European Journal of Psychology of Education (2022) 37:833–852
https://doi.org/10.1007/s10212-021-00565-x

Cognitive engagement in self-regulated learning: an integrative model

Shan Li[1] · Susanne P. Lajoie[1]

Received: 8 December 2020 / Revised: 27 May 2021 / Accepted: 30 May 2021 /
Published online: 8 June 2021

Abstract
Integrating the two dominant theories of self-regulated learning (SRL) and cognitive engagement could advance our understanding of what makes students more efficient, effective learners. An integration of these theories has yet to be explored, and this paper addresses this gap by proposing a novel integrative model of SRL engagement. Specifically, we identified the nature of cognitive engagement (i.e., changing consecutively, context-dependent, comprising quantitative and qualitative dimensions, occurring consciously or unconsciously), based on which we compared the conceptual differences and similarities between cognitive engagement and SRL. We reviewed three models that have investigated cognitive engagement within the frameworks of SRL, analyzed their features and weaknesses, and proposed an extension of previous models linking SRL and cognitive engagement. The proposed model is one of the first to clarify the mechanisms of how SRL phases and subprocesses relate to the functioning of cognitive engagement. In addition to adding to the theoretical discussions of the relations between cognitive engagement and SRL, the model informs the design of adaptive scaffoldings and the practice of learning analytics. Several recommendations are presented for future research in this area to test this new model empirically.

Keywords Self-regulated learning · Cognitive engagement · Similarity and difference · SRL engagement · Integrative model

Introduction

Self-regulated learning (SRL) and student engagement are distinct areas of research, but both aim to understand students' functioning and performance within academic settings. Self-regulated learning (SRL) is a widely adopted theoretical framework in the education field

✉ Shan Li
shan.li2@mail.mcgill.ca

[1] Department of Educational and Counselling Psychology, McGill University, B148, 3700 McTavish St, Education Building, Montreal, QC, Canada

for researchers to study how students consciously coordinate their behavioral, cognitive, affective, and motivational aspects of learning to obtain academic success (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). Student engagement is often referred to as a learner's active participation and involvement in achievement-related activities (Boekaerts, 2016; Sinatra et al., 2015). Just as SRL has been referred to as a multidimensional construct, most researchers view student engagement similarly, in that it involves both overt, external factors (e.g., behavioral), and covert, internal factors (e.g., cognitive and emotional) (Eccles, 2016; Finn & Zimmer, 2012; Fredricks et al., 2004; Wolters & Taylor, 2012). Moreover, both SRL and student engagement have been found to play a mediating role between students' personal and contextual characteristics and their academic performance (Wolters & Taylor, 2012; Zusho, 2017).

Considering the substantial overlaps between the two frameworks (i.e., SRL and student engagement), Wolters and Taylor (2012) argue that "the research on self-regulated learning and student engagement can, and should, be integrated to a greater extent" (p. 647). A more integrated model of SRL and student engagement would benefit each area of research and enhance a holistic understanding of students' learning (Cleary & Zimmerman, 2012; Wolters & Taylor, 2012; Zusho, 2017). Therefore, the purpose of this paper is to advance the theoretical specifications of relations between SRL and student engagement. While we acknowledge that both the two frameworks involve multidimensional learning processes such as cognition and emotion, our discussion will be focused primarily on the cognitive aspect of learning. One crucial consideration is that the integration between the two broad umbrella concepts of SRL and student engagement is beyond the scope of one study, considering that both SRL and student engagement are complex multi-componential, multitemporal constructs. Moreover, most SRL theories that rely on a cyclical feedback loop to describe how students' learning unfolds over time are cognitive in nature (Cleary & Zimmerman, 2012).

To link the theories of SRL and cognitive engagement, this article builds from previous work that examined cognitive engagement in specific learning contexts (e.g., Jarvela et al., 2016; Pardo et al., 2017; Sinatra et al., 2015) and work that embedded cognitive engagement within models of SRL (Cleary & Zimmerman, 2012; Wolters & Taylor, 2012; Zusho, 2017). Specifically, we define cognitive engagement as "the extent to which individuals think strategically along a continuum across the learning or problem-solving process in a specific task." This definition is adapted from Cleary and Zimmerman (2012) but more plainly refers to the changing nature of cognitive engagement. In particular, the ideas in our definition of cognitive engagement are four-fold: First, this definition suggests that cognitive engagement is essentially a consecutive process, which fluctuates over time as students immerse themselves in learning. Second, cognitive engagement is meant to associate with specific topics or learning activities. Third, it indicates that cognitive engagement consists of both qualitative and quantitative dimensions; i.e., students can allocate varying amounts of cognitive resources for different strategies in learning, which is in consonance with the research of Miller (2015). And last, this definition highlights the cognitive aspect of learning, which could either occur unconsciously or be metacognitively governed. Conceptualizing cognitive engagement in this way represents a conceptual change among researchers from considering cognitive engagement as a static aptitude or ability (Appleton et al., 2006; Jarvela et al., 2016; Rotgans & Schmidt, 2011) to a dynamic ever-changing series of events that exist along the learning process (Cleary & Zimmerman, 2012; Sinatra et al., 2015).

In the present paper, we first elaborate on the nature of cognitive engagement to pave the way for comparison with SRL in terms of theoretical similarities and differences. As

pointed out by Azevedo (2015), a key issue that plagues the research of cognitive engagement is the lack of agreement among researchers about the nature of this construct. For example, a critical contention is whether researchers should view cognitive engagement as a stable, trait-like attribute or a dynamic, state-like process. This choice is crucial because different epistemologies lead to different study designs and measurements concerning cognitive engagement. Although our definition provides insights about what cognitive engagement is, it is necessary to draw a full picture of its features by synopsizing different perspectives and contemporary findings. We then examine similarities and differences between cognitive engagement and SRL. This discussion is followed by an introduction of recent attempts to investigating cognitive engagement within models of SRL. Finally, we end with a proposed integrative model of SRL engagement. We discuss a few important implications drawn from the integrative model of SRL engagement, as well as some of the key issues to address in future research.

The nature of cognitive engagement

Cognitive engagement as a consecutive process

Cognitive engagement is extensively studied as a dichotomous process, such as deep or meaningful versus shallow cognitive engagement, deep versus surface processing, and cognitive engagement versus disengagement (Azevedo, 2015; Dinsmore & Alexander, 2012; Greene, 2015). As an example, Greene (2015) defined two types of cognitive engagement: deep and shallow engagements, based on Craik and Lockhart's (1972) depth of processing model. Specifically, Greene (2015) viewed deep engagement as involving the active use of prior knowledge and deep strategies (e.g., monitoring and self-reflection) in learning, whereby more complex knowledge structures are generated. Shallow engagement involves the use of intentional but mechanical strategies that need limited thoughtful cognitive actions, such as verbatim memorization and rehearsal. However, as pointed out by Azevedo (2015), using dichotomies to investigate engagement-related processes is problematic, since the dichotomies underestimate the complex nature of cognitive engagement and do not help clarify this construct. Furthermore, since there is no robust theoretical basis for separating deep from shallow engagement, it is difficult to align behavioral and cognitive indicators to deep or shallow categories across studies (Bernacki et al., 2012). For instance, Dinsmore and Alexander (2012) examined 221 engagement-related studies and had difficulty making comparisons across these studies since there were varying clarifications of deep and surface processing and situational factors. Although cognitive engagement is often examined at a deep or surface level, researchers are reaching a consensus that cognitive engagement is not a dichotomous construct but rather a dynamic phenomenon that can change over time as learning occurs. Cognitive engagement, as basic processing operations to initiate or sustain students' interaction with specific tasks, activities, and learning environments, is inherent to all learning processes (Boekaerts, 2016).

