Chapter 1

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ABSTRACT
Recent research suggests that technologically enhanced learning environments (TELEs) represent an opportunity for students to build their ability to self-regulate, and for some, leverage their ability to apply self-regulated learning (SRL) to acquire knowledge. This chapter reviews 55 empirical studies and interprets their findings to answer the following questions: (1) What is the theoretical basis for understanding the possible relations among SRL and TELEs? (2) What types of TELE have been used to study these relations? (3) When participants engage in SRL behaviors in a well-designed TELE, do they show greater learning than their peers who engage in fewer SRL behaviors? (4) How have TELEs been shown to promote SRL tendencies in learners? and (5) How do pre-existing SRL tendencies influence the ways in which learners interact with TELEs? Our review suggests that TELEs can promote SRL and are best used by those who can self-regulate learning. SRL training should occur before the task, or be embedded in the TELE. Knowledge acquisition in TELEs is supported by learner self-regulation and by design features that include immediate and adaptive feedback and tools which support SRL behaviors.

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INTRODUCTION

Technology-enhanced learning environments (TELEs) have become increasingly prevalent over the past 25 years. Although the growth in TELEs is due to a number of factors, the most influential include the widespread availability of relevant technologies (e.g., personal computers, wireless communication, teleconferencing, etc.; One Laptop Per Child, 2009; Pea, Wulf, Elliot & Darling, 2003), the need to serve large numbers of students who reside in locations that are far removed from brick and mortar institutions, (Sloan Consortium, 2006) increased appreciation for the fact that technology can present information and capture performance in ways that traditional instruction cannot (Mayer, 2005; Winne & Perry, 2000) and generational shifts in comfort levels with technology. In addition, the increased popularity of distance and online learning options have created opportunities for new courses that are motivating even the most reluctant faculty to offer at least some of their programs online (Waits & Lewis, 2003).

Each time a new form of TELEs emerges, it is usually promoted as holding considerable promise (Winne, 2005). However, the gap between such predictions and reality have forced many to acknowledge the role that students play in getting the most out of a TELE. Even a well-designed technology will only have its desired effects if teachers and students take advantage of what it has to offer. In what follows, we expand on this basic premise and examine the empirical evidence related to TELEs as we provide answers to the following five questions: (1) What is the theoretical basis for understanding the possible relations among SRL and TELEs? (2) What types of TELE have been used to study these relations? (3) When participants engage in SRL behaviors in a well-designed TELE, do they show greater learning than their peers who engage in fewer self-regulatory behaviors? (4) How have TELEs been shown to promote SRL tendencies in learners? and (5) How do pre-existing SRL tendencies influence the ways in which learners interact with TELEs? After providing answers to these questions in turn, we draw conclusions.

QUESTION 1: WHAT IS THE THEORETICAL BASIS FOR UNDERSTANDING THE POSSIBLE RELATIONS AMONG SRL AND TELEs?

As will become evident in subsequent sections of this chapter, researchers who have examined the linkage between SRL and TELEs have implicitly or explicitly adopted a particular theoretical stance to predict and explain the behavior of their participants. Some authors have also evaluated TELEs in terms of how well these environments support SRL as defined by particular theories (e.g., Zimmerman & Tsikalas, 2005). As such, it is useful to begin our review by engaging in a brief theoretical and meta-theoretical analysis of the literature on SRL in TELEs prior to describing the findings of empirical studies. At the core of our analysis are three issues. The first is relevance—the (reasonable) presumption that SRL may be particularly germane to TELEs. The second is parsimony—the problem of multiple, partially overlapping theories in the literature, which generally explain the same phenomenon with slightly different terminology. The third is utility—specifically, the utility of an Opportunity-Propensity framework for understanding the relations between SRL and TELEs.

Relevance

It is important to note that environments differ in the extent to which students need to be self-regulated in order to be successful. If a learning environment is highly structured, engaging, and focused on the acquisition of a simple (non-demanding) skill or task, students need not be self-regulated in order to be successful in that environment. In contrast, self-regulation is par-
particularly required when: (a) the environment is focused on complex, multi-step tasks in which possible solution strategies and outcomes are not known in advance (so the learner must plan and monitor performance), (b) it is easy for the learner to become distracted, lose interest, or forget the main goals of the task, (c) the task requires the use of strategies (e.g., note-taking) to overcome the processing limitations of the mind, and (d) learners must engage in helpful behaviors (e.g., planning, monitoring, strategy use, etc.) on their own, without guidance, pressure, or prompting from others. In such environments, learners who engage in SRL behaviors are far more likely to be successful than learners who do not engage in SRL behaviors. Given that many (though conceivably not all) TELEs focus on complex problems, require strategies to overcome processing limitations, and so on, it is reasonable to expect that a self-regulated learner would show higher rates of learning in a TELE than their less self-regulated peers.

**Parsimony**

The foregoing discussion, however, makes clear the fact that one can only know whether a TELE requires SRL (or whether it is helpful to be self-regulated in that environment) only if one has in mind a definition of what it means to be self-regulated. Unfortunately, the literature contains a number of distinct and partially overlapping theoretical models (and definitions) of self-regulation. As a result, one must answer the question, “Does this TELE require SRL?” with the answer, “It depends on the SRL theorist you have in mind.” To illustrate some of the differences among specific approaches, consider the contrasting models of Zimmerman and his colleagues, on the one hand, and Boekaerts and her colleagues on the other.

Zimmerman and Tsikalas (2005) argue that self-regulation emerges in learning contexts in three cyclical phases: forethought, performance and self-reflection. During the **forethought** phase, self-regulated students engage in metacognitive processes (i.e., *task analysis, goal setting, strategic planning*) and self-motivational processes (*task interest, values, intrinsic interest, self-efficacy*). During the **performance phase**, they engage in metacognitive strategies (*e.g., self-instruction, attention focusing*), behavioral strategies, metacognitive monitoring and behavioral recording. Finally, during the **self-reflection phase**, they reflect upon and react to their performance (*e.g., causal attributions* for success; feelings of satisfaction).

Boekaerts and Niemivirta (2000), in contrast, suggest that the key theoretical construct is the notion of **appraisal**. Depending on how a task is appraised, a learner decides whether or not to even attempt it (a metacognitive belief), and also decides which way to proceed to successfully complete the task. Metacognitive beliefs, in turn, are moderated by motivational factors. If learners develop positive appraisals, they advance to a goal process which involves goal setting and action. If the appraisal is negative, learners choose instead to not complete a task and protect their ego, resources, and well-being. Depending upon the learning context, two different action patterns are generated. If it is deemed that this context is similar to one previously encountered, an automatic action pattern is followed, and the learner proceeds immediately to goal setting and carrying out an action plan. A learning context which has not been previously encountered requires additional consideration, where learners must complete the appraisal process and determine if (a) the task is within their ability to complete, (b) it represents any threat to their well-being to attempt and (c) the task is worth completing.

