

2nd Edition

Handbook of Self-Regulation of Learning and Performance

Edited by
Dale H. Schunk and
Jeffrey A. Greene



**Handbook of Self-Regulation of Learning and
Performance**

The second edition of the popular *Handbook of Self-Regulation of Learning and Performance* responds to and incorporates the wealth of new research that the first edition inspired on the subject. At the same time, it advances meaningful perspectives on the scholarship and history that originally shaped the field. Divided into five major sections—basic domains, context, technology, methodology and assessment, and individual and group differences—this thoroughly updated handbook addresses recent theoretical refinements and advances in instruction and intervention that have changed approaches to developing learners’ capabilities to self-regulate in educational settings. Chapters written by leading experts in the field include discussions of methodological advances and expansions into new technologies and the role of learner differences in such areas as contexts and cultures. As a comprehensive guide to a rapidly evolving and increasingly influential subject area, this volume represents contemporary and future thinking in self-regulation theory, research, and applications.

- **Chapter Structure**—To ensure uniformity and coherence across chapters, each chapter author addresses the theoretical ideas underlying their topic, research evidence bearing on these ideas, future research directions, and implications for educational practice.
- **Global**—A significant number of international contributors are included to reflect the increasingly international research on self-regulation.
- **Readable**—In order to make the book accessible to students, chapters have been carefully edited for clarity, conciseness, and organizational consistency.
- **Expertise**—All chapters are written by leading researchers who are highly regarded experts on their particular topics and are active contributors to the field.

Dale H. Schunk is Professor in the Department of Teacher Education and Higher Education in the School of Education at the University of North Carolina at Greensboro, USA.

Jeffrey A. Greene is Associate Professor in the Learning Sciences and Psychological Studies program in the School of Education at the University of North Carolina at Chapel Hill, USA.

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Contributors

Roger Azevedo, Professor, Department of Psychology, North Carolina State University, USA.

Ryan S. Baker, Associate Professor of Education, Graduate School of Education, University of Pennsylvania, USA.

Maria Bannert, Professor of Teaching and Learning with Digital Media, School of Education, Technical University of Munich, Germany.

Héfer Bembenuity, Associate Professor, Department of Secondary Education and Youth Services, Queens College, The City University of New York, USA.

Matthew L. Bernacki, Associate Professor, Department of Educational Psychology and Higher Education, University of Nevada, Las Vegas, USA.

Gautam Biswas, Professor of Computer Science and Education, Department of Electrical Engineering and Computer Science, Vanderbilt University, USA.

Victoria Brown, MA, Department of Counseling and Clinical Psychology, Teachers College Columbia University, USA.

Deborah L. Butler, Professor, Department of Educational and Counselling Psychology and Special Education, University of British Columbia, Canada.

Gregory L. Callan, Assistant Professor, Department of Educational Psychology, Ball State University, USA.

Sylvie C. Cartier, Professor, Department of Educational Psychology and Andragogy, University of Montreal, Canada.

Peggy P. Chen, Associate Professor, Department of Educational Foundations & Counseling Programs, and Co-Founder, Master's Program in Educational Psychology, Hunter College, The City University of New York, USA.

Timothy J. Cleary, Associate Professor, Chair, Department of Applied Psychology, School Psychology Program, Rutgers, The State University of New Jersey, USA.

Dana Z. Copeland, Doctoral Student, Department of Curriculum and Instruction, The University of North Carolina at Chapel Hill, USA.

Deborah B. Corbato, Senior Associate Athletic Director, Performance, Well-Being and Risk Management, George Mason University, USA.

Anique B. H. de Bruin, Associate Professor of Educational Psychology, School of Health Professions Education, Maastricht University, The Netherlands.

Erik De Corte, Emeritus Professor of Educational Psychology, Center for Instructional Psychology and Technology, University of Leuven, Belgium.

Victor M. Deekens, Doctoral Student, School of Education, The University of North Carolina at Chapel Hill, USA.

Amy L. Dent, College Fellow, Department of Psychology, Harvard University, USA.

