the capacity to self-regulate.

Keywords: Self-regulated learning, Digital environment, Digital technology, Learning environments, Instructional technology, Self-efficacy, Metacognition, Scaffolding.

INTRODUCTION

The term *self-regulation* (i.e., collective actions used to progress toward a desired goal) first appeared in the educational literature in the 1960s.[1] In educational discourse, the concept of s*elf-regulated learning* (SRL) emerged in the 1980s and gained prominence in the 1990s.[2]

Theoretically, SRL involves cognitive strategies such as rehearsal, elaboration, organization and metacognition.[3,4] *Metacognition* is the knowledge and awareness related to thinking processes together with the strategies and ability to appraise and adjust those processes.[5,6] The

self-regulated student intentionally exerts effort toward managing and directing complicated learning activities.[7] Self-regulation in learning is critically related to learning effectiveness and high-achieving students are typically highly self-regulated in their approach to learning.[8-11]

Instructional applications of digital technology have proven particularly effective in promoting SRL.[12-16] According to Wang[17] "the main advantage of e-Learning is that it overcomes the limits of time and space and provides learners opportunities to perform self-directed learning". This is fortunate since, as a result of increased autonomy, "online learners must take greater responsibility for the management and control of their own academic progress".[18] This paper summarizes current theoretical models of SRL and reviews recent empirical investigations germane to applications of digital technology to promote SRL. Based upon such theoretical and applied research, a comprehensive instructional framework of SRL in digital environments is presented. Such a framework organizes the relationships between the processes of SRL and the mechanisms by which course designers can develop, and teachers/tutors can deliver, digital learning experiences that support and assist in the development SRL.

Theoretical models of self-regulated learning

Self-regulated students set task-oriented and reasonable goals, take responsibility for their learning and are highly motivated to learn. [19] Zimmerman[20] proposed a unique and cyclical three phase theoretical models of SRL which comprises forethought, performance and reflection. The *forethought phase* includes motivation and cognitive processes such as goal setting and strategic planning. The motivation stems from beliefs about learning (i.e., personal

ability and task purpose) and is a consequence of self-efficacy, outcome expectation and goal orientation. The *performance phase* involves self-control and self-observation. *Self-control* refers to the use of specific strategies such as self-talk and self-instruction. *Self-observation* includes self-monitoring, time-management and study skills.[21,22] Self-judgement and self-reaction from the third phase, *reflection*. *Self-judgment* involves self-evaluation, which is the comparison of observed performance against a standard[23,24] and perceptions of the reasons for success and failure. [25] *Self-reaction* refers to the individual views of performance and can be either defensive or adaptive. With respect to SRL, defensive reactions include withdrawing or avoiding opportunities to learn.[26]; adaptive reactions include changing learning strategies or behaviors to increase the effectiveness of goal-directed behaviour.[27]

The three phase framework described by Zimmerman[20] is complemented by Winne's[28] *Four Turning Points Model* which outlines critical processes or turning points required for SRL. Related to the forethought phase, the first turning point occurs when the student *understands* the learning environment and task requirements. This turning point requires individual comprehension of the factors that affect academic success, such as time requirements and environmental opportunities and constraints. Also subsumed within the forethought phase, *goal setting* (i.e., Turning Point # 2) requires the student to identify the learning task or academic goal and to adapt or develop strategies for achieving that goal. Related to the performance phase, the ability to *apply strategies* (i.e., Turning Point # 3) occurs when Turning Points 1 and 2 are satisfied. Corresponding to the reflection phase, the learner must also be motivated to monitor personal progress toward the goal

and to *adjust strategies* (Turning Point # 4) as may be necessary."Although there are important differences between various theoretical definitions, self-regulated learners are generally characterized as active, efficiently managing their own learning through monitoring and strategy use". [29]

