A Heuristic Evaluative Framework for Self-Regulated Learning Design

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Researchers and educators have explored a variety of technologies to facilitate self-regulated learning (SRL). Drawing from contemporary perspectives on SRL, this paper articulates two fundamental design principles for SRL-promoting technologies: the *platform principle* and the *support principle*. This paper then discusses how usability inspection methods, such as *heuristic evaluations* and *cognitive walkthroughs*, can readily assess whether and how these needs are met. This framework can assist researchers and educators in evaluating technologies to make strategic design and implementation decisions aligned with self-regulation.

Introduction

Self-regulated learning (SRL) refers to iterative learning processes wherein individuals make plans, set goals, attempt to complete tasks, monitor their progress, and adapt to improve (Azevedo, 2009; Panadero, 2017). These self-directed activities have been cited as a key element of success in *K-12 and higher education* (Ben-Eliyahu & Linnenbrink-Garcia, 2015; Dent & Koenka, 2016; Greene et al., 2010), *online learning* (Broadbent & Poon, 2015; Kizilcec et al., 2017; Littlejohn et al., 2016; Wong et al., 2018), and *workplace learning* (Margaryan et al., 2013; Siadaty et al., 2016).

To promote SRL, researchers and educators have explored computer-based learning environments to teach SRL strategies or provide a platform for self-regulation (Devolder et al., 2012; Winters et al., 2008). Many technologies now also track inputs and performance to offer personalized feedback (Roll & Winne, 2015; Tabuenca et al., 2015). And, these tools are increasingly mobile; they leverage the portability of phones and tablets to afford SRL "on the go" (Sha et al., 2012; Tabuenca et al., 2015).

The efficacy of such systems relies on the quality of their design (Roscoe et al., 2017; Winters et al., 2008), and researchers have previously adapted usability assessments for e-learning (Mehlenbacher et al., 2005; Zaharias & Koutsabasis, 2012). To advance these efforts, this paper offers *a heuristic evaluative framework aligned to SRL-promoting technologies*. We review (a) SRL research to inform two design principles for enabling and scaffolding self-regulation, and (b) usability testing research to suggest tractable inspection methods.

Enabling Strategic SRL

SRL models describe phases of *planning*, *enacting*, *monitoring*, and *adapting*, which unfold iteratively and interdependently. Progress through the phases can be nonlinear, and the inputs and products of each phase can influence each other.

In *planning*, learners analyze their tasks, gather resources, choose strategies, set goals, and establish evaluation criteria (Kostons et al., 2012; McCardle et al., 2017). Good plans allow learners to be efficient, identify strategies and metrics, and craft contingencies for failure. In *enacting*, learners try to complete their tasks, which may require applying or gaining knowledge, solving problems, making decisions, and other tasks. In this stage, learners also enact their plans. Thus, learners who lack clear plans are disadvantaged because they have less direction, fewer steps to follow, and may be unprepared to detect errors.

In *monitoring*, learners assess their own knowledge and products, predict outcomes, and diagnose errors (Deekens et al., 2018; Kostons et al., 2012), and may do so before, during, and after the task (Baars et al., 2014). Such self-evaluations are essential because learning and task performance rarely unfold smoothly or without error (Bjork et al., 2013), and mistakes can halt progress or lead to faulty solutions and misconceptions. In *adapting*, self-regulated learners try to adapt and improve in response to problems detected via self-monitoring.

Across all phases, strategies are essential. Success in most activities is facilitated by general and task-specific procedures that impose structure, guide attention, promote reasoning, or otherwise improve efficiency (Alexander et al., 1998; Donker et al., 2014). For instance, planning entails assessing time constraints and scheduling tasks. Thus, self-regulation may benefit from time management strategies (Hartwig & Dunlosky, 2012; Rodriguez et al., 2018). Similarly, self-questioning strategies (Joseph et al., 2016) and self-testing strategies (Hartwig & Dunlosky, 2012; Rodriguez et al., 2018) help students assess their own learning. Students also have a variety of strategies for adaptation, such as information-seeking (Walraven et al., 2013) and help-seeking (Roll et al., 2014).