Context dependent

Researchers generally agree that cognitive engagement is context-specific, which means it varies across academic domains and learning situations (Boekaerts, 2016; Cleary &

Zimmerman, 2012; Fredricks et al., 2004; Jarvela et al., 2016; Miller, 2015). Cognitive engagement occurs as students interact with specific learning tasks and environments. According to Helme and Clarke (2001), there exist three interacting factors that impact cognitive engagement, i.e., the individual, the learning environment, and the tasks per se. First of all, the characteristics that the individual brings to the learning context (e.g., skills, disposition, and motivational beliefs) influence his/her cognitive engagement, which has already been corroborated by a wide range of empirical studies (Helme & Clarke, 2001). Furthermore, learning environments also play a role in cognitive engagement since they can either promote or constrain one's use of particular learning strategies and types of interactions with other stakeholders. Finally, the characteristics of tasks, be they well-structured versus ill-structured, have an impact on cognitive engagement, although the relations are not clear. For example, ill-structured tasks stimulate more deep strategies and effort when compared with well-structured tasks, but they might also hamper the cognitive engagement of a learner if he/she perceives the task as too difficult (Jarvela et al., 2016). In sum, cognitive engagement is dependent on the context, and it depends on the complex interplay of personal and contextual influences (Cleary & Zimmerman, 2012; Greene, 2015; Helme & Clarke, 2001).

Changes quantitatively and qualitatively in learning

In a recent special issue on student engagement and learning in *Learning and Instruction*, Boekaerts (2016) found that all contributors found engagement to be malleable rather than stable across learning situations. Greene (2015) further argued that cognitive engagement is "not a stable characteristic of either a learner or a learning environment but rather a fluid set of processes that can be influenced by learners themselves and by the environment" (p. 27). These ideas support the context-sensitive nature of cognitive engagement. It appears that a consensus has been reached that cognitive engagement is malleable during learning. However, it is still worth highlighting the changing nature of cognitive engagement based on the following considerations. First, researchers who defined cognitive engagement as involving students' willingness to learn still viewed this construct as a more or less stable trait of learners, disregarding the pressing need to distinguish cognitive engagement from motivational constructs as recognized by modern perspectives of cognitive engagement (Rotgans & Schmidt, 2011). Second, there are discrepancies between how researchers define cognitive engagement and how they measure this construct. That is, researchers are found to be using instruments designed to measure generally stable, trait-like cognitive engagement, such as retrospective self-report questionnaires and interviews, although they acknowledge that cognitive engagement is a dynamic process (D'Mello et al., 2017; Rotgans & Schmidt, 2011; Wolters & Taylor, 2012). In fact, few shreds of evidence can be obtained from previous studies about how cognitive engagement dynamically shifts or changes in students' learning processes (Cleary & Zimmerman, 2012).

Miller (2015) contributed to this area of research by providing a description of how changes in cognitive engagement in learning might be examined. According to Miller (2015), students' cognitive engagement changes quantitatively and qualitatively when solving a task. Students may distribute varying amounts and forms of cognitive resources between and within academic tasks. Specifically, high levels of cognitive engagement typically involve the allocation of large amounts of cognitive resources, as well as the use of deep processing and metacognitive strategies. On the contrary, students who have a low level of cognitive engagement would use a relatively small amount of cognitive resources to perform shallow

processing and heuristic strategies. This depiction is partially in line with Linnenbrink's (2005) proposition that cognitive engagement included both the quality and quantity of self-regulation. Specifically, the quality of self-regulation refers to students' use of self-regulatory strategies, while the quantity of self-regulation means their persistence in learning when facing obstacles. Furthermore, Miller's (2015) depiction is also consistent with Cleary and Zimmerman's (2012) definition of cognitive engagement, as well as with the definition proposed by this paper, since both definitions emphasize the importance of taking the quantitative (i.e., to what extent students think strategically) and qualitative (i.e., what types of thinking strategies students use) aspects of cognitive engagement into consideration. It is worth mentioning that the terms "the extent to which students think strategically" and *persistence* can both describe the process of quantitative effort in learning whereby students engage actively and constructively toward personal goals. However, they are distinct constructs. The term "the extent to which students think strategically" is concerned with simply the amount of effort students invest in learning, whereas persistence refers to students' tendency to maintain effort when obstacles are encountered. Persistence as such requires a continuing investment in learning and substantial effort.

To conclude, cognitive engagement changes quantitatively in that students continuously change the frequency, duration, and intensity of effort over the learning or problem-solving process. From a SRL perspective, students are active participants who can purposefully manage the allocation of effort based on their internal conditions and task environments. At the same time, cognitive engagement changes qualitatively in that students adaptively choose different learning strategies to fulfill personal goals (Boekaerts, 2006; Miller, 2015).

Can be either conscious or unconscious

According to Boekaerts (2006), students who are already cognitively engaged in a task may—consciously or unconsciously—increase or decrease their levels of cognitive engagement by manipulating the amount of attention, energy, or time in the process of problem-solving. The idea of adjusting one's cognitive engagement, consciously or unconsciously, is in accordance with Dole and Sinatra's (1998) research, in which they report a continuum of cognitive engagement from "low cognitive engagement" (which they defined as minimal cognitive effort and use of surface-level strategies) to "high metacognitive engagement" (which they defined as more cognitive effort and use of deep and metacognitive strategies). Along this continuum, the "low cognitive engagement" is considered automatic, without personal consciousness, while the other end is considered "high metacognitive engagement," which is deliberate and metacognitively governed (Miller, 2015). In short, sustaining cognitive engagement in learning can be either conscious or unconscious, depending on whether or not metacognitive activities are involved.

Self-regulated learning and cognitive engagement

Self-regulated learning

Panadero (2017) conducted a review of SRL models and found that six models were prevalent in the literature, including those developed by Pintrich (2000), Zimmerman (2000), Winne and Hadwin (1998), Boekaerts and Niemivirta (2000), Efklides (2011), and Hadwin et al. (2011).

We provided a comparison of the six dominant SRL models in Table 1. In particular, the SRL model proposed by Pintrich (2000) puts emphasis on how motivational constructs, especially goal orientation, are related to SRL processes. Zimmerman's (2000) cyclical phase model of SRL is very similar to that of Pintrich (2000) in terms of background theory, definition, components, and empirical research (Puustinen & Pulkkinen, 2001). The four-stage model of SRL proposed by Winne and Hadwin (1998) argued that metacognitive monitoring produces internal feedback in each phase of SRL, which distinguishes this model from all the others (Puustinen & Pulkkinen, 2001). In addition, Winne and Hadwin's (1998) SRL model differed from others in that the model described each SRL phase with the COPES (i.e., conditions, operations, products, evaluations, and standards) cognitive structure. In the extended model of adaptable learning (Boekaerts & Niemivirta, 2000), there are two goal pathways (i.e., the mastery/growth pathway and the well-being pathway) that drive students' regulation of behaviors, cognitions, and emotions. Regarding the metacognitive and affective model of SRL (MASRL) (Efklides, 2011), it is unique in that the model distinguishes two levels of functioning in SRL, namely, the person level and the task × person level. The most salient feature of the model developed by Hadwin et al. (2011) is probably the distinction between the three modes of regulation in collaborative settings: self-regulation, co-regulation, and shared regulation. In this study, we do not intend to duplicate Panadero's (2017) review of the six SRL models, since he provided a detailed description of the history, development, features, and measurement instruments for each model. Instead, we discuss some basic assumptions underlying most SRL models and the state of the art of SRL research so that a shared understanding can be reached when comparing SRL with other constructs.

