

Directed Self-Regulated Learning and Learning System Support

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ABSTRACT

Among the strongest military assets in today's complex warfare domains are personnel who are self-starters, able to quickly adapt to new missions, technologies, and other job challenges; in other words, personnel who are self-regulated learners. Self-regulated learning (SRL) allows individuals to select learning topics based on job demands or other interests and manage their learning through processes such as goal setting, strategy selection, and monitoring. Decades of research show that the behaviors associated with SRL are linked to positive learning outcomes. However, despite the benefits of SRL, it is also well-recognized that learners do not automatically use strategies that support SRL. Given the state of the research and the importance of SRL, the purpose of this paper, first, is to describe a competency framework for self-regulated learning that was developed to support experimentation with Army University. The framework was tailored for adult learners who, because of factors such as work demands, schedule variability, and proficiency levels, have difficulty learning how to learn. Second, this paper delineates how learning systems can be used support learners engaging in SRL. This work is timely given the advancement of standards that support learning, including those encompassed by the Advanced Distributed Learning Initiative's Total Learning Architecture (TLA). The TLA is a collection of data interoperability standards and business rules that enable data-driven, comprehensive, and responsive life-long learning opportunities. This paper will delineate how initiatives such as TLA can be used to support directed SRL (Brydges, Dubrowski, & Regehr, 2010), in which learners are taught, mentored, monitored and assessed as they engage in SRL.

ABOUT THE AUTHOR

Dr. Jennifer Fowlkes-Ratliff is a SETA contractor supporting the ADL Initiative. In a career spanning over 30 years, Dr. Fowlkes worked for both government and industry in areas focused on enhancing training experiences and performance assessment methods. While at the Naval Air Warfare Center Training Systems Division, Dr. Fowlkes supported the Navy's Ready Relevant Learning initiative and other programs by co-creating methods that allowed analysis teams to visualize learning and career continua, and therefore better plan relevant training content, the timing of training delivery, and training infrastructure needs. Also, while working for the Navy, Dr. Fowlkes led the development of a Navy-accredited proficiency model that was used to predict training needs for Navy aviators. Elements of the proficiency model have been widely used, for example, to support media fidelity acquisition decisions for Navy aviators and to optimize training content and media mixes. Prior to her work for the government, Dr. Fowlkes led or co-led programs focused on training effectiveness assessment, eliciting knowledge from experts, and training strategies supporting advanced learning.

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One of the most valuable assets in today's military are personnel who are self-starters in terms of being able to quickly adapt to new missions, technologies and other job challenges; in other words, who engage in self-regulated learning (SRL). Self-regulated learning allows individuals to select learning topics based on job demands or other interests and then control and enhance their learning through processes such as goal setting, strategy selection, and monitoring. Specifically, Pintrich and Zusho (2002, p. 64) define SRL as:

an active process whereby learners set goals for their learning and monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features of the environment.

Decades of research show that learning strategies embedded in SRL result in improved learning and retention (Hattie & Donoghue, 2016; Panadero, Jonsson, & Botella, 2020; Zimmerman, 1990). Hattie and Donoghue (2016), for example, reported large effect sizes for strategies associated with SRL across learning topics and phases of learning. Data also show that students may prefer taking more control of their learning. Brydges et al. found that medical students, if given a choice, prefer more independent study over study that is regulated and monitored. However, despite the benefits of SRL, it is well-documented that students do not necessarily use SRL-related strategies. To this point, Milligan and Griffin (2016) assessed the extent to which learners within two Massive Open Online Courses (MOOC) engaged in expert learning behaviors. A key finding was that, within the context of MOOCs, only 2% of the over 8000 participants engaged in behaviors that would lead to higher order learning. Kornell and Bjork (2007) reviewed research showing that students rely on ineffective strategies for deciding what to study, how long to study, and how to study. In addition, they found that students lack basic mental models about human learning processes and strategies needed to engage in SRL. Zimmerman (2002) noted that it is not surprising that students do not develop independent learning skills:

Students are seldom given choices regarding academic tasks to pursue, methods for carrying out complex assignments, or study partners. Few teachers encourage students to establish specific goals for their academic work or estimate their competence on new tasks. Teachers seldom assess student's beliefs about learning, such as self-efficacy perceptions or causal attributions, in order to identify cognitive or motivational difficulties before they become problematic. (p. 69).

In addition, as implied in Pintrich and Zusho's (2002) definition above, in real world settings, ideal learning circumstances are difficult to create. Competing demands, complexity of material, time constraints, and human propensities are just some of the variables that, in addition to lack of knowledge about human learning, prevent learners from reaching optimized learning scenarios. Kornell & Bjork (2007) acknowledge that students, often out of necessity, make study decisions by triage rather than to improve learning and retention.