Although it is possible to work out points of overlap in these two accounts, it should be clear that two researchers could make very different predictions about the degree of SRL that would take place in the very same TELE, depending on which of these theories each person advocated. Because this ultimately is an untenable obstacle that limits scientific progress and the development of truly effective forms of intervention, we
propose that a useful solution to this problem is to propose a consensus definition of SRL that distills and integrates the key constructs evident in various approaches. In particular, we define SRL as having the following attributes:

- **SRL is Metacognitive**, in the sense that the learner engages in effective forms of planning, organizing, task analysis, goal-setting and monitoring of progress.
- **SRL is Strategic**, in the sense that the learner utilizes effective domain-general (e.g., help-seeking, note-taking) and domain-specific strategies (e.g., reading strategies) that help them overcome processing limitations, overcome emotional distress and/or promote better comprehension and retention of material.
- **SRL is Adaptive**, in the sense that the learner adjusts appropriately to changes in circumstances and demonstrates an emotional and motivational profile that is associated with achievement (e.g., a calibrated sense of ability, self-efficacy, being concerned about the right kind of things)
- **SRL is Engaged**, in the sense that the learner is focused and remains focused on learning the material and is able to avoid being distracted.
- **SRL is Self-initiating**, in the sense that they do not need others to urge them to begin tasks, remain focused, organize themselves, use strategies and so on. They engage in self-regulatory behaviors on their own because they want to be successful and understand how these behaviors help them be more successful.

**Utility**

Anyone who has experience as an educator would probably view the aforementioned list of attributes of a self-regulated learner (i.e., metacognitive, strategic, adaptive, engaged and self-initiating) as representing an ideal that few students demonstrate. Researchers who study SRL within TELEs would also probably agree. Many students fail to take full advantage of even a well-designed TELE. A useful way to understand this phenomenon is to cast it within an Opportunity-Propensity (O-P) framework that has been used to successfully explain the acquisition of knowledge in other kinds of settings (e.g., Byrnes & Miller, 2007; Byrnes & Wasik, 2009). The basic premise of the O-P framework is that learners are more likely to attain high levels of achievement within a particular domain (e.g., mathematics) if two necessary conditions are met: (a) they are given genuine opportunities to enhance their skills in the domain (the opportunity condition) and (b) they are willing and able to take advantage of these opportunities (the propensity condition). When individual or group differences are observed in achievement, advocates of the O-P framework would account for this outcome by determining the extent to which the opportunity and propensity conditions had been fulfilled in individuals who performed poorly. In particular, the account suggests the utility of testing the following three hypotheses:

1. low performers were presented with fewer opportunities to learn than high performers,
2. low performers were presented with as many opportunities as high performers but the former were unable to benefit from these opportunities (e.g., due to lack of preparation) and
3. low performers were presented with as many opportunities as high performers but the former were unwilling to engage fully and benefit.

Starting with this central premise, one then considers how each of the factors proposed in the literature might relate either to opportunities to learn or to the propensity to take advantage of opportunities to learn. Byrnes and Miller (2007) define opportunities to learn as *culturally defined contexts in which an individual is presented with content to learn* (e.g., by a teacher or parent, an author, etc.) *or given opportunities to practice skills*. Thus, opportunities can occur both within
school and outside of school. We argue that any variables related to exposure (e.g., coursework, content coverage, a teacher’s emphasis, homework, amount of repetition, etc.) or teaching quality (e.g., use of proven techniques, communication skills, classroom management, equitable treatment of students) would fall into the domain of an opportunity factor (Opdenakker, Van Damme, De Fraine, Van Langegehm & Onghena, 2002; Pressley, Wharton-McDonald & Raphael, 2002; Tate, 1995). That is, children would be expected to show higher achievement if they are taught by a skilled teacher who treats all children fairly and equitably and if they are adequately and systematically exposed to the content required on end-of-year assessments. When applied to the current theme of the present book, learners are presented with an opportunity to learn when they find themselves in a well-designed TELE.

In contrast, propensity factors are any factors that relate to the ability or willingness to learn content once it has been exposed or presented in particular contexts (Byrnes & Miller, 2007). As such, factors such as domain-specific aptitude, pre-existing knowledge, motivation and self-regulation all pertain to the propensity component. That is, children would be more willing and able to take advantage of learning opportunities if they bring to these learning opportunities prerequisite skills, aptitudes, the desire to learn the content, and the spontaneous tendency to utilize effective strategies where appropriate (Byrnes, 2003; Byrnes & Miller, 2007; Carroll, 1989; Corno et al., 2002; Jones & Byrnes, 2006; Pintrich, 2000; Reynolds & Walberg, 1991; Wigfield, Byrnes, & Eccles, 2005). Thus, self-regulation is an important aspect of propensity.

Viewed in this light, learning successes and failures within TELEs can be diagnosed in a retrospective manner. For example, when students evince relatively low levels of self-regulation or low levels of learning, these disappointing results could either be due to the fact that the TELE did not represent a genuine opportunity to learn (e.g., because it was poorly designed or confusing) or due to the fact that students failed to enter the TELE with a sufficient level of prior knowledge, aptitude, motivation and self-regulation.

QUESTION 2: WHAT TYPES OF TELE HAVE BEEN USED TO EXAMINE THE RELATIONS BETWEEN SRL AND TELES?

Until this point, we have been focused primarily on the assumptions made by various theorists as they define SRL, and the ways in which we can collectively discuss them using like terms. We do so in order to explore the potential interaction between aspects of SRL and learning in TELEs.

We now turn our attention to the remaining questions posed in the introduction, and attempt to answer such inquiries by relying on the body of empirical evidence collected to date. To complete this task, we reviewed 75 empirical studies. Because many studies attempted to answer multiple questions, we first summarize common methodologies, and then treat findings as they relate to each question separately. Twenty of the studies had too many shortcomings to draw firm conclusions, so we limit our discussion to the 55 listed in Table 1.

When reviewing empirical studies, it became clear that three main types of TELEs were employed in these studies. The first TELE is a didactic learning environment that was designed to teach students how to be self-regulated, either through pre-task training, or through prompting and scaffolding of specific SRL activities. These TELEs often tutor or prompt students to self-regulate learning by encouraging planning, monitoring, strategy use or reflection (e.g. Cognitive Tutor; Aleven, McLaren, Roll & Koedinger, 2006). A second class of TELEs are less instructional, but instead are designed to facilitate students’ naturally occurring self-regulation of learning (e.g. gStudy; Nesbit, Winne, Jamieson-
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Tools to promote strategy use, monitoring and reflection are made available, but students must seek out these tools for their own use instead of being prompted or externally regulated by the environment. These designs lend themselves to exploratory methodologies which seek to identify naturally occurring trends in learners’ SRL use. A third class of TELEs is simply a computerized representation of content that is not enhanced in any fashion. These are analogous to paper based learning environments which include identical content and no additional features. The main difference between these and paper-based learning environments is the presentation of content across multiple nodes. These lend themselves to comparisons of how readers navigate the text in both environments, and direct comparisons of the benefits of paper-based versus computer-based presentations.