Researchers generally agree that SRL models form an integrative and coherent framework (Panadero, 2017). Across most SRL models, self-regulated learning is reviewed as an active, iterative process through which learners purposefully control and monitor their behavioral, cognitive, emotional, and motivational aspects of learning to fulfill learning goals (Boekaerts et al., 2005; Pintrich, 2004; Wolters & Taylor, 2012). Moreover, all the SRL models share four basic assumptions about learning (Pintrich, 2000). One assumption is that learners are active, constructive participants who can construct their own meanings from the information available in the internal and external environments. Second, all the models assume that learners can potentially monitor, control, and regulate certain aspects of learning process and environments. A third assumption is that self-regulation of learning and performance is goal-driven, suggesting that learners continuously compare their learning processes with certain criteria or standards. Lastly, there are complicated interplays between personal/contextual characteristics and actual performance, which are mediated by learners' self-regulatory activities. In addition to these four basic assumptions, researchers have reached a consensus that SRL is a contextualized, cyclical process consisting of feedback loops (Schunk & Greene, 2017).

While the six SRL models are all theoretically sound and are supported by ample empirical evidence, they are not without shortcomings. As shown in Table 1, one weakness of the six models lies in the fact that they comprise a limited number of components, typically ranging from three to five cyclical phases or elements (Zeidner, 2019). Considering that the complexity of the learning process has been simplified in the six dominant SRL models, they explain only a fraction of learning phenomena. As pointed out by Zeidner (2019), "future models may need to be less simplistic and more complex than current models, incorporating dynamic concepts and additional structural components in the model" (p. 266). This study takes the initiative to enrich the repertoire of SRL models by exploring the role of cognitive engagement in SRL.

Table 1 A comparison of the six dominant SRL models

SRL model	Background theory	Phases and processes	Main distinguishing features
Pintrich (2000): A general framework for SRL	Social cognitive theory	Four phases: forethought, monitoring, control, and reflection	The model emphasizes the role of motivation, especially goal orientation, in SRL
Zimmerman (2000): Cyclical phases model of SRL	Social cognitive theory	Three phases: forethought, performance, and self-reflection	The model suggests that SRL is both motivation and strategy oriented
Winne and Hadwin (1998): Four-stage model of SRL	Information-processing theory	Four phases: task definition, goal setting and planning, studying tactics, and adaptations to metacognition	Each phase shares the same COPES (conditions, operations, products, evaluations, standards) structure
Boekaerts and Niemivirta (2000): An extended model of adaptable learning	Action control theory and transactional stress theory	Five key processes: an identification process, two interpretation processes (task-focused and self-focused), and primary and secondary appraisal processes	The model describes two parallel processing modes: a mastery or learning mode and a coping or well-being mode
Efklides (2011): Metacognitive and affective model of SRL (MASRL)	Social cognitive theory and extant SRL models	Three phases in the task processing: task representation, cognitive processing, and performance	The model distinguishes two levels of functioning in SRL, namely, the person level and the task × person level
Hadwin et al. (2011): A model of regulation in collaboration	Heavily influenced by Winne and Hadwin's (1998) SRL model	Four phases: task understanding, goal setting and planning, task enactment, and large- and small-scale adaptation	The model describes self-regulation, co-regulation, and shared regulation in collaborative learning environments

Table 2 Perspectives on the relationships between SRL and cognitive engagement

Relationship	Argumentation
SRL contains cognitive engagement	Self-regulated learners should be cognitively engaged Cognitive engagement is defined as involving the use of SRL strategies (Furlong & Christenson, 2008; Horner & Shwery, 2002) There is little difference between cognitive engagement and the cognitive aspect of SRL with respect to their measurements (Wolters & Taylor, 2012)
SRL is one form of cognitive engagement	There are four forms of cognitive engagement, i.e., SRL, task focus, resource management, and recipience. SRL is the highest form of cognitive engagement (Corno & Mandinach, 1983)
SRL associates with cognitive engagement	Cognitive engagement has a role in each of the SRL components, i.e., cognitive strategies, management and control of effort, and metacognitive strategies (Pintrich & de Groot, 1990) Cognitive engagement unfolds across and within SRL phases (Goh & Zeng, 2014; Jarvela et al., 2016)

Similarities and differences between SRL and cognitive engagement

Regarding the relationships between SRL and cognitive engagement, there mainly exist three perspectives, as shown in Table 2. Wolters and Taylor (2012) examined the relations between the cognitive aspects of SRL and cognitive engagement and concluded that there are considerable overlaps between these two constructs. For instance, students viewed as self-regulated learners should be cognitively engaged in learning or problem-solving, while cognitive engagement is explicitly defined by some researchers as involving the use of SRL strategies (Furlong & Christenson, 2008; Horner & Shwery, 2002). The increased use of cognitive/metacognitive strategies is considered essential in both the SRL framework and cognitive engagement. There is also little practical difference between the cognitive aspect of SRL and cognitive engagement in some research (Wolters & Taylor, 2012). As an example, Pizzimenti and Axelson (2015) drew upon the SRL framework, specifically the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & de Groot, 1990), to infer students' level of cognitive engagement.

Considering the substantial conceptual consistency, some researchers considered SRL as a special form of cognitive engagement. For example, Mandinach and Corno (1985) conceptualized four forms of cognitive engagement: self-regulated learning, resource management, recipient learning, and "task-focused" learning. Specifically, self-regulated learning is the highest form of cognitive engagement during which students are cognitively engaged in planning, monitoring, and adjusting their own problem-solving processes (Corno & Mandinach, 1983). Resource management refers to the situation where students reduce their self-regulatory learning activities to some extent and rely on external resources to accomplish a task, while recipient learning requires a minimal investment of cognitive effort as students receive information passively. Task-focused learning refers to investing considerable effort but failing to consider information beyond the task itself, i.e., cues and feedback. SRL is considered the most sophisticated form of cognitive engagement, while the other three forms of cognitive engagement emphasize different aspects of SRL. Students may use a form of cognitive engagement qualitatively different from SRL by emphasizing some SRL processes and deemphasizing others (Corno & Mandinach, 1983). The application of appropriate forms of cognitive engagement according to task demands and instructional features is essential to learning (Mandinach & Corno, 1985).