Based on research findings such as these, researchers and practitioners advocate for the use of "directed" SRL in which learners are coached and monitored as they engage in SRL (e.g., Stevens, Seiser, Lyons, Bohannon, & Tovar, 2019). Brydges et al. (2010) identified ways in which learning systems can support learners: support learners' assessment of their skill and knowledge, challenge them to engage in scenarios designed to take their learning to the next level, support them through periods of frustration that inevitably accompany learning, and provide guidance on study strategies that, while highly effective, are counterintuitive and therefore seldom used. This view supports the notion of scaffolding adult learners in learning methods for improved learning outcomes.

The purpose of this paper is to identify ways in which learning systems can support SRL, where a learning system encompasses the people, technologies, strategies and materials that support learning. This type of initiative is timely with ongoing initiatives in the DoD to provide infrastructures supporting career or life-long learning. The present effort was performed in support of the Advanced Distributed Learning (ADL) Initiative's Total Learning

Architecture (TLA), a project that defines a set of policies, specifications, and standards for enabling the DoD's future learning ecosystem. The ADL Initiative's data strategy includes strategies that enable SRL because of its importance to life-long learning. Therefore, in support of this goal, below an SRL competency framework was developed. This framework was tailored for adult learners who, because of factors such as work demands, schedule variability, and proficiency levels, have difficulty learning how to learn. As each of the SRL competencies is described, we identify functions that learning systems can provide to support SRL. The identification of the competencies and methods for supporting them is a necessary step towards the thoughtful development of specifications supporting SRL.

SELF-REGULATED LEARNING COMPETENCIES

Skills and knowledge that support SRL were identified based on a review of established, research-based models of SRL including from Zimmerman (1990, 2000), Nicol and Macfarlane-Dick (2006), and Pintrich (2000, 2003). Table 1 provides an overview of the SRL skills that were identified and the knowledge that supports SRL skill execution. Performance of these skills by learners is initiated upon assignment to, or selection of, a learning event. Learning events vary in scope such that an overall course can trigger SRL as well as, for example, specific class assignments (e.g., essay), study sessions, and outside reading. Usually, multiple learning events--and hence SRL processes--are occurring at any one time. For example, the learner may be taking multiple courses, or may be learning a new sport or hobby in addition to taking a class.

The SRL skills shown in column 1 include analysis of the learning task, selection of goals for learning and, linked to the goals, and selection of strategies that support achievement of the goals. These skills can be sequentially performed, however, that is not assumed. For example, individuals selecting learning strategies may realize that they do not know enough about the learning topic and therefore circle back to analysis of the learning task. The SRL skills of monitoring, reflection, coordination, and adaptation ideally accompany the performance of the other skills.

The SRL subskills are clustered into three categories, accommodating Pintrich's (2000) notion that SRL includes cognitive and attitudinal processes as well as processes to manage contextual factors that can affect achievement of learning goals. Cognitive skills address methods and actions that support encoding of the information being taught or the skills being learned in the learning event. These skills directly target how to learn the material given the nature of the material and learning goals.

The second category addresses affective components. Affective components nearly always accompany and influence learning but are rarely acknowledged. Most students can remember a feeling of satisfaction that accompanied excellent task performance after hours of practice, such as operating a weapon system, negotiating an agreement, or other achievement. Conversely, learning is also accompanied by frustration when it seems to be going slowly or at a standstill. Lack of motivation accompanies learning for all learners at some points, even for individuals who generally show high interest in learning. While learners cannot always control affective components, being aware of them, and taking steps to modify them, can lead to better learning outcomes.

Finally, the third subskill category is control of context factors and includes controlling or adapting to elements of the environment that may facilitate or hinder learning, including the learning system, and other events or tasks that are ongoing during learning and that may impact goal or strategy selection. In addition, we emphasize context factors, similar to Pintrich (2000), because of their importance to adult learning. These elements are discussed in the remainder of this paper.

Analyze Learning Event

Good learners "assess" the cognitive, affective, and contextual aspects of the learning event, meaning that at the outset of a learning event, prior to formulating a plan about how to learn, they consider the opportunities and barriers inherent in the specific learning opportunity. Learning event assessment is updated throughout the event as learners gain more information or learning event demands change. For example, they come to better understand the preferences of the instructor, the difficulty of the content, and so forth. While largely automatic in many learners, a more deliberate assessment on the part of the learner sets the stage for SRL. Zimmerman (2002) emphasizes that expert learners use information about the course in a deliberate manner to set goals and select strategies, whereas novice learners are more likely to set goals and strategies reactively, maybe only after performing poorly.