Based on the theoretical models of Zimmerman[20] and Winne,[28] Figure 1 presents a summary of the essential cyclical processes of SRL. *Comprehending* the learning environment and the required task, at least in a preliminary sense, is fundamental to attempting to approach, address or complete the task and, thus, constitutes the core of SRL. First and foremost, the self-regulated learner must understand what is required in terms of demonstrations of learning and completion of assigned tasks. A student's comprehension or understanding of task requirements is the consequence of prior knowledge, experience and interaction with others, including teachers and peers. [30,31] *Planning* refers to the manner in which the learner intends to tackle the required task. Planning involves allocating time to satisfy identified task requirements and *strategizing* with respect to actions directed toward achieving the specified objectives. [32] Planning and strategizing are ongoing and complementary processes of SRL. Strategies are identified, implemented and adapted or discarded in relation to their perceived utility in achieving task requirements. As the student works toward the task objective, self-monitoring facilitates personal evaluation of progress and allows for adjustment or regulation of individual goal-directedbehaviour.[21,33] At a metacognitive level, self-regulated learners are continually *evaluating* their movement toward task completion and correspondingly evaluating the perceived effectiveness of the executed plan and related strategies. If progress toward completion of the required task is determined to be unsatisfactory, the task may be redefined or reinterpreted, the plan revised, strategies adjusted and so the cyclical processes continue until the task is satisfied relative to learner goals.[34] (See figure 1.)

Zimmerman[20] maintained that SRL is not an innate characteristic, but can be developed via instruction and modelling by, for example, parents, teachers, coaches and peers. Winne,[28] argued that a fundamental objective of education is to enhance student capacity for independent learning (i.e., SRL). All learning environments, including digital environments, are directly focused on facilitating student success and, ultimately, focused on facilitating independent, self-regulated and lifelong learning.[13] Programs aimed at enhancing SRL typically include; 1) modelling demonstrations, 2) guided practice and 3) independent or self-reflective practice.[16] Technological developments have resulted in environments that are interactive and student centred and permit for distinct individual learning activities.[35,36] Although terms vary, a considerable volume of theoretical and applied research supports the contention that the instructional tools available in e-learning or digital learning environments are particularly well-suited to promoting SRL.[37]

Self-regulated learning in digital environments: Theoretical and applied research

Various terms are used to describe instructional applications of contemporary technologies. For example, *e-learning* is a general term used to describe learning environments that are: 1) networked, which enable instant updating, storage / retrieval, distribution and sharing of instructions or information; 2) available to the end user via a computer using standard internet technology; and 3) focused on the broadest

view of learning that goes beyond the typical paradigms of instruction.[38] Similarly, *Technology Enhanced Learning Environments* (TELE) refer to "technology-based learning and instructional systems through which students acquire skills or knowledge, usually with the help of teachers or facilitators, learning support tools, and technological resources".[17] With respect to *Web-Based Learning Environments* (WBLE), the internet is used to access materials and communicate with peers and instructors.[39] *Digital Learning Environments* (DLEs) are technical solutions that support learning, teaching and studying activities.[40] DLEs include any combination of educational software, digital learning tools, online study programs and e-learning resource.[41] It is common for DLEs in higher education to include a learning management system (LMS) that is able to track and report on instructional activities, classroom and online events, e-learning programs and learning content.[42] LMSs vary from being able to manage training and educational records to having the ability to distribute courses over the internet with features for online collaboration.[43] Although the generic nature of the term DLE is preferred, regardless of the specific expression used, the flexibility, adaptability and comprehensive range of available digital technologies are increasingly conceptualized as inherently supporting SRL.[44,45]

In traditional learning environments (i.e., face-to-face classrooms), teachers use instructional procedures to present curriculum materials.[46] In DLEs, learners make use of curriculum materials and instructional procedures via tools and technologies. Elements of the DLE (i.e., instructional technologies, materials and procedures) have the potential to facilitate SRL. Digital technology such as LMS (e.g., Moodle and Blackboard) and other resources (e.g., Apple teaching apps)

support the delivery of instruction by providing teachers and students with accurate, meaningful and accessible information. Specific online tools (e.g., web-conferencing, blogs and discussion forums) facilitate student collaboration with teachers and peers.[47] Computer-based assessments deliver immediate and formative feedback (e.g., online grade books). Such technologies have the capacity to promote the cyclical phases of SRL including task comprehension and then planning, strategizing and evaluating moving toward completion of the necessary task. In DLEs, technological systems, curriculum materials and instructional procedures enhance SRL by providing mechanisms and opportunities for students to clarify their understanding of the task, develop effective plans, select from repositories of strategies and monitor personal mastery of learning requirements.[18,4] Steffens[16] concluded that SRL is maximized in TELEs that, in addition to content, provide opportunities for student interaction, feedback and self-monitoring.