Table 3 The differences between SRL and cognitive engagement

SRL	Cognitive engagement
Learning is not necessarily an SRL process	Cognitive engagement is inherent in all learning processes
SRL is metacognitively governed	Cognitive engagement may occur unconsciously or consciously
SRL is a cyclical process that consists of clear phases or subprocesses	Cognitive engagement has been considered as a continuous variable changing along a continuum
SRL involves a variety of cognitive processes, such as the management of mental effort, environmental influences, and internal constraints	Cognitive engagement is mainly concerned with the investment and allocation of mental effort on learning strategies

Despite conceptual overlaps between the SRL and cognitive engagement constructs, there are points on which they diverge (see Table 3). For one, learning is not necessarily an SRL process, whereas cognitive engagement is inherent in all learning processes (Boekaerts, 2016). For example, when students are forced to accomplish a task with rigid but clear procedures, they may appear cognitively engaged but would likely not be self-regulated (Wolters & Taylor, 2012); Secondly, SRL is metacognitively governed (Boekaerts, 2006), which means self-regulated learners metacognitively monitor qualities of their problem-solving processes and exercise control to make adjustments (Winne, 2010). In contrast, changing or sustaining one's level of cognitive engagement can be either conscious or unconscious (Dole & Sinatra, 1998). Thirdly, SRL has clear stages that complete the process of learning or problem-solving, while cognitive engagement has been considered as a continuous variable along a continuum. For example, Winne and Hadwin (1998) argued that SRL consists of four interdependent and recursive phases: task definition, goal setting and planning, enactment, and adaptation. Zimmerman (2000) contended that SRL involves three cyclical phases: forethought, performance, and self-reflection. With respect to cognitive engagement, it exists along a continuum from the level of low to high across the learning process (Dole & Sinatra, 1998; Gonzalez et al., 2016). Lastly, the cognitive aspect of SRL is more than cognitive engagement. It also involves other components, such as the management of environmental or internal constraints during learning (Cleary & Zimmerman, 2012).

Thus, taking SRL as the highest form of cognitive engagement could be problematic, given that SRL is an evolving process in nature, whereby students exert an *appropriate* amount of cognitive resources to solve a task. It does not necessarily mean sustaining the highest level of cognitive engagement across the whole SRL process (Greene, 2015). Furthermore, it is problematic to explore cognitive engagement by only utilizing parts of SRL questionnaires, such as the MSLQ, since (1) it mixes the boundary between SRL and cognitive engagement and (2) it often captures the qualitative aspect of cognitive engagement, i.e., the use of SRL strategies, while the quantitative aspect of cognitive engagement (i.e., to what extent students apply SRL strategies) is overlooked. However, research on SRL and cognitive engagement has advanced mutual theoretical frameworks and helped researchers develop a more holistic understanding of students' learning. For example, Greene (2015) mentioned that Pintrich and de Groot's (1990) conceptualization of self-regulated learning (SRL) contributed to cognitive engagement studies by introducing two types of learning strategies: cognitive strategy (which can be further classified into shallow strategies and deep strategies) and self-regulation. Thus, Greene (2015) developed a scale that consisted of three components (i.e., self-regulation, deep strategy use, and shallow strategy use) to measure the extent to which

students engaged cognitively in the problem-solving process. Meanwhile, research on SRL also benefited from the literature on cognitive engagement. Inspired by research on deep versus surface learning, Blom and Severiens (2008) identified two types of learning patterns, self-regulated deep learning and self-regulated surface learning. In self-regulated deep learning, students apply deep learning strategies, like elaboration and critical thinking, to accomplish tasks, while students mainly use surface strategies (e.g., rehearsal) in self-regulated surface learning.

In summary, SRL and cognitive engagement are two distinct constructs, but they share many similarities. Researchers who adopted this perspective tended to focus on the mechanisms of how SRL phases are related to the functioning of cognitive engagement instead of considering one construct contains the other. For instance, Pintrich and de Groot (1990) argued that there were three crucial components of SRL, i.e., cognitive strategies, students' management and control of their effort, and metacognitive strategies. Cognitive engagement has a role in each of these SRL components. For instance, different cognitive strategies such as rehearsal and elaboration foster an individual's cognitive engagement; students' management and control of effort necessitate learners' cognitive engagement; and metacognitive strategies serve to adjust the levels of cognitive engagement in response to internal and external feedback. There are also emerging empirical studies examining how cognitive engagement unfolds across and within SRL phases. For example, Jarvela et al. (2016) collected 84 hours of video recordings of 44 students' interaction in collaboration during a math course and coded these video recordings in terms of types of engagement (i.e., cognitive and socioemotional) and SRL phases (i.e., forethought, performance, and reflection). Goh and Zeng (2014) reported a longitudinal study involving four students engaged with SRL activities in English listening tests. They tracked the learners' engagement during four phases of SRL, namely, task definition, goal setting and planning, strategy enactment, and metacognitive adaptation. Both studies found that cognitive engagement occurred differently across the SRL phases, regardless of different SRL models.

Models linking SRL and cognitive engagement

To further advance our understanding of the role cognitive engagement plays in SRL, one necessary step is to establish more comprehensive theoretical specifications as to how cognitive engagement and SRL are related. Some progress has been made in this direction, as is shown by the work of Butler and Winne (1995), Cleary and Zimmerman (2012), and Zusho (2017).

The elaborated model of SRL

Butler and Winne (1995) proposed an elaborated model of SRL for analyzing students' cognitive processes, which spotlights "the cognitive operation of monitoring as the hub of self-regulated cognitive engagement" (p. 245). According to Butler and Winne (1995), self-regulated cognitive engagement describes a process during which students are aware of the qualities of their cognitive engagement and the discrepancy between the current level of cognitive engagement and a predetermined goal. Students can monitor and self-regulate the extent to which they cognitively engage in learning. There are two main arguments in Butler and Winne's (1995) description of self-regulated cognitive engagement: First, the goals students adopt in SRL drive their cognitive engagement. When encountering obstacles in

pursuing a goal, students may modify their cognitive engagement by adjusting existing ones or even set new goals. Second, internal monitoring and feedback play a crucial role in self-regulated engagement. Specifically, internal monitoring of one's cognitive engagement in SRL generates feedback, which in turn influences the individual's regulation of subsequent cognitive engagement. However, Butler and Winne (1995) did not provide a clear definition of self-regulated cognitive engagement. Unfortunately, they used SRL, self-regulated engagement, and self-regulated cognitive engagement interchangeably, causing some confusion on how such terms differ. Moreover, they did not draw a distinction between cognitive engagement and cognitive processing in their research. They define cognitive engagement as a broad term referring to as an unfolding cognitive process that involves students' beliefs, knowledge, and learning strategies. Although Butler and Winne (1995) expanded the research examining the relations between cognitive engagement and SRL, questions remain as to how cognitive engagement should be conceptualized in SRL contexts and how it unfolds dynamically in SRL.

The theoretical framework of self-regulatory engagement

Cleary and Zimmerman (2012) linked the constructs of SRL and cognitive engagement and delineated a theoretical framework of self-regulatory engagement. In this framework, Cleary and Zimmerman (2012) were primarily concerned with the extent to which students became cognitively engaged in the three sequential phases of self-regulatory learning, i.e., forethought, performance, and self-reflection. Students who proactively engage in the forethought phase seek to identify the requirements of a learning task (task analysis), set goals, and develop plans to achieve one's goals. During the performance phase, highly SRL-engaged students utilize various self-control processes (e.g., self-instruction, attention focusing, use of cognitive and metacognitive strategies) to optimize their problem-solving trajectories. In terms of the self-reflection phase, SRL-engaged learners evaluate whether their levels of cognitive engagement yield expected performance, attribute success and failure to the strategies they applied during learning, and make adjustments to their learning strategies correspondingly. Although students can attribute their performance to other contextual and personal factors, a key point in the self-reflection phase of SRL-engaged learning is that students display consistent thinking in the sphere of strategies (Cleary & Zimmerman, 2012). Having been rooted in the three-phase SRL theory proposed by Zimmerman (2000), the framework of self-regulatory engagement delineates a clearly defined "process" account of how students self-regulate their levels of cognitive engagement over time. However, this framework does not address the question of how students initially become cognitively engaged in learning. The question related to the functioning of cognitive engagement in SRL phases is also unclear. Moreover, this framework emphasizes the use of strategies but overlooks the extent to which students allocate mental effort on strategy use.