The Platform Principle

In the design of computer-based learning environments, the platform principle states *that SRL-promoting technologies should offer platforms for planning, enacting, monitoring, and adapting*. Technologies that seek to promote SRL must allow learners to accomplish self-regulatory tasks *via the software*. Importantly, such platforms can be instantiated based on concrete strategies. For example, "create a calendar" and "make a list" are both planning strategies, and thus software might include "calendar tools" for learners to plan their studying or "to-do list tools" for setting goals.

We hypothesize that technologies that offer more and diverse platforms will be more effective than technologies that offer fewer platforms—a fully-featured system might allow learners to engage in all phases without exiting the system.

Scaffolding Strategic SRL

Learners often need substantial assistance to develop SRL proficiency (Azevedo et al., 2008; Bjork et al., 2013; Devolder et al., 2012; Dignath & Büttner, 2008; Lee et al., 2010; Nicol & Macfarlane-Dick, 2006; van Meeuwen et al., 2018).

Many learners benefit from *direct instruction* about SRL and strategies (e.g., goal-setting techniques) and opportunities to practice these skills. *Direct and indirect prompts* can remind learners, suggest optimal actions, and draw attention to key ideas and tools (Bannert et al., 2015; Müller & Seufert, 2018). Another approach is to provide *feedback* in response to learners' inputs and actions (Lee et al., 2010; Nicol & Macfarlane-Dick, 2006). Students are not always skilled at self-regulation, and feedback can reveal gaps and errors, convey information, and recommend strategies.

Self-assessment and *formative assessment* resources can also facilitate self-monitoring and learning (Fraile et al., 2017; Panadero et al., 2017). Learners can use rubrics to study assessment criteria and exemplars, which makes these guidelines more accessible and usable. Relatedly, learning analytics tools are increasingly using student data to personalize assistance and feedback (Azevedo & Gašević, 2019; Gašević et al., 2017; Roll & Winne, 2015; Tabuenca et al., 2015; Winne & Baker, 2013). Algorithms that detect learner actions and inputs can guide responding to students' knowledge, skills, and cognitive-affective states in real-time.

Targets for Support. *Strategies* are essential for SRL, and direct instruction can teach strategies and provide opportunities to for practice (Zepeda et al., 2015). Once learners have begun to acquire the strategies, prompts can serve as reminders to use them. Similarly, learners can receive immediate feedback on recent steps or delayed feedback after completing longer tasks. Feedback can introduce strategies, help learners monitor their strategy use, and reveal how a new strategy might work better.

Another impediment is that many learners lack proficiency in *self-monitoring* (Alexander, 2013; Azevedo, 2009), such as overestimating their performance or relying on misleading cues to judge their understanding (Bjork et al., 2013). Support for monitoring may take the form of guidelines, prompts, or rubrics that remind learners when and how to self-assess. Similarly, the demands of self-monitoring can be "offloaded" on to others (e.g., tutors) who offer external assessment and regulation while learners are still developing their own skills. In the case of SRL-promoting technologies, learning analytics tools can sometimes conduct these assessments automatically.

Numerous links between SRL and *motivation* have also been observed (Duffy & Azevedo, 2015; Littlejohn et al., 2016; Smit et al., 2017). Learners with lower motivation or self-efficacy are less likely to engage in SRL. Technologies can support intrinsic motivation by enabling opportunities to feel competent, autonomous, and connected (Reeve et al., 2008). Similarly, self-efficacy beliefs develop through experience, observation, and feedback (Ahn et al., 2016). Technologies might help learners improve self-efficacy by modeling strategies or giving feedback that highlights both successes and opportunities to grow. Finally, researchers are exploring the use of learning analytics to detect cognitive-affective states (e.g., frustration) in real-time, which enables systems to intervene if learners disengage (Calvo & D'Mello, 2010; Spann et al., 2019).