Maria K. DiBenedetto, Science Department Chair and Teacher, Bishop McGuinness Catholic High School, USA.

Anastasia Efklides, Professor Emerita, School of Psychology, Aristotle University of Thessaloniki, Greece.

Paul Evans, Senior Lecturer, Educational Psychology Research Group, School of Education, The University of New South Wales, Australia.

Eleftheria N. Gonida, Associate Professor of Educational Psychology and Human Development, School of Psychology, Aristotle University of Thessaloniki, Greece.

Steve Graham, Warner Professor, Division of Educational Leadership and Innovation, Arizona State University, USA.

Jeffrey A. Greene, Associate Professor, School of Education, The University of North Carolina at Chapel Hill, USA.

Allyson Hadwin, Associate Professor, Technology Integration and Evaluation Research Lab, Department of Educational Psychology and Leadership Studies, University of Victoria, Canada.

Karen R. Harris, Warner Professor, Division of Educational Leadership and Innovation, Arizona State University, USA.

Rick H. Hoyle, Professor, Department of Psychology and Neuroscience, Duke University, USA.

Lynda R. Hutchinson, Assistant Professor, Department of Psychology, King's University College at Western University, Canada.

Sanna Järvelä, Professor, Learning and Educational Technology Research Unit, Department of Educational Sciences, University of Oulu, Finland.

Stuart A. Karabenick, Research Professor, Combined Program in Education and Psychology, University of Michigan, USA.

Maria Kavussanu, Senior Lecturer, School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, UK.

Ronnel B. King, Assistant Professor, Department of Curriculum and Instruction, The Education University of Hong Kong, Hong Kong.

Anastasia Kitsantas, Professor, Program in Educational Psychology, George Mason University, USA.

Bracha Kramarski, Associate Professor of Education, Department of Education, University of Bar Ilan at Ramat-Gan, Israel.

Susanne P. Lajoie, Professor and Canadian Research Chair, Department of Educational and Counselling Psychology, McGill University, Canada.

Elina Määttä, Head of Educational Programs, Turku Complex Systems Institute, Vancouver, Canada.

Charles MacArthur, Professor, School of Education, University of Delaware, USA.

Linda H. Mason, Professor and Endowed Director, Helen A. Keller Institute for Human Disability, Division of Special Education and Disability Research, George Mason University, USA.

Dennis M. McInerney, Professor of Educational Psychology, Department of Special Education and Counselling, The Education University of Hong Kong, Hong Kong.

Gary E. McPherson, Ormond Professor and Director, Melbourne Conservatorium of Music, The University of Melbourne, Australia.

Zemira R. Mevarech, President and Professor of Education, David Yellin Academic College of Education, Israel.

Peter Miksza, Associate Professor of Music, Music Education Department, Jacobs School of Music, Indiana University, USA.

Mariel Miller, Manager, Department of Technology Integrated Learning, University of Victoria, Canada.

Daniel C. Moos, Associate Professor of Education, Department of Education, Gustavus Adolphus College, USA.

Nicholas V. Mudrick, Graduate Student, Department of Psychology, North Carolina State University, USA.

Krista R. Muis, Associate Professor and Canada Research Chair in Epistemic Cognition and Self-Regulated Learning, Department of Educational and Counselling Psychology, McGill University, Canada.

John L. Nietfeld, Professor of Education, Teacher Education and Learning Sciences, North Carolina State University, USA.

Luc Paquette, Assistant Professor of Education, Department of Curriculum and Instruction, University of Illinois at Urbana-Champaign, USA.

Nancy E. Perry, Professor of Education, Dorothy Lam Chair in Special Education, Department of Educational and Counselling Psychology and Special Education, University of British Columbia, Canada.

Eric G. Poitras, Assistant Professor of Instructional Design and Educational Technology, Department of Educational Psychology, University of Utah, USA.

Robert Reid, Emeritus Professor, Special Education and Communication Disorders, University of Nebraska-Lincoln, USA.