The integrative model of student learning

A recent study by Zusho (2017) also contributed to the development of an integrated model of SRL and cognitive engagement. Specifically, Zusho (2017) proposed an integrative model of student learning by first providing a critical analysis of three distinct yet overlapping streams of research (i.e., SRL, patterns of learning, and student engagement) and by taking into consideration the strengths of each of these

approaches. At the heart of this model is the interaction between cognition (i.e., use of cognitive and self-regulatory strategies) and motivation, which is influenced by both personal and contextual factors at varying levels. Zusho (2017) argued that the interacting effect of cognitive and motivational processes accounted for students' learning outcomes, including understanding, academic risk-taking, engagement, and achievement. Engagement was considered an outcome and was indicated by effort, choice, and persistence. A marked feature of Zusho's (2017) model is its ambitious attempt to integrate the three influential models of students" learning; however, this integrated model was not without criticism. First, some central theoretical claims pertaining to each stream of research (e.g., SRL and student engagement) were overlooked in the integrated model. Although Zusho (2017) claimed that this model was heavily influenced by SRL research, she provided no illustration with regard to how students self-regulate their learning in a cyclical feedback loop. Instead of delineating the functioning of various types of engagement (e.g., cognitive and behavioral) and their roles in SRL, Zusho (2017) used the term student engagement broadly. Furthermore, some researchers question whether engagement can be categorized as a learning outcome since many researchers considered engagement as an inherent aspect of the learning process (Boekaerts, 2016; D'Mello et al., 2017; Eccles, 2016).

In a word, more work is needed to advance the integration of theories of SRL and cognitive engagement, since each of the aforementioned models has its own shortcomings. Researchers generally agree that the integration of SRL and cognitive engagement is still in its infancy (Cleary & Zimmerman, 2012; Wolters & Taylor, 2012; Zusho, 2017). Nevertheless, it is noteworthy that previous research can inform future studies: First, an integrative model should situate the construct of cognitive engagement in the context of SRL rather than SRL being considered part of cognitive engagement. Second, cognitive engagement should be clearly defined to avoid conceptual conflations with existing constructs, and the integrative model should be integrally consistent with that definition of cognitive engagement. And lastly, the integrative model should not only describe SRL-engaged learning but also illustrate the mechanisms of how students shift or change their cognitive engagement within and across SRL phases.

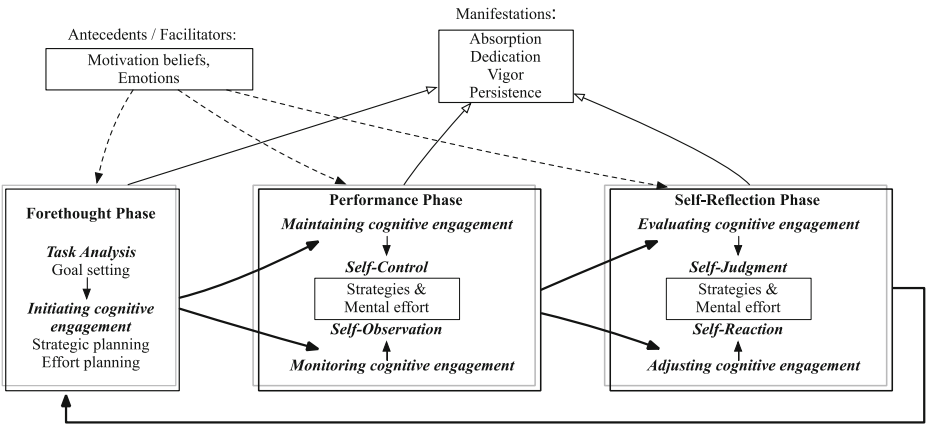

Fig. 1 The integrative model of SRL engagement

An integrative model of SRL engagement

We propose an extension of previous models linking SRL and cognitive engagement and label it as an integrative model of SRL engagement. The proposed integrative model of SRL engagement is shown in Fig. 1. Rooted in Zimmerman's (2000) three-phase SRL model, the integrative model of SRL engagement also consists of three sequential phases: forethought, performance, and self-reflection.

In the forethought phase, students analyze the task and set goals. They also plan the strategies used to solve the task and corresponding effort needed on these strategies to reach their goals. Our model is different from Zimmerman's (2000) model, which only involves strategic planning in the forethought phase. Our model consists of two subprocesses of planning: strategic planning and effort planning. This emphasis is in line with Dweck and Leggett's (1988) research, which claimed that students with learning goals could plan not only their learning processes (e.g., planning hypothesis-testing strategies), but also their levels of mental effort exerted in these processes. The two subprocesses are driven by the goals set before, whereby learners initially become cognitively engaged in learning or problem-solving. Consistent with Butler and Winne's (1995) argument that the goals students adopt in SRL drive their cognitive engagement, this model also considers a predetermined goal to be the primary source that influences the self-regulation of cognitive engagement in the three cyclical SRL phases.

In terms of the performance phase, students maintain their initial level of cognitive engagement to reduce performance discrepancy against a goal state. In this phase, students generally self-control (1) what cognitive strategies they choose and (2) the level of intensity (e.g., the amount of mental effort) in which they engage in the utilization of a strategy. Although the use of deep level strategies implies that students are more cognitively intensely involved in learning compared with the use of relatively simple or surface-level strategies (e.g., rehearsal), there are differences among students on the allocation of mental efforts toward even the same deep strategy, reflected by their choices of the frequency, duration, or intensity of that strategy (Pintrich & Schauben, 1992). This argument provides important insights into the SRL studies regarding the optimization of the problem-solving process. Students adaptively assemble appropriate strategies and amounts of mental effort to solve problems rather than exert themselves on tasks. In this sense, the proposed model describes how self-regulated learners strategically manage their engagement to be cognitively efficient in learning or problem-solving. Cognitive efficiency is a core feature of SRL engagement. As a subprocess of the performance phase, self-observation serves an information function in that students become aware of the state and qualities of their cognitive engagement. From an engagement perspective, this regulatory process involves monitoring one's use of strategies and the mental effort invested in these strategies.

During the self-reflection phase, students first make judgments on their self-monitored cognitive engagement to see whether the current level of cognitive engagement is sufficient for reaching expected performance. This process is crucial because it determines how students adjust their cognitive engagement to meet their predetermined goals. Although the two subprocesses (i.e., self-judgment and self-reaction) are the same as Cleary and Zimmerman's (2012) SRL engagement model, there are two main differences: First, the focus of self-judgment in the proposed model is one's cognitive engagement, i.e., the effectiveness of learning strategies and the appropriateness of amounts of mental effort. However, the focus of self-judgment in Cleary and Zimmerman's (2012) model is one's level of success or

performance, based on which students make adjustments to their learning strategies. Second, self-reflection in Cleary and Zimmerman's (2012) model is considered as a multicomponent cognitive process involving subprocesses of self-evaluation, causal attributions, adaptive inferences, self-satisfaction, and so on (Cleary & Zimmerman, 2012). To keep theoretical and conceptual consistencies in illustrating the mechanisms of cognitive engagement in SRL, the self-reflection phase in the proposed model mainly focuses on students reflecting the extent to which (i.e., mental effort) they think strategically (i.e., learning strategies) in performance.