Importantly, scaffolding should not be permanent. If the goal is to promote *self*-regulation, then external supports cannot assist learners in perpetuity. Thus, a final aspect of SRL support is to *promote independence*. In educational research, "fading" refers to the gradual and adaptive removal of support until learners can perform tasks on their own (Azevedo & Hadwin, 2005; Belland, 2014; Devolder et al., 2012). Fading does not necessarily require the removal of all assistance, but if learners receive adequate training and practice, then the mere presence of the platforms may serve as sufficient cues for SRL.

The Support Principle

In the design of computer-based learning environments, the support principle states that *SRL-promoting technologies should include scaffolds for strategies, metacognition, motivation, and independence*. We do not endorse any specific method. However, we hypothesize that more robust systems will likely offer support for every included platform (i.e., if the tool enables notetaking, it should also include notetaking help), and might have multiple forms of support (e.g., hints for note-taking strategies and automated feedback on note quality). These supports should encourage learners to be proactive and independent, including the ability to deactivate hints, prompts, and feedback as learners become more self-directed.

Evaluating SRL Technology Design

This paper proposes a heuristic evaluative framework (see Figure 1) for assessing adherence to the platform and support principles. Usability can be defined as the extent to which products, devices, or systems can be learned and used by intended audiences to complete tasks with accuracy, ease, speed, and satisfaction (ISO 9241, ISO 2018; Nielsen & Budiu, 2013). Usability assessments consider the above variables to identify and remove usability threats (Dumas & Fox, 2009; Kortum & Sorber, 2015; Zhang & Adipat, 2005).

	SRL Phase			
Heuristic	**Planning**	**Enacting**	**Monitoring**	**Adapting**
Platform Implementation	**Yes | No**	**Yes | No**	**Yes | No**	**Yes | No**
Strategy Support Implementation	**Yes | No**	**Yes | No**	**Yes | No**	**Yes | No**
Metacognition Support Implementation	**Yes | No**	**Yes | No**	**Yes | No**	**Yes | No**
Motivation Support Implementation	**Yes | No**	**Yes | No**	**Yes | No**	**Yes | No**
Independence Support Implementation	**Yes | No**	**Yes | No**	**Yes | No**	**Yes | No**

Figure 1. Heuristic Evaluation Template

Within this process, inspection methods offer a principled way for developers to assess and update designs from the earliest stages of development. Exemplar methods include *heuristic evaluations* (Hvannberg et al., 2007; Nielsen & Budiu, 2013) and *cognitive walkthroughs* (Huart et al., 2004; Khajouei et al., 2017; Mahatody et al., 2010; Polson et al., 1992). Our heuristic framework specifies design criteria for these tests.

Importantly, the "ideal" of including platforms and supports for all phases is not always feasible. Moreover, there is no requirement for the system to be the only platform or support. Activities may be offline (e.g., paper-and-pencil worksheets) or may use a separate technology (e.g., a chemistry simulation). Instructors can provide verbal instructions, discuss strategies, demonstrate methods, and provide feedback. This blend of "online" and "offline" SRL should be explicitly indicated in system documentation and usability inspections—developers should make users aware of these expectations and perhaps offer recommendations for how to achieve those goals.

Heuristic Evaluations of SRL Design

Heuristic evaluations entail systematic inspections of tools and systems, based on predefined parameters, to reveal violations of design principles, potential usability problems, and possible causes or remedies (Gómez et al., 2014; Hvannberg et al., 2007; Nielsen & Budiu, 2013; Zaharias & Koutsabasis, 2012). These evaluations can be conducted "in house" before end users ever interact with the system, and the speed and low cost of heuristic evaluations facilitates multiple iterations.