Peter Reimann, Professor of Education, Sydney School of Education and Social Work, Sydney University, Australia.

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Historical, Contemporary, and Future Perspectives on Self-Regulated Learning and Performance

Dale H. Schunk and Jeffrey A. Greene

Recent years have seen tremendous advances in theory development, research, and practice relevant to the field of the self-regulation of learning and performance in educational settings. As used in this volume, self-regulation refers to the ways that learners systematically activate and sustain their cognitions, motivations, behaviors, and affects, toward the attainment of their goals. The distinction between self-regulation of learning and self-regulation of performance is that in the former the goals involve learning.

As this volume makes clear, there are numerous theoretical perspectives on self-regulation that have relevance to educational settings. Regardless of perspective, however, these perspectives share common features. One feature is that self-regulation involves being behaviorally, cognitively, metacognitively, and motivationally active in one's learning and performance (Zimmerman, 2001). Second, goal setting and striving trigger self-regulation by maintaining students' focus on goal-directed activities and the use of task-relevant strategies (Sitzmann & Ely, 2011). Goals that include learning skills and improving competencies result in better self-regulation than those oriented toward simply completing tasks (Schunk & Swartz, 1993). A third common feature is that self-regulation is a dynamic and cyclical process comprising feedback loops (Lord, Diefendorff, Schmidt, & Hall, 2010). Self-regulated learners set goals and metacognitively monitor their progress toward them. They respond to their monitoring, as well as to external feedback, in ways they believe will help them attain their goals, such as by working harder or changing their strategies. Goal attainment leads to setting new goals. Fourth, there is an emphasis on motivation, or why persons choose to self-regulate and sustain their efforts. Motivational variables are critical for learning, and can affect students' likelihood of pursuing or abandoning goals (Schunk & Zimmerman, 2008). Lastly, emotions play a key role in both directing self-regulation as well as in maintaining energy to attain goals (Efklides, 2011).

Since the first edition of the Handbook of Self-Regulation of Learning and Performance (Zimmerman & Schunk, 2011), many exciting developments in the field of self-regulation have occurred. But the purpose of this second edition remains the same as that of the first: to provide readers with self-regulation theoretical models, principles, research findings, and practical applications to educational settings. To accomplish this purpose, we have assembled an outstanding group of scholars to contribute chapters. The Handbook is divided into five major sections: basic domains, context, technology, methodology and assessment, and individual and group differences. As a means of promoting some consistency across chapters, we have asked contributors to address four major topics in their chapters: key theoretical ideas, pertinent research evidence, future research directions, and implications of theory and research for educational practice. We believe that this organization of topics and consistency across chapters will assist readers' understanding of the important topics discussed.

New developments are outlined in all five sections of this Handbook. For example, since the last Handbook, theoretical refinements have been proposed, new instructional issues have arisen as researchers apply self-regulated learning outside of traditional educational learning settings, advances in instruction and intervention have changed approaches to developing learners' capabilities to self-regulate, methodological advances have been developed, tested, and implemented, and researchers have expanded their investigation of the role of learner differences in such areas as contexts and cultures. This second edition not only updates developments since the first edition but also reflects new directions in the field.

In this introductory chapter, we address key historical, contemporary, and future developments in the field. We also briefly summarize the chapters that follow, and identify important directions for future research. The next section discusses historical perspectives on self-regulation of learning and performance in educational contexts.

Historical Perspectives

The impetus for studying self-regulation in educational settings arose from diverse sources (Zimmerman & Schunk, 2011). Beginning in the 1970s, cognitive-behavioral researchers studied how to improve students' self-control (e.g., control of impulsivity) and thereby their academic learning. Cognitive-behavioral methods were implemented in interventions and included the use of self-instruction and self-reinforcement. From this perspective, self-regulation comprised ways individuals controlled the antecedents and consequences of their behaviors, as well as their overt reactions such as feelings of anxiety (Thoresen & Mahoney, 1974). Self-instruction, which included learners' modeled verbalizations and behaviors, followed by guided practice and the fading of verbalizations to a covert level, was shown to be effective in promoting students' task focus and achievement (Meichenbaum & Asarnow, 1979).