It is notable that our model highlights the changing nature of cognitive engagement, suggesting that individuals are always in the process of making adjustments on the fly in terms of the quantitative and qualitative aspects of cognitive engagement. The flexible adjustments of the two aspects of cognitive engagement occur in an ongoing manner throughout the learning process, although students do not necessarily change the two aspects simultaneously. Considering that cognitive engagement is inherent in all learning processes (Boekaerts, 2016), the quantitative component of cognitive engagement (i.e., level of mental effort) does not vanish in learning but changes along a continuum ranging from effortlessness to maximum effort. Regarding the qualitative component of cognitive engagement, students continuously activate or deactivate certain learning strategies depending on their judgments or reflection of the effectiveness of such strategies. We contend that the two components of cognitive engagement do not compensate or constrain each other in general, although varying initial levels of mental effort are needed for different learning strategies to be activated. For example, a student may sustain a high level of mental effort on a shallow strategy (e.g., rehearsal) for a long time. It might also be the case that students spend relatively little time on deep strategies. Moreover, this model gives particular emphasis to the issue of how cognitive engagement unfolds across and within SRL phases. In particular, students' personal goals initiate the quantitative and qualitative aspects of cognitive engagement, performance discrepancy sustains the two aspects of cognitive engagement, and student self-reflection drives the adjustments of cognitive engagement.

While admitting that motivation beliefs and emotions are integral to the SRL process, this model views these components as antecedents or facilitators of cognitive engagement in the three SRL phases. This is in line with previous research, which claims that motivation constructs predict or facilitate one's level of cognitive engagement (Corno & Mandinach, 1983; Greene, 2015; Greene et al., 2004). In addition, our model steps further to differentiate cognitive engagement from its manifestations such as absorption, dedication, vigor, and persistence (Wouters et al., 2017). Contrary to Zusho's (2017) model in which engagement is characterized as outcomes, we consider the manifestations of cognitive engagement rather than cognitive engagement per se to be learning products.

Taken together, the elaborated integrative model of SRL engagement contributes significantly to the body of research on the integration of SRL and cognitive engagement. A unique feature of this model is that it takes the nature of cognitive engagement into account, allowing new educational research leads to emerge to reveal the essence of students' learning. Moreover, the development of the proposed model is based on a thorough analysis of the similarities and differences between cognitive engagement and SRL, as well as an analytical review of the three prominent integrated frameworks. Furthermore, the proposed SRL engagement model is one of the first to clarify the mechanisms of how SRL phases and subprocesses are related to the functioning of cognitive engagement. In addition to adding to the theoretical discussions of the relations between cognitive engagement and SRL, our model informs the design of adaptive scaffoldings and the practice of learning analytics. In particular, this model suggests

that high performers can strategically regulate their cognitive engagement in different SRL phases, which means that shallow engagement is not always dysfunctional and detrimental to students' performance. On a practical level, instructors should allow the presence of shallow engagement, since keeping students deeply engaged throughout the learning process can be cognitively demanding or even impractical in certain circumstances. The focus of instructional scaffoldings or interventions should be placed on the key subprocesses of learning, where a high level of cognitive engagement contributes most to students' performance. Moreover, this model highlights the importance of tracking, modeling, and visualizing the dynamics of cognitive engagement over the course of SRL, which informs the practice of learning analytics. For instance, it is suggested to model not only what strategies high-performing students use in different SRL phases but also the extent to which they use such strategies, in order to reveal significant and effective problem-solving patterns.

Based on the integrative model of SRL engagement, many fruitful lines of research can be generated. First, the proposed model calls for more empirical studies designed to validate its theoretical specifications, such as whether or not students plan not only learning strategies but also the amount of mental effort needed in the forethought phase. Of particular interest for future research is to examine how cognitive engagement shifts or sustains within and across SRL phases, considering it is an underexplored research area (Cleary, 2011; Cleary & Zimmerman, 2012). It is also valuable to recognize the common truth regarding how cognitive engagement changes in cyclical SRL phases from studies conducted in various contexts and with different populations. A second line of future research that scholars may find important is the joint effects of SRL and cognitive engagement on learning performance (Pardo et al., 2017). Considering the absence of studies documenting students' effort on various learning strategies in different SRL phases, as a consequence, there is no surprise that much work is needed to be done when taking an extra factor of students' performance into consideration (Wolters & Taylor, 2012). In addition, researchers studying student engagement are highly interested in promoting students' cognitive engagement, leaving the efficiency of cognition and engagement largely unexplored. Therefore, it would be promising to investigate the efficiency of SRL engagement and its associations with students' SRL skills, task features, and performance. A final recommendation for future research is to study the influences of motivation and emotion on cognitive engagement in different SRL phases. For example, self-efficacy has been shown to be a crucial motivational source of students' cognitive engagement (Cleary & Zimmerman, 2012), while a predetermined goal has been claimed to drive one's cognitive engagement (Butler & Winne, 1995). It is unclear whether a predetermined goal plays a more significant role in sustaining one's cognitive engagement than self-efficacy or vice versa. The future research directions described here are not inclusive but have shown promise for providing new knowledge on the research of SRL and cognitive engagement.

While the proposed model opens up new research directions, a crucial question that needs to be addressed first is how can we measure cognitive engagement in a way that captures its nature? In an attempt to answer this question, we proposed several suggestions which could inform future researchers of the measurement of cognitive engagement underlying the proposed model. The core idea of cognitive engagement, as illustrated in this paper, is about how students allocate their mental effort on different learning strategies. Therefore, it is a necessity to collect multichannel data using multiple methods so that the level of mental effort (i.e., the

quantitative aspect of cognitive engagement) and corresponding learning strategies (i.e., the qualitative aspect of cognitive engagement) can be assessed simultaneously. In fact, researchers are increasingly calling for the use of multiple methods to measuring cognitive engagement rather than relying merely on a single instrument (Betts, 2012; Greene, 2015; Sinatra et al., 2015). Moreover, the measurement should be able to capture the dynamics of cognitive engagement, especially the changing levels of mental effort, at a fine-grained temporal resolution. Experience sampling method (ESM) provides a feasible solution since it allows students to report on their changing effort levels during different stages of learning or problem-solving. Alternatively, researchers can use advanced techniques, such as eye-tracking, psychological measures (e.g., EEG), and text mining, to capture the changes of mental effort in fine-grained sizes. The use of learning strategies can be measured via observations, think-aloud, and log files. Taking one of our previous studies as an example (Li et al., 2021), we inferred the learning strategies students used in solving a clinical problem from system log files, and we detected the level of mental effort that was allocated on each learning strategy based on students' facial behavioral cues.

Conclusion

The research on SRL and student engagement is at a crossroads. Both two areas of research attempt to understand students' learning processes and the underlying factors that account for students' academic success and task performance. Nevertheless, studies on SRL and student engagement have been conducted by separate research groups to date (Zusho, 2017), which prevents researchers from obtaining a holistic understanding of how learning occurs and how to improve learning. In this paper, we focused on the integration of SRL and cognitive engagement, which could potentially help the field move forward. Specifically, we identified the nature of cognitive engagement (i.e., changing consecutively, context-dependent, comprising quantitative and qualitative dimensions, occurring consciously or unconsciously), based on which we compared the differences and similarities between cognitive engagement and SRL. Afterward, we reviewed three models that have investigated cognitive engagement within the frameworks of SRL, analyzed their features and weaknesses, and proposed an integrative model of SRL engagement. The proposed model explicitly illustrates the functioning of cognitive engagement in SRL phases, for example, when cognitive engagement begins and how it relates to different learning subprocesses.