Table 1. Overview of SRL Skills and Supporting Knowledge

Skills	Subskills			Supporting Knowledge
	Cognitive	Affective	Context	
Analyze learning event	Assess: <ul style="list-style-type: none"> • Course demands (assignments, deadlines, grading criteria) • Type and difficulty of content • Previous relevant domain and metacognitive knowledge 	Assess: <ul style="list-style-type: none"> • Self-efficacy • Motivation • Interest 	Assess: <ul style="list-style-type: none"> • Extra course demands • Environmental factors that facilitate or hinder studying 	<ul style="list-style-type: none"> • Learning demands of different types of learning content • Instructor characteristics • Self-efficacy construct and relationship to learning • Previous domain knowledge • Previous metacognitive knowledge (e.g., use of SRL behaviors)
Set goals	<ul style="list-style-type: none"> • Select performance and/or learning goals • Set outcome and process goals 	<ul style="list-style-type: none"> • Set goals that address motivation, interest, and confidence, as needed 	<ul style="list-style-type: none"> • Set goals that address structuring or adapting to the environment to achieve desired learning outcomes 	<ul style="list-style-type: none"> • Difference between process and outcome goals • Difference between performance and learning goals • Characteristics of good goals • Knowledge of skill decay
Select strategies	<ul style="list-style-type: none"> • Select strategies that facilitate encoding 	<ul style="list-style-type: none"> • Select strategies that enhance motivation 	<ul style="list-style-type: none"> • Select strategies for adapting to env. conditions • Selects strategies to manage workload 	<ul style="list-style-type: none"> • Learning strategies for different content and complexity • Differentiates myths from fact in terms of study strategies that work • Knowledge of skill decay
Identify and collect materials	<ul style="list-style-type: none"> • Identify and collect materials related to the topics to be learned 	N/A	N/A	<ul style="list-style-type: none"> • Search methods • Importance of judging the quality of learning materials
Enact learning	<ul style="list-style-type: none"> • Implement learning strategies • Use tools that support interactions with content (e.g., search tools) 	<ul style="list-style-type: none"> • Implement strategies to manage affective states • Persist in learning 	<ul style="list-style-type: none"> • Implement strategies to manage contextual factors 	<ul style="list-style-type: none"> • Knowledge of learning system features
Monitor learning progress	<ul style="list-style-type: none"> • Monitor learning progress using multiple methods 	<ul style="list-style-type: none"> • Monitor affective states such as motivation, frustration, and self-efficacy 	<ul style="list-style-type: none"> • Monitor contextual factors that may affect learning 	<ul style="list-style-type: none"> • Monitoring techniques (e.g., log keeping) • Effective self-evaluation practices • Importance of affective states and context factors in affecting learning outcomes
Reflect on learning progress	<ul style="list-style-type: none"> • Accurately assess learning progress • Make causal attributions pertaining to learning progress • Predict future performance • Recognize when help is needed 	<ul style="list-style-type: none"> • Assess affective states • Make causal attributions pertaining to affective states 	<ul style="list-style-type: none"> • Assess success in controlling or managing contextual factors 	<ul style="list-style-type: none"> • Biases affecting self-assessment • Attribution effects • General human learning principles • Links between learning and affective states, especially self-efficacy
Adapt SRL behaviors to improve learning outcomes	<ul style="list-style-type: none"> • Set process goals that meet requirements for iteration (i.e., observable, timely) • Adapt goals and strategies to improve learning 	<ul style="list-style-type: none"> • Adapt goals and strategies to manage affective states that affect learning 	<ul style="list-style-type: none"> • Adapt goals and strategies to control or manage contextual factors that affect learning 	<ul style="list-style-type: none"> • Characteristics of process goals • Dynamic nature of self-regulated learning • Repertoire of strategies linked to learning outcomes • Metacognitive processes for recognizing learning challenges
Collaborate with others to support learning	<ul style="list-style-type: none"> • Seek help when needed • Obtain feedback and other inputs on learning products • Provide feedback to peers • Produce informal artifacts on which feedback can be obtained 	<ul style="list-style-type: none"> • Seek help when needed • Obtain feedback on learning products • Provide feedback to peers 	<ul style="list-style-type: none"> • Seek help when needed • Obtain feedback on learning products • Provide feedback to peers 	<ul style="list-style-type: none"> • Attitudes towards help seeking • Teamwork skills

There are many opportunities for learning systems to set the stage for SRL and model good SRL behaviors.