Although the processes of SRL are cyclical (Figure 1), initial understanding of the task or problem is prerequisite to regulate approaches to satisfying the task requirements or solving the problem.[28,48] Darabi and colleagues[22] established that software such as Electronic Performance Support Systems and Electronic Plan (ePLan) promoted SRL in students by providing direction and assistance in delineation of the problem or the required learning task. Narciss, Proske and Koerndle[49] demonstrated that computer learning tools such as Study Desk supported SRL by providing note taking features and allowing students to seek further explanations as may be required. Santhanam, Sasidharan and Webster[50] reported that SRL increased by promoting

students' understanding of required e-learning activities.

Having determined preliminary understanding of required learning tasks, students who are self-regulated develop a plan and select strategies by which to approach the required tasks.[28,48] Banyard, Underwood and Twinner[51] reported that internet use in the classroom promoted SRL strategies such as planning, pacing and self-management. Green, Bolick and Robertson[52] established that student planning was facilitated in a WBLE. Kramarski and Mizarchi[33] observed that the use of an online discussion tool increased peer interaction and use of SRL strategies such as self-evaluation. Yang[32] established that student use of performance control (i.e., self-instruction and self-monitoring) and cognitive strategies were increased in WBLE. Hu and Gramling[53] noted that students in WBLE demonstrated metacognitive SRL processes (i.e., goal setting, strategic planning, self-monitoring and self-evaluation). Students also selected and executed both specific and general learning strategies including rereading, note taking, visualizing, using online audio support, help-seeking, time-management and effort-regulation.

From a metacognitive perspective, students who regulate their learning continuously monitor the accuracy of their understanding of the task and the utility of the plans and strategies used to satisfy the requirements of the task or achieve the desired outcome.[28,48] Such continuous evaluation allows for modification of plans and strategies, as may be required. Nicol[30] confirmed that the use of LMS by first-year university students increased SRL strategies such as progress monitoring. Denton, Madden, Roberts and Rowe[14] found that the use of computer-based assessment supported SRL by providing timely and relevant progress monitoring and feedback. Miller[23]

reported that a majority of students expressed satisfaction for the capabilities of computer-based assessment in providing prompt grading and feedback. In a DLE, Kitsantas and Zimmerman[34] attributed improved motor-skills to continual progress monitoring. Geddes'[15] sample of business students confirmed that online gradebook monitoring positively impacted on academic achievement and was used more than any other feedback tool.

SRL is promoted by teachers who provide instruction architecture that encourages students to ensure that the learning task is fully understood, select and execute effective plans and strategies and monitor personal progress. [28] Such instructional architecture is more readily available and applied in digital, as opposed to traditional, learning environments. [48,16] Trigano[54] established that scaffolded guidance in the TELE enhanced student use of cognitive strategies. Azevedo, Cromley, Thomas, Seibert and Trom[55] reported that the use of metacognitive guidance in WBLE was related to student use of SRL, this is, students provided with scaffolded guidance used planning strategies more often than students not provided with such online guidance. Azevedo, Moos, Greene, Winters and Cromley[56] confirmed that students who were provided with online scaffolded support, compared to those who were not, demonstrated significantly increased SRL (i.e., planning, strategizing and monitoring). Similarly, Kramarski and Michalsky[33] showed that students who were encouraged to use SRL through online scaffolded guidance outperformed students who were not provided with such guidance. Shen and colleagues[24] noted that scaffolded support of problem-based learning scenarios in WBLE improved student grades and SRL. Roll and others[3] established that computer-based tutoring systems such as the Geometry Cognitive Tutor provided students with

automated scaffolding support to help-seeking strategies. With respect to college students, "some research evidence suggests that faculty can use social software tools to facilitate student self-regulated learning processes, such as goal setting, self-evaluation, and help seeking".[57]