We recognize that the proposed model is not without limitations. Although the model is theoretically solid, there is currently few empirical evidence to verify its effectiveness. More research is needed in the future to address concerns regarding the model's validity. Moreover, we consider students' motivational beliefs and emotions as antecedents or facilitators of cognitive engagement in the three SRL phases. However, the underlying mechanisms of how motivational beliefs or emotions affect the dynamic changes of cognitive engagement in SRL are still unclear, which instills some obscurity into our model. Despite the limitations, our model provides a framework for asking important research questions and guiding future research.

Funding This research was funded by the Fonds de recherche du Québec - Société et culture (FRQSC) and the Social Sciences and Humanities Research Council of Canada (SSHRC).

Declarations

Ethics approval Not applicable

Competing interests The authors declare no competing interests.

References

Appleton, J. J., Christenson, S. L., Kim, D., & Reschly, A. L. (2006). Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument. *Journal of School Psychology, 44*(5), 427–445. https://doi.org/10.1016/j.jsp.2006.04.002.

Azevedo, R. (2015). Defining and measuring engagement and learning in science: Conceptual, theoretical, methodological, and analytical issues. *Educational Psychologist, 50*(1), 84–94. https://doi.org/10.1080/00461520.2015.1004069.

Bernacki, M. L., Byrnes, J. P., & Cromley, J. G. (2012). The effects of achievement goals and self-regulated learning behaviors on reading comprehension in technology-enhanced learning environments. *Contemporary Educational Psychology, 37*(2), 148–161. https://doi.org/10.1016/j.cedpsych.2011.12.001.

Betts, J. (2012). Issues and methods in the measurement of student engagement: Advancing the construct through statistical modeling. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 783–803). Springer Science + Business Media. https://doi.org/10.1007/978-1-4614-2018-7_38.

Blom, S., & Severiens, S. (2008). Engagement in self-regulated deep learning of successful immigrant and non-immigrant students in inner city schools. *European Journal of Psychology of Education, 23*(1), 41–58. https://doi.org/10.1007/BF03173139.

Boekaerts, M. (2006). *Self-regulation and effort investment* (pp. 345–377). Child Psychology in Practice.

Boekaerts, M. (2016). Engagement as an inherent aspect of the learning process. *Learning and Instruction, 43*, 76–83. https://doi.org/10.1016/j.learninstruc.2016.02.001.

Boekaerts, M., & Niemivirta, M. (2000). Self-regulated learning: Finding a balance between learning goals and ego-protective goals. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-Regulation* (1st ed., pp. 417–450). Academic Press. https://doi.org/10.1016/B978-012109890-2/50042-1.

Boekaerts, M., Maes, S., & Karoly, P. (2005). Self-regulation across domains of applied psychology: Is there an emerging consensus? *Applied Psychology, 54*(2), 149–154. https://doi.org/10.1111/j.1464-0597.2005.00201.x.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning. *Review of Educational Research, 65*(3), 245–281.

Cleary, T. J. (2011). Emergence of self-regulated learning microanalysis: Historical overview, essential features, and implications for research and practice. In D. H. Schunk & B. Zimmerman (Eds.), *Handbook of self-regulation of learning and performance* (1st ed., pp. 329–345). Routledge. https://doi.org/10.1037/t09161-000.

Cleary, T. J., & Zimmerman, B. J. (2012). A cyclical self-regulatory account of student engagement- Theoretical foundations and applications. In S. L. Christenson, A. Wylie, & C. Reschly (Eds.), *Handbook of Research on Student Engagement* (pp. 237–257). Springer Science+Business Media. https://doi.org/10.1007/978-1-4614-2018-7.

Corno, L., & Mandinach, E. B. (1983). The role of cognitive engagement in classroom learning and motivation. *Educational Psychologist, 18*(2), 88–108 https://doi.org/10.1080/00461528309529266.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 671–684. https://doi.org/10.1016/S0022-5371(72)80001-X.

D'Mello, S., Dieterle, E., & Duckworth, A. (2017). Advanced, analytic, automated (AAA) measurement of engagement during learning. *Educational Psychologist, 52*(2), 104–123. https://doi.org/10.1080/00461520.2017.1281747.

Dinsmore, D. L., & Alexander, P. A. (2012). A critical discussion of deep and surface processing: What it means, how it is measured, the role of context, and model specification. *Educational Psychology Review, 24*(4), 499–567. https://doi.org/10.1007/s10648-012-9198-7.

Dole, J. A., & Sinatra, G. M. (1998). Reconceptalizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*(2/3), 109–128. https://doi.org/10.1080/00461520.1998.9653294.

Dweck, C. S., & Leggett, E. L. (1988). A social cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256–273. https://doi.org/10.1037/0033-295X.95.2.256.

Eccles, J. S. (2016). Engagement: Where to next? *Learning and Instruction, 43*, 71–75. https://doi.org/10.1016/j.learninstruc.2016.02.003.

Efklides, A. (2011). Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model. *Educational Psychologist, 46*(1), 6–25. https://doi.org/10.1080/00461520.2011.538645.

Finn, J. D., & Zimmer, K. S. (2012). Student engagement: What is it? Why does it matter? In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 97–131). Springer Science+Business Media. https://doi.org/10.1007/978-1-4614-2018-7_5.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109. https://doi.org/10.3102/00346543074001059.

Furlong, M. J., & Christenson, S. L. (2008). Engaging students at school and with learning: A relevant construct for all students. In *Psychology in the Schools* (Vol. 45, Issue 5, pp. 365–368). https://doi.org/10.1002/pits.20302

Goh, C., & Zeng, Y. (2014). How learners' engagement in a self-regulated learning program affected their listening development differently. In *Proceedings - IEEE 14th International Conference on Advanced Learning Technologies, ICALT 2014* (pp. 469–473). https://doi.org/10.1109/ICALT.2014.139.

Gonzalez, A., Rodriguez, Y., Failde, J. M., & Carrera, M. V. (2016). Anxiety in the statistics class: Structural relations with self-concept, intrinsic value, and engagement in two samples of undergraduates. *Learning and Individual Differences, 45*, 214–221. https://doi.org/10.1016/j.lindif.2015.12.019.

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections from over 20 years of research. *Educational Psychologist, 50*(1), 14–30. https://doi.org/10.1080/00461520.2014.989230.

Greene, B. A., Miller, R. B., Crowson, H. M., Duke, B. L., & Akey, K. L. (2004). Predicting high school students' cognitive engagement and achievement: Contributions of classroom perceptions and motivation. *Contemporary Educational Psychology, 29*(4), 462–482. https://doi.org/10.1016/j.cedpsych.2004.01.006.

Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (1st ed., pp. 65–84). Routledge. https://doi.org/10.1027/1016-9040/a000226.

Helme, S., & Clarke, D. (2001). Identifying cognitive engagement in the mathematics classroom. *Mathematics Education Research Journal, 13*(2), 133–153.

Horner, S. L., & Shwery, C. S. (2002). Becoming an engaged, self-regulated reader. *Theory Into Practice, 41*(2), 102–109.

Jarvela, S., Jarvenoja, H., Malmberg, J., Isohatala, J., & Marta, S. (2016). How do types of interaction and phases of self-regulated learning set a stage for collaborative engagement? *Learning and Instruction, 43*, 39–51. https://doi.org/10.1016/j.learninstruc.2016.01.005.