As one might expect, the relationship between a learning environment and student’s employment of SRL processes depends heavily on the nature of

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<th>Facilitative TELEs</th>
<th>Unenhanced Environments</th>
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1 – researched whether use of TELE affects knowledge gain
2 – researched how TELEs can influence SRL behaviors
3 – researched how pre-existing SRL tendencies influence TELE use
* – study makes comparisons between different types of TELEs
the learning environment itself. This will become evident in our study descriptions, as students behave differently in different types of TELEs. To illustrate the trends in utilization of different types of TELEs, we include Table 1 that groups studies by the structure of the learning environment. Each column contains studies that employ a didactic TELE (which uses external regulation and encourages SRL through tutoring, including human tutoring or by scaffolds and prompts), facilitative TELE (which supports self-regulation by providing tools but not prompting their use) and a computer-based learning environment (CBLE), which contains no enhancements. When multiple conditions are used, studies are grouped based on the condition that has been particularly foregrounded and an asterisk indicates comparison with other TELEs that serve as controls. Though argument can be made that a continuum exist in which TELEs are fully didactic through completely unenhanced, such a grouping is meant to enhance readers’ understanding of the prevailing types of TELEs in use, and to draw connections between studies that employ similar procedures and arrive at similar or contrasting conclusions about how TELEs influence SRL. Further, to cue readers to the findings of each of these studies, superscripts have been applied that denote each study’s content as it relates to our three research questions. These questions are answered in the next three sections of the chapter.

As can be seen from Table 1, considerable effort has been put forth to design and research TELEs which teach students to learn in self-regulated ways. Additional research has been conducted to determine how students will use TELEs and the tools which support SRL practices. The next three sections detail the findings of these studies. What we find is that different structures within a TELE, including the presence of tutors, prompts and tools, influence the learning process in unique ways.

**QUESTION 3: WHEN INDIVIDUALS ENGAGE IN SRL BEHAVIORS IN A WELL-DESIGNED TELE, DO THEY SHOW GREATER LEARNING THAN THEIR PEERS WHO ENGAGE IN FEWER SRL BEHAVIORS?**

Of the questions we posed in the beginning of this chapter, this question can be answered in the most straightforward manner. While learning with paper-based and identical but computer-based learning materials yield non-significant differences in achievement, TELEs do cause learners to acquire more knowledge than non-enhanced conditions. Training students to be more self-regulated causes them to be so, and to acquire more knowledge as a result (Azevedo & Cromley, 2004; Manlove, Lazonder & de Jong, 2006; 2007; 2008; 2009). Additionally, TELEs can successfully increase students’ SRL behavior, though their impact on achievement is not definitive.

We answer this question in two parts. First, do TELEs seem to be superior to paper-based or computer-based learning tasks which are not technologically enhanced? The answer, as we detail below, seems to be “yes.” Second, we address the question, “Do self-regulated learners actually learn more when using TELEs than less self-regulated peers?” Again, the answer is yes, and we can identify specific SRL processes that drive this phenomenon.

**Knowledge Acquisition and TELE Type**

Considering first the differences in learning outcome by TELE type, there is evidence that students’ use of paper-based learning tasks and simple computer-based versions of the same task yield similar learning outcomes (Rui & Lui, 2007). Rui and Lui (2007) explored differences in a problem solving activity when students used different forms of data organization and found that students using the computerized database
reported that it functioned as an organizational tool that decreased task difficulty. They also solved more science problems accurately than participants in both the paper database and no database conditions. Opening up our discussion to include learning environments that are technologically enhanced, evidence suggests that learners who use TELEs in lieu of or in addition to lecture and paper-based learning materials do experience increased knowledge acquisition (Dabbagh & Denisar, 2005; Manlove, Lazonder & de Jong 2009; Proske, Narciss & Koerndle, 2007; Rui & Lui, 2007).

Manlove, Lazonder, and de Jong (2009) found that when high school students interact with a TELE to facilitate problem-solving tasks, learners demonstrated increased accuracy while solving physics problems and constructed more accurate solution models than the control group. Dabbagh and Denisar (2006) provide a qualitative explanation of how TELEs can promote problem solving by comparing the students’ solutions to problems whose scenarios were structured hierarchically or heterarchically. Content analysis indicated solutions derived from heterarchically structured problem were more cogent and comprehensive than the comparison structure. The TELE allowed students to approach the organization of the problem in different ways and influenced the process and quality of the students’ solution.

Knowledge Acquisition and Engaging in SRL Actions in a TELE

Having documented the utility of TELEs for learners in general, we now turn our attention to how learners who self-regulate benefit from TELE use. Speaking generally about SRL and its impact on knowledge gain, it seems that, based upon the collected findings of individual studies across SRL classes, the tendency to self-regulate learning, is positively associated with knowledge acquisition in learners using TELEs (Azevedo & Cromley, 2004; Azevedo, Seibert, Guthrie, Cromley, Wang & Tron, 2002; Greene & Azevedo, 2007; Greene & Azevedo, 2009; Proske, Narciss, & Koerndle, 2007). These findings have been documented with a variety of student populations including high school students classified as low achieving (Azevedo, Winters & Moos, 2004), on grade level and gifted (Greene, Moos, Azevedo & Winters, 2008), as well as middle school (Greene & Azevedo, 2007; 2009) and college students (Azevedo & Cromley, 2004; Azevedo, Green, Moos, 2007; Kauffman, 2004; Kauffman, Gie, Xie & Chen, 2008; Manlove, Lazonder & de Jong, 2006; 2007; 2008; 2009).

Cited by many subsequent studies which attempt to answer this question, Azevedo and Cromley (2004) found that learners who receive 30 minutes of training before completing a science learning task in hypermedia experience greater declarative and conceptual knowledge gains than those who were not trained. Further, Wang and Lin (2007) found that self-efficacy moderates the benefits of TELE use. When using TELEs like Net-Ports, which support collaborative and individual learning, groups of students who felt efficacious about their TELE experience produced more high-quality ideas than less efficacious groups.

Individual macro-level SRL behaviors applied in TELEs such as monitoring (as compared to planning, strategy use, and others) have been found to predict knowledge gain (Greene & Azevedo, 2009). Dissecting these macro levels of SRL behavior into subcategories, specific behaviors within each category of SRL activity (planning, monitoring, strategy use and the handling of task difficulty and demands) have been identified as significant predictors of knowledge acquisition, as detailed in the studies below. As such, we can state that students who are more self-regulated tend to acquire more knowledge. This statement underscores the importance of identifying and building specific SRL behaviors into students’ approach to a learning task.