- Evaluate student understanding of course objectives and assessment criteria. At the outset of a learning event, a review of course topics, learning objectives, timelines, and assessment criteria provides a framework of requirements, constraints and affordances that sets the stage for SRL. Learning systems should ensure that students understand what is expected of them in terms of assignments, performance standards, and grading criteria. Nicol and Macfarlane-Dick (2006) argue that a written syllabus is not enough by itself to convey the richness of course information; they recommend discussions, talk backs, and even assessments. It makes sense to go the extra mile to ensure students understand expectations. Hattie and Donoghue argue that students need “notions of what success looks like before investing in learning.” (p. 6).
- Activate relevant prior knowledge. Activating prior knowledge is a key to advanced learning because it allows learners to build integrated knowledge, making connections from existing knowledge to new knowledge (Merrill, 2002). Pintrich (2000) points out that the process of prior knowledge activation will occur automatically to some extent. As learners review course topics, they will likely spontaneously recall relevant domain knowledge. However, good learners will deliberately ask themselves “what do I know about this topic?” and from that gauge the amount and difficulty of the learning needed to succeed as well as appreciate how the existing knowledge and skill they possess will be augmented by the new learning. Learning systems can participate in this process in a number of ways. Most simply, learning systems can prompt students to ask themselves what they know that can help them learn the new topic. Precourse knowledge assessment, discussed below, would also activate relevant prior knowledge. At a more sophisticated level, enterprise level learning systems that support career long learning can provide visualizations and descriptions of 1) where a learning opportunity fits into a career path, 2) the enabling skills and knowledge possessed by the student based on their learning history, and 3) how the current learning opportunity facilitates career growth.
- Provide learning or career map. Career maps allow learners to set career goals, create learning milestones and systematically record the training and experiences accumulated to reach goals. Learning systems should provide the capability for students to build, populate, view, modify, and otherwise use their learning maps.
- Evaluate pre-course knowledge and skill. Pre-course assessments aimed at determining existing skills and knowledge are useful for instructors, and also provide a baseline for students to better understand what they know or don’t know, activate prior, related knowledge, monitor learning, and provide an idea of material complexity. All of these are important for goal setting. In addition, providing students a meaningful, diagnostic assessment of their understanding of course topics models a method that they can use for their own self-assessments.
- Educate students on different classes of learning outcomes and pertinent learning strategies. Knowledgeable learners will analyze the type of material to be learned in order to set goals and select strategies because it directs the type of processing and practice that is needed. For example, an anatomy class will require learning of facts, and learning to treat injuries will require procedural knowledge as well as decision making. The forms that this education could take include a short instructional unit or a simple “cheat sheet” that identifies different types of learning outcomes and strategies that are best applied to learning them. Arming students with this knowledge would increase their repertoire of strategies, better enabling them to adapt to different learning demands. Hattie and Donoghue (2016) argue that education about SRL is best applied as part of a course rather than as a standalone instructional unit.
- Help students identify challenges. Identify the areas in which students have difficulty performing. Expected difficult topics can be conveyed to students through course data, such as average test scores for each topic, or discussed with them, allowing them to prepare for difficult content areas. In addition, challenges related to attitudes (e.g., lack of motivation) and context factors (e.g., lack of a suitable study location, lack of time) can be addressed through group discussions or occasional one-on-one time with instructors.
- Assess student confidence in performing well. Self-efficacy is a belief about one’s own capability to be successful in achieving desired learning and performance goals. Self-efficacy is important in SRL because it impacts effort expended, persistence, and goal-setting (Schunk, 1990). Some of the relationships between SRL and self-efficacy, based on Schunk and others’ work, are summarized below:

- Learners who exert little control over their learning tend to have low-self-efficacy and they tend to attribute their performance to lack of ability or lack of effort. In contrast, students who exert control over their learning tend to have higher self-efficacy and are more likely to attribute their performance to use of learning strategies. The latter is a more useful attribution because it is actionable.
- Students with high self-efficacy are more likely to persist in their attempts to learn during frustration periods and have higher motivation.
- High self-efficacy leads students to set more challenging learning goals.
- When students set intermediate goals for themselves that are specific and of short duration, allowing them to easily gauge progress, their self-efficacy is enhanced.

Given the importance of self-efficacy, it would be useful for learning systems to provide students with a self-efficacy survey that was tailored to the course. Attached to the survey could be amplifying information that educated students about the importance of self-efficacy for learning and what can be done via goals and strategies to address low self-efficacy.

- Survey and maintain repertoire of SRL behaviors. Create a repository of the classes' SRL behaviors that students can add to or refer to throughout the course. Periodically, these could be discussed in a group setting regarding what the behaviors are, when they have been applied, and to what success, allowing the group to expand their repertoire.
- Ensure students understand resources available to them. Ensure students understand the resources provided to them by the learning system that aid in learning, including mentors, practice tests, flash cards, links to other materials, etc.

Set Learning Goals

Based on the learner's assessment of the course content and demands, learning goals are set. Table 2 identifies two dimensions of learning goals, the first of which is the performance versus mastery stance. That is, goals can relate to attaining a performance standard such as performing well on tests or, conversely, to the mastery of material such as learning and retaining content and transferring what has been learned to the job. The latter is assumed to be adopted by students, however both orientations have use. If a course enables better job performance it behooves learners to strive to retain the knowledge and skills gained; that is, set learning goals. If a course is mandatory but has no obvious connection to the learner's work, the learner may choose to "just get through it" by performing well on graded artifacts.