Heuristic evaluations have been used to improve e-learning and online instruction, such as web-based writing courses (Miller-Cochran & Rodrigo, 2006), web-based tools for collaboration (Hvannberg et al., 2007), web-based support for competence maps (Stoof et al., 2007), online employee training (Zaharias & Poulymenakou, 2009), MOOC-like online courses (Zaharias & Koutsabasis, 2012), virtual laboratories (Davids et al., 2013), game-based social skills training (Tan et al., 2013), and peer communication (Carmichael & MacEachen, 2017). These tests were able to reveal issues in system design (e.g., access, navigation, and clarity), which allowed the developers to address problems in future studies or interventions.

Methodologically, the parameters assessed in heuristic evaluation can be set based on knowledge of best practices or the features of specific tasks. By developing these checklists in conjunction with instructional concerns, these principles can be tailored to learning contexts (Zaharias & Koutsabasis, 2012; Reeves et al., 2002; Tan et al., 2013).

According to the platform principle, SRL-promoting technologies must include one or more platforms for *planning*, *enacting*, *monitoring*, and *adapting*. Heuristically, developers can document (a) whether and (b) how platforms are realized (see Figure 1). The former can be implemented as a binary evaluation (i.e., yes or no). The latter entails summaries of the actual *implementation*: if a platform is included, developers should document those functions or features. According to the support principle, the system must scaffold learners' *strategies*, *metacognition*, *motivation*, and *independence*. The presence or absence of supports is a binary evaluation. And, if supports are present, evaluators then document the specific tools, functions, or features that implement the support (see Figure 1).

Cognitive Walkthroughs for SRL Design

In a walkthrough, developers adopt the role of users to complete tasks while documenting potential actions, feature clarity and salience, resources, sources of confusion, and communication (Mahatody et al., 2010; Polson et al., 1992). These tests can be performed with prototypes, wireframes, or other incomplete versions—missing features may be simulated (Mavrikis & Gutierrez-Santos, 2010). Walkthroughs can also be performed quickly, iteratively, cheaply, and "in house" without recruiting end users. However, whereas heuristic evaluations focus on the presence design features, walkthroughs help to anticipate users' actions, thoughts, feelings, and needs.

A few studies have used walkthroughs to evaluate learning technologies, such as multimedia applications (Huart et al., 2004), e-portals for history courses (Karahoca & Karahoca, 2009), analytics toolkits for teachers (Dyckhoff et al., 2012), digital textbooks (Lim et al., 2012), writing evaluation (Roscoe et al., 2014), and augmented reality (Kiourexidou et al., 2015). These walkthroughs revealed usability threats in each system along with misalignments between intended and actual use.

We suggest two levels of walkthrough for assessing SRL-promoting technologies. At the *technology level*, designers explore features (documented via heuristic analysis) built into the system to complete relevant tasks. If a system includes quiz, calendar, or reminder functions, then walkthroughs should explore each function to inspect usability. In addition, learners must have the opportunity to "close the loop"—to enact *all four* SRL phases. Thus, at the *self-regulatory level*, developers should consider self-regulation itself as the walkthrough task. Can people use the system to make plans, take action, self-monitor, *and* adapt without exiting the system?

Conclusion

The effectiveness of SRL-promoting learning technologies depends on the quality of their design. This paper articulated two design principles for evaluating such systems via concrete inspection methods. Researchers, educators, and developers can use this approach to systematically document the strengths of their tools and to articulate targets for strategic new designs.

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14. ABSTRACT
Researchers and educators have explored a variety of technologies to facilitate self-regulated learning (SRL). Drawing from contemporary perspectives on SRL, this paper articulates two fundamental design principles for SRL-promoting technologies: the platform principle and the support principle. This paper then discusses how usability inspection methods, such as heuristic evaluations and cognitive walkthroughs, can readily assess whether and how these needs are met. This framework can assist researchers and educators in evaluating technologies to make strategic design and implementation decisions aligned with self-regulation.

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