SRL processes that predict larger gains in conceptual understanding include planning,
monitoring and use of a higher proportion of effective strategies (Azevedo, Guthrie & Seibert, 2004). These include selecting new information sources, summarizing, re-reading, making inferences, hypothesizing, and elaborating. Greene and Azevedo (2007) analyzed trajectories of knowledge gains and patterns of SRL behaviors amongst adolescents and found that SRL microprocesses predict knowledge acquisitions in hypermedia learning tasks. SRL strategies like: coordinating information sources (text to diagram), making inferences, knowledge elaboration and monitoring activities like identifying the adequacy of information (assessing usefulness of content), and feeling of knowing (monitoring understanding) are associated with higher levels of knowledge gain. The tendency of students to focus on controlling conditions of the learning task (clicking to toggle settings features of a TELE such as zoom) was negatively associated with knowledge gain. We can say with some confidence that strategy use and monitoring are critical SRL behaviors for acquiring knowledge when using hypermedia.

While some TELEs provide students free reign to utilize or ignore features of a learning environment, others are more forceful and include regulative scaffolding to guide learning. Generally, there is less consistent evidence that TELEs that regulate (as compared to allowing student to self-regulate) learning improve knowledge acquisition. The forms of regulative support that have been studied include the effects of providing feedback (McKendree, 1990; Gao, 2003; Graesser, McNamara, & Van Lehn, 2005, prompting reflection (Kauffman, 2004; Kauffman, Gie, Xie & Chen, 2008; van den Boom, Paas, van Merrienboer, & van Gog, 2004), scaffolding metacognition (Alevin, McLaren, Roll & Koedginer, 2006; Kramarski, 2002; Kramarski & Gutman, 2006; Kramarski and Hirsch; 2003; Kramarski & Mizrahi, 2006; Kramarski & Ritkof, 2002), and scaffolding overall self-regulation (Jacobsen & Achiddiou, 2000; Manlove, Lazonder & de Jong, 2006; 2007; 2008; 2009; McNamara, O’Reilly, Best & Ozuru, 2006). Several studies have demonstrated that learning environments with immediate and elaborate feedback are superior to environments without these conditions in terms of knowledge acquisition (McKendree, 1990; Gao, 2003; Graesser, Lu, Jackson, Mitchell, Ventura, Olney, & Louverse, 2004). However, in studies where feedback is conducted through e-messages and is less immediate, its benefits are less clear (van den Boom, Paas, van Merriënboer & van Gog, 2004). Prompting reflection has been shown to be effective at improving students’ knowledge in mathematics, but also influences student behavior by encouraging students to allow themselves to become reliant on this external regulation.

Further demonstrating the efficacy of enhancing TELE with regulative scaffolds is the effect of metacognitive training on declarative and conceptual knowledge. Kramarski and Hirsch (2003) found that students who received math instruction with self-regulation skill lessons, when compared to their counterparts without self-regulation support, performed better on symbolic reasoning and patterns items, but not significantly better on manipulating algorithms and analysis change items. Reinforcing these conclusions, Kramarski and Mevarech (2003) found that middle school students who received metacognitive training in math outperformed their counterparts in overall reasoning including math explanations. These researchers also established that integrating metacognitive training into more than one domain yields higher learning gains than only including the support in one area (Kramarski, Mevarech & Lieberman, 2001). Additionally, their research indicated that peer emailing enhanced the effectiveness of these TELEs as evidenced by improved math explanations (Kramarski, 2002; Kramarski & Ritkof, 2002).

These findings are encouraging, yet they beg another question—are gains due primarily to this metacognitive training being embedded in the TELE or can a similar training provided by a human tutor produce similar results? Kramarski and
Mizrachi (2006) addressed this methodological concern, and found that middle school students who received metacognitive training online demonstrated heightened math literacy skills over and beyond that of their counterparts who received the same training from a human tutor. Azevedo and colleagues (Azevedo, Cromley & Seibert, 2004; Azevedo, Cromley, Seibert & Tron, 2003; Azevedo, Cromley, Thomas, Seibert & Tron, 2003; Azevedo, Cromley, Winters, Moos & Greene, 2005; Azevedo, Greene & Moos, 2007), however, find that when a human tutor trains learners to be self-regulated prior to the task and scaffolds their learning process, a change in behavior pattern accompanies increased learning. Learners who had a tutor more often engage in help seeking than other self-regulatory behaviors. Learners were utilizing resources and conducted co-regulation (with the tutor) instead of self-regulation of learning, which led to similar knowledge gains (Azevedo, Cromley & Seibert, 2004; Azevedo, Cromley, Winters, Moos & Greene, 2005). It seems then that if learners’ metacognition is appropriately scaffolded by a TELE itself, or by a human tutor, learning gains will follow, though tutors who intend to also foster SRL should be wary of students’ over-reliance on the tutor.

While adaptive scaffolding provided by a human tutor and computerized tutors have been shown to be beneficial for student learning, some TELEs provide automated scaffolding that is not adapted to student’s needs. The benefit of these regulatory prompts is less clear. Specific TELE design features that prompt all students, regardless of SRL tendency, to conduct SRL behaviors have been shown to improve learning outcomes. Kauffman (2004) investigated whether web-based instructional prompts (to take notes, self monitor learning, and to consider one’s self-efficacy) influenced SRL behavior and knowledge acquisition while completing a WebQuest. Findings suggest that those who took notes using the matrix tool provided and were prompted to reflect on learning gained more knowledge than those who were not prompted and those who took freeform notes. Significant main effects of note-taking condition and of monitoring were also found where each experimental group gained more knowledge than control groups, suggesting prompting does improve knowledge acquisition. These results indicate that TELEs that scaffold strategy use (note taking format) and metacognition (embedded prompts) primed learners to engage in SRL activities, which resulted in knowledge gain. However, additional study by Kauffman, Gie, Xie & Chen (2008) into how prompts impact problem solving and writing quality suggest that problem solving prompts, alone and in combination with self-reflection prompts, improved learning outcomes, while self-reflection prompts did not. We can conclude then that not all prompts are equally beneficial, and that additional research needs to be done to examine what effect different kinds of externally regulative objects employed in TELEs have on students, and how they might interact with SRL tendencies.

One final feature we have yet to review is the provision of tools that students may use to mark content in the TELE. These include highlighters, note taking tools, linking tools, and ways that students can build “information objects” onto pre-existing content from the learning task. These tools are available in TELEs such as gStudy (Nesbit, Winne, Jamieson-Noel, Code, Zhou, & MacAllister, 2006) and in Study 2000 (Proske, Narciss and Koerndle, 2007). Proske, Narciss and Koerndle (2007) found that use of marking and note taking tools is positively associated with improvements in knowledge gain.

Knowledge Acquisition and TELEs that Employ Multiple Features of Self-Regulation

While many basic TELEs include just one or two features aimed at regulating or encouraging self-regulation during learning, there have been successful interventions where multiple features of
Self-regulation were embedded in the instruction. Manlove, Lazonder, and de Jong (2006; 2007; 2008; 2009) conducted a series of intervention studies that consistently demonstrated science learning gains measured in scientific inquiry tasks (not mere declarative knowledge tasks) for students using multi-featured TELEs. The multiple features of SRL that were embedded in the treatment TELE were: goal lists, hints, prompts, cue and templates specifically designed for science inquiry. Similarly, Jacobson and Archididou (2000) successfully used scaffolds to assist students in transforming their naïve mental models of biology to more complete and advanced models. In light of the collected findings on different TELEs and their influence on student knowledge gain, we can conclude that students generally experience increased learning from TELEs.