SRL is associated with a range of individual student differences, including level of self-efficacy, motivation and emotional control. [58,59] Such student characteristics may be more easily accommodated in digital, as opposed to traditional, learning environments.[15,60,61] Darabi and colleagues[22] established that training software increased student level of self-efficacy. Joo, Bong and Choi[62] reported that self-efficacy in learning predicted student cognitive strategy use and test performance in WBLE. Trigano[54] and Lenne, Abel, Trigabo and Leblanc[63] observed that TELE promoted student motivation. Steffens[31] discovered that TELEs supported cognitive and motivational components of SRL. Edens[64] demonstrated that elements of online course design improved student motivation and preparation for class. Lee and Tsai[65] reported a significant difference in collaboration, information searching and SRL between online and traditional learning environments; students perceived online or WBLE/TELE as offering a better collaboration experience. In reviewing the capacity of TELEs to promote SRL, Steffens[16] concluded that "self-regulated learning not only involved cognitive, but also motivational and emotional factors" and, by inference, that SRL is enhanced by teachers who provide students with emotional encouragement and support in the processes of learning.

Supported by the previously reviewed theoretical and applied research, SRL (i.e., comprehending the task, planning, strategizing and evaluating movement

toward task completion) is influenced by a variety of: 1) learner characteristics such as self-efficacy, motivation and emotional control; 2) instructional elements such as scaffolded guidance, teacher feedback and peer collaboration; and 3) aspects of the digital environment such as LMS, teaching applications and collaborative tools. A comprehensive instructional framework organizes such influences on SRL in digital environments. While teachers and course designers have no direct or immediate control over innate student characteristics, they have considerable control over the selection and implementation of instructional elements and aspects of the digital environment. Puzziferro[10] acknowledged that, in addition to autonomously accessing and reading web-based resources, e-learners must also manage the structure and pace of their own learning processes and strategies. According to Wang,[61] "if learners cannot use self-regulatory learning behaviors to perform self-regulated learning, they will not have good e-Learning effectiveness".

Self-regulated learning in digital environments: An instructional framework

With respect to instructional design, "technical and pedagogical choices are closely related".[63] Proposed as a preliminary instructional framework, Table 1 organizes the relationships between the fundamental processes of SRL and the mechanisms by which course designers can develop, and teachers/tutors can deliver, digital learning experiences that support and facilitate SRL. Specifically, students must understand the requirements of the task to be completed, the skills to be demonstrated and/or the content to be learned. Teachers support such student comprehension by providing detailed directions and specific instructions. Such directions and instructions are provided in

the DLE via a range of electronic resources. For example, live or recorded web-conferencing sessions may include teacher explanation of essay requirements including marking criteria and submission dates. Answers to student questions during the live session may address many of the questions of students who view the recorded session. Alternatively, via asynchronous announcements, students might be encouraged to submit questions to be answered during the upcoming live web-conferencing session. To maximize student use of the recorded sessions and thereby reduce demands on the tutor to repeatedly respond to student queries, the session link might be labelled, for example, *Response to Student Questions on the First Essay*. Organized as links to electronic resources, the DLE should include samples of essays that achieved low, average and high grades, detailed essay marking criteria, including rubrics and a list of common errors for which marks were deducted in previously student cohorts. Online discussion boards may facilitate peer interaction with respect to paraphrasing the required elements in the essay assignment and seeking peer review. A necessary conclusion to the task comprehension process of SRL is the development of a personal goal (e.g., a minimal passing grade, an average grade relative to the class, at least 80%, impress peers, hide inadequacies)."Online instructors can help learners identify and set challenging, proximal goals".[66] Setting reasonable obtainable goals tends to allow students to be more motivated to perform than those students who are not given goals or who are merely encouraged to do their best. (See table 1.)