Another group of researchers approached self-regulation from a cognitive-developmental perspective. Although young children show genetic differences in their behavioral control, with development language plays a greater role in self-regulation. Vygotsky (1962) postulated a developmental account in which the speech of others in children's environments is internalized (i.e., adopted as their own) and then assumes a covert self-directive function (Diaz, Neil, & Amaya-Williams, 1990). A key conceptualization is the zone of proximal development, which describes how higher levels of functioning can be achieved with support (i.e., scaffolding) from others. Language becomes internalized in the zone of proximal development and assumes a self-regulatory role.

Another developmental topic relevant to self-regulation is delay of gratification (Zimmerman & Schunk, 2011). With development, children can better resist immediate rewards in favor of greater rewards associated with time delays (Mischel, 1961). Delay of gratification is important for self-regulation because it allows learners to set and pursue challenging but rewarding distal goals, and effectively cope with potential briefly-gratifying distractions and instead focus on learning tasks.

A third group of researchers examined metacognitive and cognitive issues (Zimmerman & Schunk, 2011). These researchers showed that students could be taught task strategies that improved their academic performances, although maintenance and transfer of the strategies over time and to new tasks often were all too rare (Pressley & McCormick, 1995). Simply teaching strategies did not guarantee their use. Researchers examined ways to promote strategy use such as by informing students of the effectiveness of the strategies and showing them how use of the strategies improved their performances (Schunk & Rice, 1987). Metacognitive knowledge and skills were also viable targets for instruction. This research revealed that, in addition to cognitive and metacognitive skills, motivation also is necessary to promote self-regulation (Schunk & Zimmerman, 2008).

Social cognitive researchers explored social and motivational influences on self-regulation. In Bandura's (1986) theory, self-regulation involves three phases: self-observation, self-judgment, and self-reaction. During self-observation learners monitor aspects of their performances; self-judgment involves students comparing their performances against standards; and self-reactions include their feelings of self-efficacy (i.e., perceived capabilities) and affective reactions to their performances (e.g., satisfaction). Social cognitive researchers showed that instructional processes such as modeling conveyed information to learners about their learning progress and raised their self-efficacy and task motivation (Schunk, 2012).

The research described in this section was conducted by different researchers operating in different domains. Despite this diversity, however, these research findings, combined with symposia at major conferences (e.g., American Educational Research Association in 1986), gave rise to the perceived need for integrated perspectives

on self-regulation. This integration set the stage for researchers to systematically explore self-regulatory processes in educational contexts.

Self-Regulation Research in Education

It is not possible to put an exact date on when systematic efforts began to explore the self-regulation of learning and performance in educational settings, but by the 1980s integrated models were being advanced and research on self-regulation was increasing (Zimmerman, 1986). The time from the mid-1980s to the present can be roughly divided into three periods, each characterized by dominant theoretical, empirical, and practical issues. This categorization runs the risk of oversimplifying, and we are not implying that the model listed for each period was the only one employed. Clearly many research issues were addressed in each period. The periods also do not neatly demarcate; there are overlaps. But this categorization summarizes the dominant issues of these periods, which we label the periods of development, intervention, and operation.

Period of Development

The period of development began in the 1980s and stretched well into the 1990s. During this time, researchers were highly interested in developing theories to guide research and methodologies to employ in that research. Theories reflecting the cognitive-behavioral, social cognitive, cognitive-metacognitive, social constructivist, and cognitive-developmental research traditions were formulated and refined.

As shown in [Figure 1.1](#), the period of development was characterized by a research model that emphasized the relation of self-regulation to outcomes such as achievement beliefs, affects, and behaviors (Model 1). Many researchers investigated which self-regulation processes students used and how this use related to outcomes. These early studies often involved self-report instruments such as questionnaires or interviews to determine the types of processes that students reported they employed, as well as how often they reported their use and in which contexts (Schunk, 2013). Commonly used instruments were the Motivated Strategies for Learning Questionnaire or MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1991, 1993) and the Learning and Study Strategies Inventory or LASSI (Weinstein, Palmer, & Schulte, 1987). These and other instruments, which displayed strong psychometric qualities, served to operationalize self-regulation processes.