Summary and Implications

To aggregate what we discussed about knowledge acquisition resulting from SRL strategy use, we can affirm that the following conditions are conducive to learning: (1) feedback must be immediate, elaborate, and in user friendly language (2) metacognitive training is effective with and without a human tutor; pre-task training amplifies this effect (3) tools that support annotation of TELE content enhance knowledge gain and (4) knowledge growth is also enhanced in TELEs where SRL training is intertwined with instruction.

In all of the studies, pretest scores ensured no differences in prior domain knowledge. These findings all apply to middle school to college students and math and science domains. Taken together, these results do emphasize the need for some type of regulative scaffolds, whether embedded in the task or provided as pre-task training, in order for students to take full advantage of the opportunity TELEs provide. Without regulative scaffolds, whether it is a human or software, most students do not have the propensity to flourish in a TELE. The regulative scaffolds are the keystone in structuring a TELE where the two necessary conditions of knowledge growth, opportunity and propensity, meet.

**QUESTION 4: HOW HAVE TELEs BEEN SHOWN TO PROMOTE SRL TENDENCIES IN LEARNERS?**

Now that we have examined how didactic, facilitative, and unenhanced TELEs impact knowledge acquisition as well as how learners’ characteristics mediate this interaction, we are compelled to determine how to use TELEs to improve learners’ SRL tendencies themselves. In doing so, we begin a dialogue on how to build a student’s propensity to maximize the full potential of the opportunities provided by a TELE.

Before discussing how TELEs have been shown to promote SRL tendencies in learners, it is helpful to first briefly review the tendencies in which a self-regulated learner engages. Following the summary of our current understandings, we discuss implications and areas that require further research related to the focal question of this section.

Recall from the descriptions of the theoretical models of Boekaerts and Zimmerman that appraisal and SRL interact and affect a learner’s performance throughout the three recursive phases of SRL (Boekaerts & Niemivirta, 2000; Zimmerman & Tsikalas, 2005).

Researchers have considered how to improve the tendencies enlisted in the forethought phase and performance/volition phases, but tendencies in the self-reflection phase, to the best of our knowledge, has received minimal attention. Moreover, promoting positive appraisals is an area of research that has received relatively scant attention. As will become evident in the following discussion, TELEs have been shown to promote SRL tendencies when their program features directly support a particular attribute. To date, researchers have implemented programs aimed
at developing the following aspects of SRL: (a) the metacognitive skills of goal setting, planning, organizing, and monitoring learning, (b) strategy use, (c) adapting and (d) self-initiating.

**Metacognitive Aspects of SRL**

**Goal Setting and Planning.** Although several studies examine the role of goal structure in TELEs, none have been conducted to actually improve the metacognitive process of setting appropriate goals. To date, all of the TELEs have presented participants with some form of prescribed goals, subgoals and hints. As such, TELEs in the literature cannot be said to promote goal-setting. Perhaps TELEs in the future can be made to solicit goals rather than prescribe them. In regard to planning, however, one study (Manlove, Lazonder & de Jong, 2008) was designed to develop the process of planning through providing regulative support. Students who received cues, hints, goal lists, prompts and templates demonstrated more planning than those who did not receive the support.

**Organizing.** Researchers have examined the utility of computerized organizational tools and different forms of hypertext organization (Rui & Liu, 2007), but little or no research (to our knowledge) has been done to improve students’ propensity to organize the material that is presented to them. All of the information provided in a TELE is pre-organized in some hierarchical or heterarchical form thereby precluding the opportunity for a student to self-initiate organizational tactics. Progress in this field of organizing information and resources is limited to the highly structured nature of TELEs.

**Monitoring Learning.** Two studies looked at improving metacognitive monitoring. White and Frederiksen (1998) used science inquiry simulations to enhance this attribute. Students demonstrated enhanced monitoring when they designed experimental plans and scenarios. Supplementing metacognition training with reflective assessment led to even higher learning gains. Kramarski and Gutman (2006) used metacognitive questions to increase monitoring of learning in the math domain. Math explanations seemed to lead to improved metacognition. Both of these programs proved efficacious in developing metacognition as measured by conceptual knowledge tasks.

**Motivational Aspects of SRL**

Empirical work has been conducted to ascertain the relationship between motivational beliefs such as self-efficacy and attitudes toward a particular domain. This relationship was analyzed in the previous section of this chapter. Without devaluing this progress, research has yet to address technology-based interventions that promote motivation. At present, we do know that learner motivation seems to increase over the course of a learning task in a TELE (Moos & Azevedo, 2008a), but additional investigation is warranted to determine why motivation increases, and if it increases similarly across all learners.

**Strategic Aspects of SRL**

Several studies have attempted to increase the quality and quantity of strategy use. The common denominator in the effective interventions is their specific nature; they focus on strategy use in a particular domain and/ or adapt the targeted instruction to the learner’s needs. Aleven and his colleagues (2006) designed Cognitive Tutor Help Tutor to increase the frequency of appropriate uses of help-seeking in geometry. This program uses the individual student’s problem solving actions to tailor feedback and guidance about the help tools (e.g. glossary) that the learner should use in order to understand the content. Students who utilized the Help Tutor decreased the frequency of inappropriate and inefficient use of help seeking strategies.

iStart (McNamara, O’Reilly, Best, & Ozuru, 2006), an interactive reading strategy trainer, aimed to improve comprehension of science
text through developing the reading strategies of paraphrasing and making connections within text. Students who learned using iStart demonstrated improved reading strategy use and comprehension in their self-explanations of text including the science text comprehension questions.

**Adaptive Aspects of SRL**

The context in which TELEs have been shown to promote an adaptive tendency in learners is research on feedback. McKendree (1990) established that learners adapt from feedback that is both immediate and elaborate, that is, it provides an explanation for incorrect responses instantly. Gao (2003) extended this finding to conclude that a generative activity such as formulating an example or scenario will aid students in adapting to the demands of a TELE. Relatedly, Graessar and his colleagues’ program, AutoTutor (2004), delivers immediate and elaborate feedback in the form of natural dialogue. The authors suggest that AutoTutor’s conversational pedagogical agent is the feature that enables learners to adapt to the demands presented in their TELE. Kramarski, Zemira, Arami & Arami (2002) found that a learning environment enhanced with metacognitive training and email helped students adapt to the requirements of the math course.