Although the processes of SRL are cyclical and fluid, it is important to suggest a progression in discussing the instructional framework presented in Table 1. That is, once the student has some understanding of the material to be learned, the task to be completed or the skill to be developed and once he/she has set a personal achievement goal, a plan must be formulated to achieve that goal. A key cognitive process is planning that "provides for the regulation of behavior such as asking questions, problem solving, self-monitoring, and impulse control".[67] In learning environments, planning involves the management and regulation of time, effort and resources. Planning also involves the development, selection and/or adaptation of strategies to achieve the personal goal.[66] To facilitate student planning, instructional designers might include calendaring tool and automated announcements to remind learners of important dates and pending deadlines.

Students who develop plans and strategies to achieve personal learning goals are actively involved in their learning.[68] Web-based technology is particularly well-suited to promoting active student involvement in the processes of learning.[68-70] According to Yu,[71] the many advantages of network technology (e.g., place, time, device and platform-independence, immense storage space, multimedia capabilities, high processing speeds, and instant data retrieval and management) enable the design and development of web-based student question-generation learning systems. Questions posed by teachers, peers and the student him/herself force consideration of approaches to answering such questions. Contemporary web-conferencing systems permit rich-media tools to be integrated, offering inventive possibilities for instantiating synchronous online learning. Screen-sharing, text chat, whiteboards, communal note areas, Voice-over IP and so on provide a powerful collection of tools with which to present information, model processes and share concepts.[72] Task and domain-specific mnemonics and algorithms

may be available to students as interactive and/or multimedia resources. The teacher/ tutor should scaffold support to students via the provision of partial solutions and learning activities that have some sections completed. In most cases, a variety of real-time and delayed-time communication options support interactions between peers and with the teacher/tutor.[66]

The student who is self-regulated continuously monitors and evaluates his/her understanding of the task, the appropriateness of his/her personal learning goals, the effectiveness of his/her plan and the success of the strategies implemented. "Teachers generally feel that students' lack of time management skills is the greatest problem and obstacle to learning in virtual environments".[68] Summarized in Table 1, as part of the planning and strategizing processes of SRL, students manage their time and effort by appropriate allocation of personal resources, actively seeking support for their learning by interacting with peers and tutors, accessing available materials and resources and making effective use of recommended and essential digital applications and tools. With respect to instructional design, calendaring tools and automated reminders may functions to support time management in students who lack such skills. Successful scaffolding requires collaboration or support for a learner or group of learners from teachers or other more able partners who afford appropriately challenging activities accompanied by the proper quantity and quality of assistance.[73]

Wang[61] claimed that self-assessment is the most fundamental aspect of SRL. Students who continuously examine their own learning and evaluate the extent to which they are moving toward personal learning goals have the capacity to modified plans and strategies, as may be necessary. Monitoring and evaluating learning efforts

and outcomes is the essence of metacognition and SRL[5,6] As presented in Table 1, the self-regulated student must continuously reconsider and refine learning goals. As capacities to self-regulate increase, personal learning goals may correspondingly be modified (e.g., from passing to excelling). As goals are fluid, at least to some extent, examination of progress toward those goals must be equally flexible. The self-regulated student revisits instructions for assignment completion and marking criteria to clarify understanding in relation to personal learning and achievement goals. A critical function of the tutor in digital environments is motivating and encouraging the student to exert and maintain learning effort.[74,31] Instructional design supports SRL by inclusion of mechanisms of self-and peer assessment and detailed teacher feedback. Grabe and Sigler[75] provided university students with four web-based study tools: short answer practice test items, multiple choice practice test items, lecture notes, and textbook notes. Students who utilized the tools academically outperformed those who did not. It may come as no surprise that the description of learning, teaching and technology described in Table 1 is generally consistent with sound instructional practice.

CONCLUSION

Promoting SRL may be aptly conceptualized as exemplary teaching. In effective instructional design, all materials and resources support student completion of the required tasks, demonstration of the required skills and mastery of required content. Given the continuously increasing volume and complexity of required learning in contemporary society, self-regulation is increasingly critical to student success. Overall, the existing empirical literature supports well-established findings from research in traditional classrooms; specifically, that academic self-regulation is

important, if not essential, for effective learning and performance in digital environments.[66] Ultimately, those who design and teach in digital environments must first consider and explicitly address the degree to which their learners have the capacity to self-regulate.