Li, S., Lajoie, S. P., Zheng, J., Wu, H., & Cheng, H. (2021). Automated detection of cognitive engagement to inform the art of staying engaged in problem-solving. *Computers & Education, 163*, 104114. https://doi.org/10.1016/j.compedu.2020.104114.

Linnenbrink, E. A. (2005). The dilemma of performance-approach goals: The use of multiple goal contexts to promote students' motivation and learning. *Journal of Educational Psychology, 97*(2), 197–213. https://doi.org/10.1037/0022-0663.97.2.197.

Mandinach, E. B., & Corno, L. (1985). Cognitive engagement variations among students of different ability level and sex in a computer problem solving game 1. *Sex Roles, 13*(3-4), 241–251.

Miller, B. W. (2015). Using reading times and eye-movements to measure cognitive engagement. *Educational Psychologist, 50*(1), 31–42. https://doi.org/10.1080/00461520.2015.1004068.

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology, 8*(APR), 1–28. https://doi.org/10.3389/fpsyg.2017.00422.

Pardo, A., Han, F., & Ellis, R. A. (2017). Combining university student self-regulated learning indicators and engagement with online learning events to predict academic performance. In *IEEE Transactions on Learning Technologies* (Vol. 10, Issue 1, pp. 82–92). https://doi.org/10.1109/TLT.2016.2639508

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (1st ed., pp. 451–502). Academic Press. https://doi.org/10.1016/B978-012109890-2/50043-3.

Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review, 16*(4), 385–407. https://doi.org/10.1007/s10648-004-0006-x.

Pintrich, P. R., & de Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33–40. https://doi.org/10.1037/0022-0663.82.1.33.

Pintrich, P. R., & Schauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom tasks. In D. H. Schunk & J. L. Meece (Eds.), *Student perceptions in the classroom: Causes and consequences* (1st ed., pp. 149–183). Lawrence Erlbaum Associates, Inc..

Pizzimenti, M. A., & Axelson, R. D. (2015). Assessing student engagement and self-regulated learning in a medical gross anatomy course. *Anatomical Sciences Education, 8*(2), 104–110. https://doi.org/10.1002/ase.1463.

Puustinen, M., & Pulkkinen, L. (2001). Models of self-regulated learning: A review. *Scandinavian Journal of Educational Research, 45*(3), 269–286. https://doi.org/10.1080/00313830120074206.

Rotgans, J. I., & Schmidt, H. G. (2011). Cognitive engagement in the problem-based learning classroom. *Advances in Health Sciences Education, 16*(4), 465–479. https://doi.org/10.1007/s10459-011-9272-9.

Schunk, D. H., & Greene, J. A. (2017). Historical, contemporary, and future perspectives on self-regulated learning and performance. In P. A. Alexander, D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 1–15). Routledge. https://doi.org/10.4324/9781315697048-1.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist, 50*(1), 1–13. https://doi.org/10.1080/00461520.2014.1002924.

Winne, P. H. (2010). Improving measurements of self-regulated learning. *Educational Psychologist, 45*(4), 267–276. https://doi.org/10.1080/00461520.2010.517150.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Taylor & Francis. https://doi.org/10.1016/j.chb.2007.09.009.

Wolters, C. A., & Taylor, D. J. (2012). A self-regulated learning perspective on student engagement. In S. L. Christenson, A. Wylie, & C. Reschly (Eds.), *Handbook of research on student engagement* (pp. 635–651). Springer Science+Business Media). https://doi.org/10.1007/978-1-4614-2018-7.

Wouters, A., Croiset, G., Schripsema, R. N., Cohen-Schotanus, J., Spaai, W. G., Hulsman, L. R., & Kusurkar, A. R. (2017). A multi-site study on medical school selection, performance, motivation and engagement. *Advances in Health Sciences Education, 22*(2), 447–462.

Zeidner, M. (2019). Self-regulated learning: Current fissures, challenges, and directions for future research. *High Ability Studies, 30*(1–2), 255–276.

Zimmerman, B. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-Regulation* (1st ed., pp. 13–39). Academic Press. https://doi.org/10.1016/B978-012109890-2/50031-7.

Zusho, A. (2017). Toward an integrated model of student learning in the college classroom. *Educational Psychology Review, 29*(2), 301–324. https://doi.org/10.1007/s10648-017-9408-4.

Shan Li. Department of Educational and Counselling Psychology, McGill University, B148, 3700 McTavish St, Education Building, Montreal, QC, Canada. E-mail: shan.li2@mail.mcgill.ca

Susanne P. Lajoie. Department of Educational and Counselling Psychology, McGill University, Montreal, QC, Canada

Current themes of research:

Self-regulated learning. Student engagement. Achievement motivation. Learning analytics.

Most relevant publications in the field of Psychology of Education:

Li, S., Zheng, J., & **Lajoie, S. P.** (2020). The relationship between cognitive engagement and students' performance in a simulation-based training environment: An information-processing perspective. *Interactive Learning Environments*. 1–14.

Li, S., Du, H., Xing, W., Zheng, J., Chen, G., & Xie, C (2020). Examining temporal dynamics of self-regulated learning behaviors in STEM learning: A network approach. *Computers and Education*. 158, 103987.

Li, S., Chen, G., Xing, W., Zheng, J., & Xie, C (2020). Longitudinal clustering of students' self-regulated learning behaviors in engineering design. *Computers and Education*, 153, 103899.

Zheng, J., Huang, L., **Li, S.**, **Lajoie, S.**, Chen Y., Hmelo-Silver, C. (2020). Self-regulation and emotion matter: A case study of instructor interactions with a learning analytics dashboard. *Computers and Education*. 161, 104061.

Li, S., Zheng, J., & Chiang, F. (2021). Examining the effects of digital devices on students' learning performance and motivation in an enhanced one-to-one environment: A longitudinal perspective. *Technology, Pedagogy and Education.*

Huang, L., **Li, S.**, Poitras, E. G., **& Lajoie, S. P**. (2021). The role of preservice teachers' metacognitive processes in technology integration. *British Journal of Educational Technology, 52*(2), 695–713.

Zheng, J., Xing, W., Huang, X., **Li, S.**, Chen, G., & Xie, C. (2020). The role of self-regulated learning on science and design knowledge gains in engineering projects. *Interactive Learning Environments.*1–13.

Wu, H., **Li, S.***, Zheng, J., & Guo, J. (2020). Medical students' motivation and academic performance: The mediating roles of self-efficacy and learning engagement. *Medical Education Online*, 25 (1), 1–9.

Zheng, J., **Li, S.**, & **Lajoie, S. P.** (2019). The role of achievement goals and self-regulated learning behaviors in clinical reasoning. *Technology, Knowledge and Learning*. 1–16.

Lajoie, S. P., Zheng, J., **Li, S.**, Jarrell, A. & Gube, M. (2019). Examining the interplay of affect and self regulation in the context of clinical reasoning. *Learning and Instruction,* 101219.

Li, S. & Zheng, J. (2018). The relationship between self-efficacy and self-regulated learning in one-to-one computing environment: The mediated role of task values. *The Asia-Pacific Education Researcher, 27*(6), 455–463.

Lajoie, S. P., Zheng, J., & **Li, S.** (2018). Examining the role of self-regulation and emotion in clinical reasoning: Implications for developing expertise. *Medical Teacher*, *40*(8), 842–844.