**Self-initiating Aspects of SRL**

A multitude of studies have investigated different TELE conditions that encourage students to self-initiate strategy use. Azevedo and his colleagues (Azevedo, Cromley, Thomas, Siebert & Tron, 2003; Azevedo & Cromley, 2004, Azevedo, Greene & Moos, 2007) have contributed a great deal to our understanding of how to initiate SRL in students. One such condition involves incorporating SRL training before engaging in a TELE. Pre-task training has been shown to promote self-initiation of a variety of learning strategies such as activating prior knowledge and managing time (Azevedo & Cromley, 2004; Azevedo, Greene & Moos, 2007). Another condition, pre-task training along with co-regulation, has reliably shown students to activate prior knowledge, monitor their learning, self-question, gauge their progress toward goals, manage time and manage effort (Azevedo, Cromley, Thomas, Siebert & Tron, 2003). In addition, Kauffman and his colleagues (2008) identified a necessary condition for using prompts to initiate self-regulation—prompts must be embedded within the problem to be solved. Yang (2006) extended these efforts by presenting students with embedded prompts and found that this approach increased self-monitoring and self-instruction.

**Summary and Implications**

To synthesize what we know so far about how TELEs have been shown to promote SRL tendencies, two particular conditions seem to be necessary: (1) the objective of the TELE must be domain specific and strategy specific and (2) the instructional methods applied by the system must be in response to the learner’s specific needs.

As with any empirical research, however, methodological shortcomings limit the implications that can be drawn from the findings. First, strategy-specific and adaptive TELEs have promoted strategy use in learners across age groups from middle school through college. It remains to be seen how these well-designed TELEs would influence elementary age students. Second, the interventions have been largely limited to just two content areas: math and science (with the exception of van den Boom and colleagues’ (2004) study involving classroom scenarios). Third, many interventions seem to work best when participants are pre-trained in SRL, and to a greater extent, tutored through a task. This “other regulation” is somewhat at odds with the construct of student initiated self-regulation of learning that we would hope to see occur naturally in students. Nevertheless, the studies in this section have shown
that TELEs can improve planning, monitoring of learning, help seeking, reading strategies, and adapting when they fit the criteria described above. That said, only a portion of the learning event has been modeled and examined in these studies. Several SRL attributes and processes that interact and affect learning have received minimal attention (to the best of our knowledge): positive appraisal, goal setting, organizing, interest, self-efficacy, motivation and self-reflective processes including causal attributions.

**Evolution of Measurement of SRL**

Learners’ tendencies to self-regulate have been measured in a variety of ways including content analyses of post-task interviews, pre-task assessment using self-report questionnaires and in-task assessment using think aloud and trace methodologies. These experimental design decisions have consequences in terms of the way we define learners as self-regulated, and color our ability to make causal or correlational attributions between SRL tendency and learner interaction with a TELE.

*Qualitative Analysis.* Early work exploring the relationship between TELE and SRL overlaps with research focusing on structures of hypertext and how learners use reading strategies to enhance their comprehension. One of the first studies to use SRL language with respect to TELEs was conducted by Balcytiene (1999), who identified three types of reading behaviors students employed when read a hypertext on architecture. From content analyses of videotaped interviews, Balcytiene determined that learners exhibit different reading strategies, and that readers could be categorized as cue-dependent or self-regulated. She concluded that TELEs are more beneficial to readers who exhibit SRL processes such as inference making, self-questioning and reflection.

While Balcytiene (1999) took a qualitative and post hoc approach to analyzing reading styles and connecting them to SRL behaviors, more recent studies of SRL tendency have evolved from quasi-experimental into experimental and exploratory designs. This trend has implications for the interpretation of findings based upon how we define a pre–existing SRL tendency.

*Quasi Experimental Designs.* Scales to measure SRL tendency rely upon the self-report of the individual and include the Motivated Strategies for Learning Questionnaire, (MSLQ; Pintrich, Smith, Garcia & McKeachie, 1991), the Learning and Study Strategies Inventory (LASSI; Weinstein, Schulte & Palmer, 1987) and many derivatives and adaptations of these early SRL scales. Such a
method of measurement follows from SRL theories which treat SRL as an aptitude which is consistent across contexts and is fixed within the individual (Boekaerts & Niemivirta, 2000). Some studies we reviewed to document the influence of learners’ SRL tendency on their behaviors in TELEs employ these self-report measures and often categorize students as either high self-regulators or low self-regulators. Using self-report scales, early research (Eom & Reiser, 2000; McManus, 2000; Wang & Lin, 2007) suggested that highly self-regulated individuals did interact differently in TELEs than their lesser regulated peers.

Trace Methodologies in Exploratory and Experimental Designs. Studies by Eom & Reiser,(2000) and McManus (2000) which sought to determine a more quantitative causal impact of SRL tendency on TELE use represent a next step in methodological complexity, but their instruments suffered from a lack of validity, and their findings must be approached with some caution. SRL measurement through self-report methods has been shown to be poorly calibrated to true SRL tendency as evidenced by learner behaviors (Winne & Jamieson-Noel, 2002). Hadwin and colleagues (2007) used trace methods to further assess the relationship between self-reported SRL behaviors and representative behaviors. Even the most well informed students tend to accurately self-report their tendency to self-regulate only 40% of the time, while the mean is closer to a quarter of the time (Hadin, Nesbit, Jamieson-Noel, Code, & Winne 2007). This discovery undermines what conclusions we can draw from studies that make use of self-report data. Instead, we choose to focus primarily on those studies that create experimental conditions by intentionally creating groups of students who are highly or minimally self-regulated in their learning behaviors through pre-task SRL training. Additional studies that employ self-report scales and traces of behavior (Nesbit, Winne, Jamieson-Noel, Code, Zhou, & MacAllister, 2006) use exploratory designs to examine patterns of SRL behaviors as they relate to SRL microprocesses (e.g. marking strategies like highlighting and note taking) might give insight into how learner characteristics influence TELE use.

Employing an experimental design and influencing SRL tendency by providing training in SRL to experimental groups (and withholding training from control groups) has demonstrated that highly self-regulated learners behave and achieve differently than minimally self-regulated learners (Azevedo, Seibert, Guthrie, Cromley, Wang & Tron, 2002; Azevedo, Cromley, Thomas, Seibert & Tron, 2003; Azevedo & Cromley, 2004). When learners are made to be more self-regulated by training, they tend to use a higher percentage of effective learning strategies than untrained peers (Azevedo, Seibert, Guthrie, Cromley, Wang & Tron, 2002; Azevedo, Cromley, Thomas, Seibert & Tron, 2003). Those who are trained in SRL prior to completing a task (high SRL) tend to spend more time coordinating sources of information, taking notes, drawing, and reading and reviewing notes than untrained (lower SRL) peers (Azevedo, Cromley, Thomas, Seibert & Tron, 2003). When not trained, learners (a) typically will vary greatly in their study tactics, (b) tend not to monitor their own learning, but do monitor the adequacy of information in TELE, (c) use strategies that include a mixture of effective and ineffective search tactics as well as repetition of goals in working memory, (d) typically do not plan and fail to integrate different sources within a TELE, (e) skip between instructional platforms (text, diagram, animation) and focus on a goal to memorize content by rereading passages and taking notes, but seldom reviewing notes and (f) will generally be performance-oriented, using only externally provided performance subgoals to guide action and will not plan their own learning. When trained however, learners behave in a more self-regulated fashion. They read, summarize, restate and activate prior knowledge. They monitor their understanding by determining if they know something, if they are learning and also conduct.
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self-questioning. When a tutor is present, they engage the tutor for assistance, and when not, they are more planful, set specific goals and then engage in reading. They monitor by judging if learning is occurring, engage in self-question and reread to clarify misunderstandings. Training clearly improves performance in TELEs in terms of both SRL use and knowledge acquisition. Azevedo and Cromley (2004) found that learners who were made to be more self-regulated through training primarily summarized, made drawings and notes, read notes, elaborated on knowledge, coordinated sources and found location in the environment. Their untrained counterparts primarily conducted searches, both goal oriented and free, and selected new informational sources as means of learning. This set of behaviors is deemed less effective in producing knowledge gain, which makes such differences an important consideration for educators considering TELE use with students of varying SRL ability. In addition to the impact of pre-task SRL training, Azevedo, Greene and Moos (2007) found that tutored learners monitor learning more and use a greater percentage of effective SRL strategies compared to learners who are left to regulate their own learning without tutoring.