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Table 1. An instructional framework of self-regulated learning in digital environments

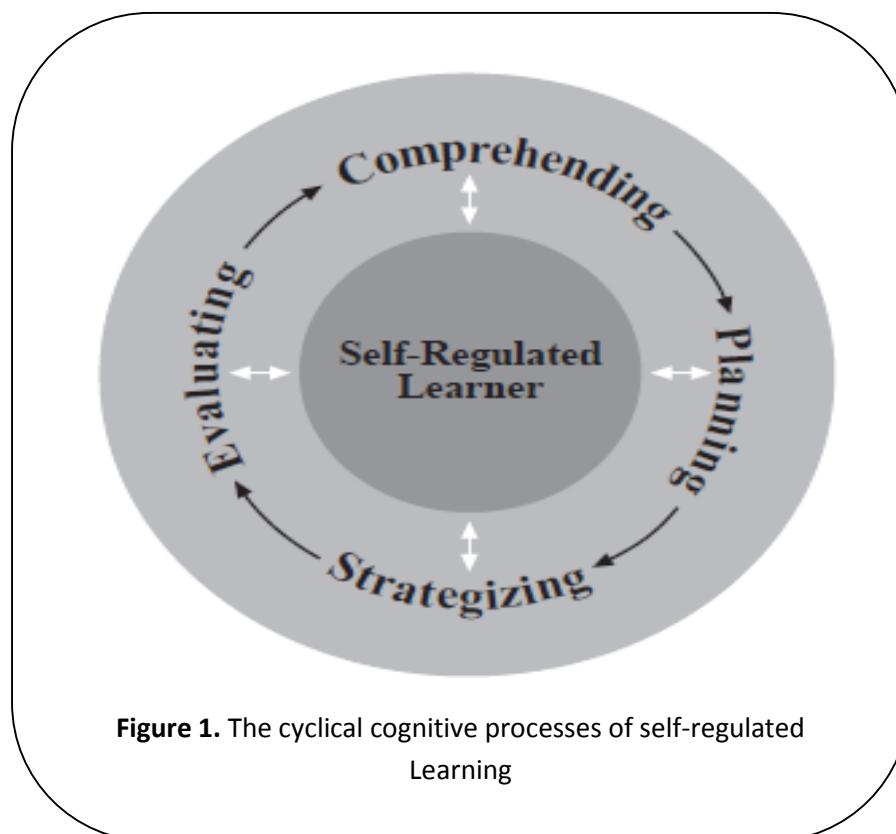| Instructional design	Self-regulated learning	Digital environment
Task comprehension support	**Student task comprehension**	**Task comprehension tools**
Detailed directions Specific instruction Examples and prototypes Marking criteria Common problems	Access materials Read and summarize Organise information Seek clarification Set personal goal	Electronic resources including web-based text, video, audio and images Tools for communicating with teacher and peers
Planning/strategizing support	**Student planning/strategizing**	**Planning/strategizing tools**
Timelines and reminders Questions and answers Mnemonics and algorithms Ideas and solutions Model and demonstrate Scaffolded guidance	Manage and monitor time Regulate effort and stress Seek help, as necessary Access learning resources and support materials Select and utilize tools	Calendaring applications Peer collaboration tools such as discussions and wiki Links and help features Online training and tutorials Communicating tools
Monitoring/evaluating support	**Student monitoring/evaluating**	**Monitoring/evaluating tools**
Encourage and motivate Review and redirect Self-assessment materials Peer assessment strategies Detailed and frequent teacher feedback	State learning goals Determine personal progress toward goals Clarify requirements Reconsider approach Revise time lines	Grades and marks apps Tracking and progress tools Online quizzes and tests Reminder/listing apps Tools for teacher and peer assessment

Figure 1. The cyclical cognitive processes of self-regulated Learning