The second dimension is outcome versus process goals. "Outcome goals" identify expected learning end states and are generally long term in nature, while "process goals" identify steps or interim goals that enable the targeted outcomes. Research shows that both are essential to SRL but process goals are especially important and especially early in learning (Zimmerman & Kitsantas, 1997). In one study, for example, Brydges, Carnahan, Safir, and Dubrowski (2009) examined the importance of outcome versus process goals using a task in which students learned wound closure skills. The 2 x 2 research design varied use or non-use of SRL strategies and use of process versus outcome goals. They found that use of SRL did not result in superior performance unless students set process goals. The group that set only outcome goals did not outperform the other groups. It makes sense that process goals are more helpful early in learning: process goals, which are generally more specific than outcome goals, can be quickly and easily assessed, and better enable learners to get feedback, reflect on their own performance, and adjust. In other words, they much better support recursion.

Table 2. Goal dichotomies and examples.

	Performance Oriented	Learning Oriented
Process	Pass exams and other assignments as efficiently as possible	Enhance understanding of a topic
Outcome	Pass course Obtain certification	Excel at work

To support goal setting, learning systems can:

- Encourage goal setting. Learning systems can simply prompt students to set goals. An example could be, “Have you set a learning goal for this unit?” or a discussion of different types of goals.
- Provide tools for setting and updating goals. Learning systems can provide tools for students to record and easily update goals, keeping in mind that goals are generally free form, may vary in number, and may be updated regularly.
- Provide examples of goals. Despite the variability in goals, students can be provided with guidance for setting process goals, and can be provided with examples of goals related to encoding, managing affective states, and managing context factors that pertain to the material to be learned.
- Provide feedback on goals. Instructors can provide feedback on goals, especially in terms of their alignment with class goals.

A final aspect of goal setting pertains to setting goals in the zone of proximal development, a concept that holds that learners should be challenged to perform at increasingly higher, more advanced levels (Vygotsky, 1978). Embedded in this notion is 1) an assessment of an individual’s current knowledge and skills, and 2) identification of topics and skill exercises that will build on these capabilities to bring them to the next level. Similar notions are foundational to Ericsson’s (2002, 2007) concept of deliberate practice in which a mentor guides a trainee to perform at increasingly higher performance levels by presenting performance challenges specifically to build targeted knowledge and skills. Deliberate practice is a streamlined way to building expertise, but it requires knowledgeable mentors or instructors who possess the desired skills. What is very attractive about it is that each practice session is purposeful in that it has a specific goal based on targeted weaknesses or skill gaps. It challenges the notion that just because you practice, and have spent a lot of time practicing, you are getting better. The downside of deliberate practice for SRL is that it is best supported by someone who is an expert and it requires knowledge of an individual’s state of learning.

To support deliberate practice, learning systems can educate students about the power and value of challenging themselves. Learning systems with sophisticated assessment capabilities and banks of curriculum and practice opportunities can provide recommended learning units or practice opportunities that are in the zone of proximal development based on diagnostic performance assessment.

Select Study Strategies

Study strategies are the methods students use to help them learn material or engage in skills practice. Table 3 shows a few examples of strategies that students might employ in each of the cognitive, affective and context skill areas. Ideally, self-regulated learners deliberately select study strategies that enable them to achieve their learning goals. Hadwin, Winne, Stickley, Nesbit and Woszczyna (2001) emphasize that there is a difference between using study strategies versus selecting them to be used based on the material at hand – where the latter points to effective self-regulated learning. “The element of intent to adapt cognitive engagement distinguishes SRL from just using tactics.” (p. 477).

However, the lack of understanding of effective strategies among students is well-documented (e.g., Karpicke, 2009; Koriat & Bjork, 2005). Kornell and Bjork (2007) found that 80% of the college students they surveyed reported that they have never been taught study strategies. Moreover, research documents that 1) students often use ineffective strategies, and 2) and often organize their time and select strategies by triage rather than to optimize learning, retention, and transfer. This, they noted, result in “perils of self-regulated study.” Accordingly, key targets are for learning system to:

- Prompt discussions between learner and instructor(s) regarding strategy selection.
- Educate learners in effective learning strategies for different types of learning outcomes pertinent to the course.
- Recommend learning strategies as part of feedback to students.
- Provide context appropriate study materials, tools, and guides (e.g., flashcards, practice tests, simulations).
- Provide opportunities for students to rehearse or practice hands-on tasks.
- Prompt students to identify strategies related to managing affective states.
- Prompt students to identify strategies related to managing contextual factors.