Additional Influence of Other Learner Characteristics

Exploratory Designs. A paradigm shift in measurement techniques resulted from Winne and Jamieson-Noel’s (2002) findings regarding calibration of SRL self-reports, and researchers have, for the most part, begun to avoid labeling individuals as high or low SRL, as an enduring trait. Instead, advances in technology have enabled TELEs to trace individuals’ behaviors in the environment using logs of their actions. A profile of learners’ SRL behaviors has since replaced offline SRL scales as the preferred method of measuring student SRL tendency in context. This method lends itself more to the process model of SRL as described by Winne and Hadwin (1998) and Zimmerman (2000) but also undermines researchers’ ability to make statements about an individual’s degree of self-regulation across learning contexts unless SRL is intentionally enhanced pre-task.

That is, if SRL can only be measured in context, it would require exposure to and measurement in multiple learning environments before an individual’s behaviors indicate that he or she is highly or minimally self-regulated, in a trait-like sense. Thus, many later studies tend to take an associative approach and discuss learners’ patterns of SRL behaviors when placed in a TELE. Examples of such research include studies by Bauer and Koedinger (2006) and Nesbit and colleagues (2006) who used software to trace students’ tendency to select segments of text while studying as it relates to goal orientation and knowledge gain.

While our primary focus in this chapter is to discuss the interaction of SRL and TELEs, we must not ignore the role of other student and TELE characteristics that influence knowledge gain. These variables play a large mediating role in the way learner and TELE interact and what knowledge gain results. Mediating characteristics include learners’ self-efficacy (Bell 2007), motivation (Moos & Azevedo, 2008c; Narciss, Proske & Koerndle, 2007; Nesbit, Winne, Jamieson-Noel, Code, Zhou, & MacAllister, 2006 2006), level of prior knowledge (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Azevedo & Cromley, 2004; Balevteine, 1999; Brusilovsky, 2004Cho, 2004; MacGregor, 1999; Moos & Azevedo, 2008a; Winters & Azevedo, 2005) and the TELE’s features which allow for learner control for the task environment (Bauer & Koedinger, 2006; Eom and Reiser, 2000). Taken collectively, these findings, that highlight interactions between SRL tendency with other learner characteristics and with TELE characteristics, underscore the need to consider multiple characteristics of the learner as well as features of the TELE when considering the benefit of a TELE for specific users.

Having now answered our question about the influence of TELEs on student knowledge
gain, we now turn our attention to the influence of TELEs on students’ tendency to self-regulate their own learning.

**Summary and Implications**

These three very different research methodologies give us considerable evidence that does suggest that the propensity to learn in a self-regulated fashion is critical. Given the evolution of research designs to capture reliable data about learner’s tendencies, this new wave of research using in-task measurement is presently in its infancy, which limits our understanding for the time being.

We can say with some certainty that learners’ propensity can be intentionally increased through offline, pre-task training, and such increased propensity increases the degree to which learners take advantage of the opportunities provided by the technological enhancements of their learning environment. When we consider the individuals in typical learning situations, they look remarkably different from those who were trained. While learners are not significantly more mastery or performance oriented (Nesbit, Winne, Jamieson-Noel, Code, Zhou, & MacAllister, 2006), they are generally not very self-regulated, as evidenced by low utilization rates of TELE tools (Brush & Saye, 2001; Narciss, Proske & Koerndle, 2007; Nesbit, Winne, Jamieson-Noel, Code, Zhou, & MacAllister, 2006; Proske, Narciss, Koerndle, 2007). This low baseline level of self-regulation suggests that educators should aim to increase students’ SRL propensity if they intend to instruct using TELEs. Without raising students’ SRL acumen, the opportunities that TELEs provide are likely to be underutilized.

**CONCLUSION**

Having discussed a broad range of empirical findings as they relate to enhancing SRL and knowledge gain, we conclude by distilling these findings into a set of take-home messages for educational practitioners and for those who intend to conduct further research into students’ SRL and its interaction with TELE. We denote these messages as both opportunities to design TELEs that best meet the needs of learners, and as chances to increase the propensity of learners to benefit from using TELEs.

**For Practitioners**

*Opportunity: The design of a TELE must be adapted to the learner.* By and large, findings revealed that the students who increased their SRL tendencies and knowledge the most were the ones who had access to TELEs that gave them all they needed and nothing they did not need. If our goal is to provide students with the best learning opportunity possible, it is important that we design the TELE to provide them appropriate scaffolding with respect to tutors that answer their questions, but also allow students who do not need “other regulation” to opt out of it. This may require some pre-task screening for particular characteristics (e.g. prior knowledge) or constant monitoring of student use of TELEs by a teacher, but is likely to result in an improved educational experience. In terms of tool provision, we should strive to give students a full complement of tools they can use. Students who have the propensity to self-regulate learning know what they need, and, if given the option of using it, they will excel.

*Opportunity: Teacher-led instruction and TELEs are not exclusionary, but complementary.* Genuine opportunities to learn require well-designed teacher-led and technologically facilitated instruction. The promise for student achievement and self-regulation that our review has demonstrated can only be fulfilled if both necessary conditions of the learning environment are maintained: complementary use of teacher-led instruction and well-designed educational software. As the label (TELE) appropriately says, learning environments are only enhanced with
computers and their software. Improvements in math, science and SRL strategies can only be replicated in a classroom if the practitioner is also providing instruction and monitoring the use of the TELE. To ensure this occurs, teachers must be trained fully in the technology before implementing the program. They must understand the theory, research and operations of the program in order to effectively integrate it into their learning environment. Otherwise, the software may be incorrectly used or not used at all. With proper training in use of TELEs, practitioners can diagnose and target the propensities that are needed for a task and ensure maximal fit between the technology and the student.

**Propensity: Pre-task training is Key.** Studies in which participants were left to their own devices to engage in SRL behaviors revealed that most participants did not engage in these behaviors very often. In contrast, studies in which participants were given pre-task training to increase their tendency to engage in SRL behaviors showed that training was effective and learning was enhanced. Thus, those who wish to create TELEs for learners would be wise to increase participants’ propensity to learn via pre-task training. The need to focus on propensities prior to presenting opportunities to learn via TELEs is reminiscent of recent findings in the achievement literature which show that achievement gaps in particular grade levels (e.g., first grade in American schools, age 6) could be substantially reduced if interventions occurred prior to students’ entry into that grade level (e.g., when students were 4 or 5 years old). When students enter a grade with the same proficiency, they show comparable levels of achievement at the end of that grade (e.g., Byrnes & Wasik, 2009).

**Propensity: Practitioners must take advantage of the online monitoring that only TELEs can perform.** To effectively diagnose, target and cultivate student propensities, practitioners need accurate data to make instructional decisions. Before TELEs, teachers could only observe individual students to collect data on their strategy use, reasoning and so on. Clearly, the amount of time this assessment consumed typically outweighed its perceived utility, therefore resulting in paper and pencil tests that are only intended to tap self-reported learning processes. However, TELEs have the capability to transform teachers’ assessments of students’ needs and abilities by improving the efficiency and accuracy of assessment. Trace methodologies track and log actual learning processes as they transpire, thereby allowing the teacher to review an organized, detailed file of a particular student’s strategy use and decisions. There are many benefits to having access to how students regulate their learning. Chief among them is the opportunity to provide individualized instruction that can be designed to keep student learning progressing rather than stagnating. Properly trained teachers who are given the time and resources to evaluate trace data on student learning processes hold tremendous promise for improved instruction and student learning.

**For Researchers**

**Opportunity: Student characteristics are numerous, interconnected and dynamic and should be measured as such.** While this chapter focused on learners’ interactions with TELEs, much attention was paid to discussing the contributing role of other student characteristics such as motivation, self-efficacy, prior knowledge and others. Because TELEs must be adapted to learners’ needs, researchers who intend to accurately describe a learner-TELE interaction must also go to great lengths to describe the characteristics of the learner. Assessing these contributing factors known to influence learning is critical. The more we know about learners, the more accurately we can characterize their behaviors and adapt future TELEs to meet their needs.

Additionally, we see that learner characteristics can change throughout a learning task. Just as SRL is an iterative process, our measurement must be iterative, monitoring changes in the student over
time that could affect the way the student interacts with the TELE. Such monitoring requires that researchers take a process approach to their research designs, and likely requires them to use trace or think aloud methodologies and reassess pre task characteristics (like motivation) in task periodically to monitor change.

Opportunity: The relationship between TELEs & SRL requires further study. In the process of mapping the relationship between TELEs, SRL and achievement, we identified gaps in our understanding that can be filled with intentionally designed future research. First, researchers have established a firm understanding of the mechanisms involved in enhancing particular self-regulatory attributes such as planning and help seeking. However, additional research is needed in the areas of: positive appraisal, motivation, goal setting, interest, self-efficacy, organizing and self-reflective processes. As these areas are explored and findings uncovered, a more comprehensive model of SRL with TELEs can be forged. Second, the generalizability of the findings we have reviewed is limited to the middle school, high school, undergraduate and graduate populations that have been studied. Researchers still need to chart these opportunity-propensity interactions in elementary school populations. Through understanding the nature and function of TELEs throughout all of the school years, designers can begin to develop programs that would scaffold content mastery as well as the necessary SRL strategies from elementary grades to high school and beyond. Third, our knowledge of the efficacy of TELEs is bound within the academic areas of science and math. TELEs that focus on improving writing, reading and social studies will broaden the scope of our inferences and implications. Certainly, it would be valuable to students to reap the benefits in conceptual knowledge and self-regulation in areas beyond math and science.

In sum, then, the literature on the relationship between SRL and TELEs has certainly grown over the years and much has been learned about this relationship. This increased insight is fortunate given the pervasiveness of TELEs in contemporary society. However, the full power of TELEs can only be harnessed if researchers and practitioners work together and share insights.

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**KEY TERMS AND DEFINITIONS**

**Adaptive Scaffold**: In task, supportive feature of a TELE that adjusts its responses according to the learner’s performance.

**Automated Scaffold**: In task, supportive feature of a TELE that provides pre-determined, non-adaptive responses to the learner’s performance.

**Causal Attribution**: Process by which a learner links a performance outcome with a controllable cause or uncontrollable cause.

**Computer-Based Learning Environment**: Learning environment designed only to represent content in a computerized form; there are no enhancements or features that promote SRL.

**Co-Regulation**: In task form of SRL scaffolding where a human tutor assists in prompting self-regulatory behaviors.

**Didactic TELE**: TELE designed to teach students how to self-regulate.

**External regulation**: In task form of SRL scaffolding where features of the TELE assist in prompting self-regulatory behaviors.

**Facilitative TELE**: TELE designed to allow learners to self-initiate self-regulatory behaviors; provides tools that support self-regulatory behaviors.

**Forethought Phase**: Phase of SRL where the learner engages in task analysis, goal setting, and strategic planning.

**Immediate & Elaborate Feedback**: TELE’s response to a learner’s action with minimal time delay & helpful information about the learner’s actions.

**Metacognitive Processes**: Evaluation and use of one’s cognitive processes and resources.

**Negative Appraisal**: Evaluation of a context as being unfavorable to one’s well-being.

**Opportunity**: Culturally defined context in which an individual is presented with content to learn or given favorable setting(s) in which to practice skills.

**Opportunity-Propensity Framework**: Framework that asserts that learners will attain high levels of achievement with in a particular domain if: (1) they are given authentic contexts to learn and practice skills (2) they are willing and able to take advantage of these contexts.

**Parsimony**: Problem of multiple, partially overlapping theories in the self-regulation literature which generally explain the same phenomenon with slightly different terminology.

**Performance Phase**: Phase of SRL where the learner engages in metacognitive and strategic actions.

**Positive Appraisal**: Evaluation of a context as being favorable to one’s well-being.
Pre-Existing SRL Tendencies: Metacognitive and strategic tendencies that a learner was trained in pre-task or that a learner spontaneously demonstrated pre-task.

Propensity: Any factors that relate to the ability or willingness to learn content once it has been exposed or presented in particular contexts.

Relevance: Presumption that SRL may be germane to the learner attaining optimal benefit from TELEs.

Self-Efficacy: Perceptions of one’s capabilities to attain a designated outcome.

Self-Reflection Phase: Phase of SRL where the learner evaluates and reacts to their performance outcome.

Self-Regulatory Behaviors: Metacognitive and strategic actions that learners engage in while performing a task.

Self-Regulated Learning (SRL): Adaptive process by which a learner self-initiates metacognitive and strategic actions to perform a task.

Self-Regulatory Tendencies: Metacognitive and strategic actions that learners engage in while performing a task; used interchangeably with the term self-regulatory behaviors.

Trace Methodology: Method of measuring SR behaviors in task using a TELE’s ability to track the learner’s metacognitive and strategic actions.

Utility: This term refers to the benefit of an Opportunity-Propensity Framework for understanding the relations between SRL and TELEs.