Table 3. Strategy Examples

Strategy Examples
<p><u>Cognitive strategies</u></p> <p>Organizing and transforming information:</p> <ul style="list-style-type: none"> • Arranging study materials to improve learning and ensuring all needed materials are present • Outlining chapters • Highlighting important information • Rewriting notes • Summarizing material • Maintaining a list of material to be learned • Maintaining a learning log <p>Selecting strategies suitable to the learning outcomes or learning goals such as:</p> <ul style="list-style-type: none"> • Choosing distributed or massed practice, depending on goal orientation • Self-testing (all learning outcomes) • Creating a concept map for learning and practicing relational knowledge • Using mnemonics for learning facts • Mental rehearsal for procedural skills • Whole task and part task practice for complex skills
<p><u>Managing affective states</u></p> <ul style="list-style-type: none"> • Social support, for example, reaching out to instructors and peers for help when needed • Rewards for reaching study milestones (e.g., get a snack, see a movie) • Reducing anxiety through exercise • Mindfulness
<p><u>Creating an environment conducive to studying and controlling other context factors</u></p> <ul style="list-style-type: none"> • Choosing to study at a quiet time and place • Wearing headphones to minimize outside noises • Getting enough sleep • Managing time

Enact and Monitor Learning

Students engage in learning, first collecting materials and tools to support learning. This can be as simple as using textbooks or online information or as complex as seeking hard to find content. It also includes discerning the relevance and quality of materials and tools that have been collected. Students then interact with the materials, adhering to the goals that have been set and implementing strategies for learning. Learning systems can support these activities:

- Provide tools that support learner interactions with learning materials (e.g., search features, note taking, annotating content, bookmarking content, sharing artifacts, advanced organizers, blogs, ratings of content)
- Provide links to materials and information that might include: syllabus, courseware/curriculum, quizzes and assessments, practice materials (e.g., flash cards), demonstrations, case studies, ebooks, virtual guided practice, and articles.
- Provide ratings of learning materials. Collect and provide student and instructor ratings of materials and leaning system tools.
- Provide links to instructors, mentors and domain experts that can be accessed for help or discussion.
- Provide mechanisms for students to monitor learning, such as a learning log, in which they can record factors such as goals set, strategies used, time spent learning, and results. Maintaining a learning log has been shown to improve learning results.

Reflection and Adaption

Figure 1 identifies several of the process that occur during an individual's reflection on their learning progress and adaption of goals and strategies, the crux of SRL. Reflection is an essential component of learning in general and

pivotal to the adaptive mechanisms that make SRL successful. Kolb (1984), in his theory of experiential learning, recognized the central importance of reflection to the integration of new experiences with existing skills and knowledge. Mann (2016) summarized other benefits of reflection that are critical to SRL: It enhances readiness to seek and accept feedback, a hallmark of expertise, and facilitates reconciliation of cognitive and affective elements of experience.

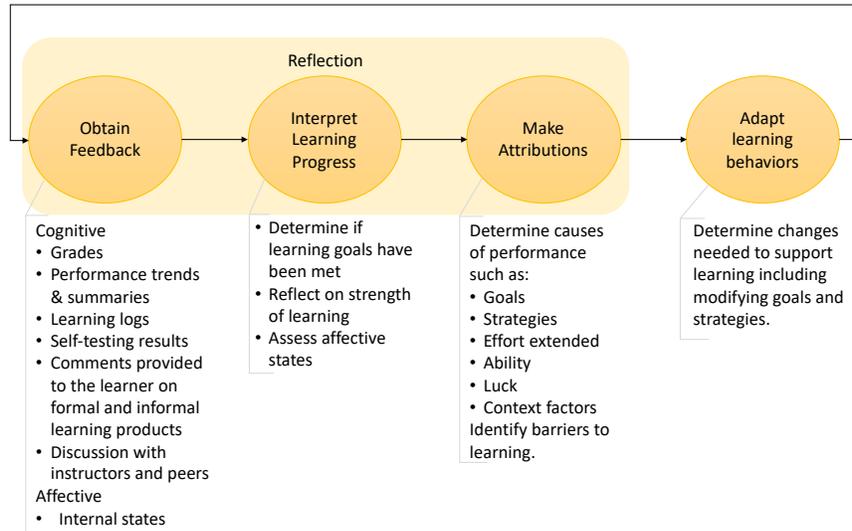


Figure 1. Feedback and Reflection Cycle

For its foundation, reflection requires feedback on how learning and performance is progressing against goals that have been set. Ideally, learners will seek a variety forms of feedback, over time, and from multiple sources such as those listed in Figure 1 (Yan, 2020). Reflecting on learning progress then involves using feedback to determine if goals have been met, determining strength of learning, and assessing internal affective states. Reflecting on strength of learning entails predicting future performance and is enhanced by asking questions such as:

- Have I “overlearned the material?”
- Has my performance been tested under different contexts?
- Have I distributed by recall practice?
- Can I teach this topic to someone else?
- How am I doing relative to my peers?
- How has my domain knowledge been changed, expanded, or clarified?
- Can I safely apply the knowledge and skills to my job?
- Can I predict my future performance?

Regarding affective states, learners may gauge their interest in the topics being learned, assess self-efficacy, and look for signs of anxiety or frustration. Low self-efficacy, frustration and anxiety are signs that interventions may be needed to improve learning outcomes. Finally, reflection includes determining the likely causes of poor learning outcomes. Attributions can include factors such as ability (qualities that the learner possesses and are usually perceived as fixed), effort expended on the learning task, task difficulty, luck, and strategies used. Learners who tend not to use SRL are more likely to attribute poor outcomes to factors such as lack of ability – or to other factors they perceive to be out of their control which in turn diminishes their motivation to change. The greatest motivational problems in the learning process, such as passivity and apathy, are connected with the students’ attributions of their failure to internal and uncontrollable causes (e.g., lack of ability) (Schunk, 1990, 1991). In contrast, learners who use SRL behaviors are more likely to attribute learning outcomes to the strategy that was used, a component that can be changed to result in better outcomes in the future.

Learning system support is crucial for reflection because, in general, learners tend to overestimate learning progress. Common tendencies are for learners to:

- look at current performance (e.g., on a set of flash cards) as an indicator of how they will perform in the future, an approach which discounts effects such as skill decay, current motivation, and current context or conditions of practice (Bjork, 1999). A well-studied example is that massed practice can result in large performance gains compared to spaced practice, leading learners to overpredict how they will perform in the future. However, retention is generally much better under spaced practice conditions.
- assume learning is complete when learning progress appears to slow down even though additional repetition would improve retention
- ignore signs of misunderstanding, a common finding in the literature on advanced learning. That is, learners tend to discount knowledge that runs counter to their understanding of a given topic area (Feltovich, Spiro, & Coulson, 1993).
- use unvarying conditions of practice which may result in better performance gains, when introducing changes can improve retention.
- avoid making mistakes, for example, by simplifying conditions of practice, mistakenly believing that mistakes reflect poor learning or learner inadequacy (Bjork, 1999).

Bjork (1999) makes the point that educational practices generally promote these behaviors, focused as they are on performance during training as opposed to longer term retention and job performance which are much more indicative of what has been learned. As he stated, “Doing anything during training that increases errors or decreases rate of improvement will not...tend to be well-received—not by management, not by instructors, and not by the trainees themselves” (Bjork, 1999, p. 454).

Therefore, learning systems provide essential support for reflection.

- Provide practice of reflection. Provide opportunities for structured reflection and self-assessment. Students can compare their conclusions and thoughts about their learning to those of an instructor or mentor.
- Provide diagnostic assessments of learning performance. In general, in most learning settings, students receive scores on tests that provide little insight on what they’re doing right and wrong, or how they can correct their study habits. Learning systems can help by providing diagnostic assessments of learning progress based on formal assessments, including as appropriate: motor or psychomotor skills, declarative knowledge, relational knowledge, problem solving, etc. Moreover, learning systems can provide feedback that links the student performance to recommended practice or study strategies based on the results of the diagnostic assessments.
- Provide feedback that equips learners to make corrections. Nicol and Macfarlane-Dick (2006) summarized research on feedback as it relates to SRL. They argue that learners struggle to understand feedback provided by instructors and that learning systems should endeavor to provide feedback that empowers learners to implement corrections. They provided guidelines for giving feedback, some of which are listed below.
 - Include both written and verbal descriptions of what constitutes good performance.
 - Provide exemplars of good performance
 - Engage in discussions with students to ensure they understand what constitutes good performance
 - Provide student learning dashboards showing data summaries and trends.
- Periodically probe students’ understanding of complex topics. Students may carry misunderstandings, especially as they learn complex topics. This occurs in all forms of learning but may be especially problematic for SRL.
- Provide students with examples of common misunderstandings that previous students have experienced so they can compare these points of difficulty to their own understanding of them.
- Educate trainees on topics of human learning that can improve habits supporting learning and reflection. Useful topics include: SRL processes, effective study techniques for different types of learning outcomes, importance of affective states for learning, and the importance of introducing desirable difficulties for learning and for gauging learning progress. Education can be imparted through forms such as tutorials, short class modules, class discussions, and information posters and “one pagers.” Education can also be embedded in feedback, as discussed below.

Finally, adapting goals and strategies based on reflection and making attributions defines the dynamic nature of SRL. Keeping the goal-strategy-learning-reflection cycles short and ongoing throughout learning appears to be one key for successful self-guided learning outcomes, enhancing metacognition and positive self-efficacy. To achieve this, the skillful use of process goals is key. While outcome goals define desired end states and have an important role for guidance, process goals define how to get there. There are many advantages to keeping process goals short term and easily observed.

- More accurate self-assessment. It is easier to get feedback on interim products and reflect on results. In turn, self-assessments, being based on observable, well-defined criteria, are more accurate.
- Better control of learning. Short cycles make it easier to make changes before learning demands get out of hand.
- Attitudinal outcomes follow. Short learning cycles affect perceptions of progress, self-efficacy beliefs about future success, and intrinsic motivation to continue to mastery.
- More useful attributions. Process-oriented learners were more likely to attribute performance to strategies versus to ability or effort extended.

There are other keys that support adaptation. Important among them is that learners knowledgeable about SRL process will be better equipped to make changes. Knowledge includes the SRL process, characteristics of process goals, general human learning principles, being skillful and experienced in goal setting, and finally possessing a repertoire of strategies. Learning systems can help with adaptation through education and more directly through assessment and feedback of SRL behaviors. Assessment can be multimethod and include: monitoring of student use of learning system features that support SRL, looking for use, persistent use, and evidence of adaptation (e.g., changing goal statements), and use of SRL surveys, one psychometrically sound example being the Strategic Learning Questionnaire (Hadwin et al., 2001).

Collaboration

Collaboration refers to involving others in one's own self-regulated learning. Students can and should develop learning partnerships, a competency that will improve all forms of learning. Obvious partnerships include working with other students and with instructors. These types of collaborations include seeking help when needed, obtaining feedback on learning products, providing feedback to peers on their learning products, and producing artifacts on which feedback can be obtained. Learning technologies support collaboration through features such as chat, virtual meetings, and the sharing of artifacts.

Students can also seek out subject matter or domain experts, individuals that can help to correct misunderstandings, fill in information gaps, and provide the types of insights that can only be gained through experience. To support these types of collaborations, learning systems can provide links to:

- Former students who now have experience in the field and who have agreed to provide support to other students
- Domain experts who can provide alternative perspectives

SUMMARY AND DISCUSSION

This paper examined ways in which learning systems can better enable SRL, systematically identifying SRL skills and then identifying ways in which learning systems can support these skills. Our approach sets the stage for the thoughtful and systematic incorporation of SRL into enterprise level learning ecosystems. Table 4 summarizes learning system features identified from previous discussions that support SRL. Organized this way, it is clear that learning systems can support learners in at least four ways. First, learning systems can educate students about SRL, human learning, and effective study strategies. A case was made that education is needed in these areas and even that traditional education systems can act in opposition to them! Second, learning systems can prompt students to engage in SRL and even provide practice and feedback of SRL skills. If prompting is done in context appropriate ways, SRL may seamlessly be incorporated into learning regimes. Third, learning systems can provide the tools needed to monitor performance. The more ways that students have to self-assess and obtain diagnostic assessments, the better equipped they are to adapt their learning approaches to achieve successful outcomes. Finally, providing career information better enables students to plan their studies in a deliberate manner to foster career and personal growth.

Table 4. Learning System Features that Support SRL.

SRL Skills	Learning System Features that Support SRL	SRL Functions			
		Educate/Model	Guide	Support Self-Assessment	Support Career Planning
Assess Course	Evaluate student understanding of course objectives and assessment criteria			X	
	Activate relevant prior knowledge			X	
	Provide learning or career map		X		X
	Evaluate precourse knowledge and skills			X	
	Educate students on relevant learning outcomes and pertinent learning strategies	X			
	Help students identify challenges			X	
	Assess student confidence in performing well			X	
	Survey and maintain repertoire of SRL behaviors	X			
Set Goals	Test understanding of course resources	X			
	Encourage goal setting		X		
	Provide methods for setting and updating goals		X		
	Provide examples of goals pertinent to the course	X			
	Provide feedback on goals			X	
	Educate students about the power and value of challenging themselves	X			
Select Strategies	Provide recommended learning units or practice opportunities that are in the zone of proximal development.		X		
	Prompt discussions regarding strategy selection	X			
	Educate students about human learning	X			
	Provide context appropriate study materials			X	
	Provide opportunities for students to rehearse or practice hands-on tasks			X	
Enact and Monitor Learning	Provide SRL Behaviors Survey	X			
	Search functions		X		
	Organizing functions		X		
	Collaboration functions		X		
Reflect and Adapt	Provide a learning log		X		
	Provide practice at reflection			X	
	Provide diagnostic assessments of performance			X	
	Provide feedback that equips students to make changes		X	X	
	Recommend learning strategies as part of feedback to students		X		
	Probe student understanding of complex topics			X	
	Provide examples of common student misunderstandings			X	
	Educate about human learning	X			
	Provide mechanisms for students to share and get feedback on a variety of learning artifacts			X	
	Address student frustrations			X	
	Provide learning challenges		X		
Collaborate	Provide feedback on student use of SRL	X			
	Provide collaboration tools		X		
	Prompt collaboration with students, instructors, mentors, and domain experts	X	X	X	X

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