A representative study from this era was conducted by Zimmerman and Martinez-Pons (1990) with students in regular and gifted classes in grades five, eight, and eleven. Using a structured interview, students were presented with scenarios such as, “When taking a test in school, do you have a particular method for obtaining as many correct answers as possible?” (Zimmerman & Martinez-Pons, 1990, p. 53). For each scenario, students described the methods they would use. Their responses were recorded and categorized into ten categories such as self-evaluating, goal setting and planning, rehearsing and memorizing, and reviewing. Results revealed that students in gifted classes reported using more self-regulatory strategies than regular-education students and that the frequency of strategy use increased with grade level.

There were many accomplishments during this period of development. Researchers refined theories and research methodologies to fit educational contexts, identified key self-regulation processes in those contexts, and drew implications of their research findings for educational policies and practices. At the same time, however, there were some issues. Self-report instruments captured students’ perceptions of their self-regulation at a given time but were limited in their ability to capture self-regulation’s defining dynamic and cyclical nature; that is, how learners change and adapt self-regulation processes while they are engaged in learning in response to their perceived progress and to changing conditions. And because much of the research conducted was correlational, causal conclusions could not be drawn, which meant that researchers could not conclude that self-regulation helped to promote achievement outcomes.

Model 1: Self-Regulated Learning → Achievement Outcomes

Model 2: Intervention → Self-Regulated Learning → Achievement Outcomes

Model 3: Self-Regulated Learning ↔ Achievement Outcomes

[Figure 1.1](#) Research paradigms commonly used in self-regulation research in education

Period of Intervention

The period of intervention stretched roughly from the late 1980s through the 1990s and into the 2000s. During this time, researchers investigated how to teach students self-regulation processes, how students used them, how their use influenced achievement outcomes, and whether their use was moderated by other variables such as learners' abilities and context (e.g., individual differences, culture). The research model reflected this causal sequence ([Figure 1.1](#), Model 2): Interventions were predicted to influence self-regulation, which in turn affected achievement outcomes. For example, researchers might administer a pretest to assess students' skills and self-regulatory processes, and then introduce an intervention in which students were taught self-regulation strategies and then practiced applying them. Follow-up assessments determined whether treatment students applied the strategies with more frequency or quality than control students, and how self-regulation strategy use related to achievement outcomes.

This methodology is illustrated in a study by Schunk and Swartz (1993). Fourth and fifth graders were taught a multi-step strategy for writing different types of paragraphs. They were pretested on self-efficacy for paragraph writing, writing achievement, and self-reported use of the strategy's steps when they wrote paragraphs. They received modeling, guided practice, and independent practice on applying the strategy to write paragraphs. Children were given either (a) a goal of learning to use the strategy to write paragraphs, (b) an outcome goal of writing paragraphs, (c) a learning goal plus feedback during the sessions linking their performance with strategy use, or (d) a general goal of doing their best. Participants were tested after the intervention, as well as six weeks later with no intervening strategy instruction. In addition, a maintenance test was given where children verbalized aloud as they wrote a paragraph, with verbalizations recorded and scored for use of the strategy. The learning goal with feedback yielded the greatest benefits in terms of skill, self-efficacy, and strategy maintenance. The learning goal was more effective than the outcome and general goals.

Intervention studies captured some of the dynamic nature of self-regulation. They also could assess causality because they showed how students' self-regulation changed as a result of an intervention, with some designs allowing data collection while the intervention was ongoing. But most interventions of this period did not assess real-time changes reflecting self-regulation's dynamic nature, such as learners adapting their approaches while engaged in tasks. Such measures better reflect theoretical models that posit a continuous dynamic process.

Period of Operation

Investigators' desire to explore self-regulation in greater depth led to the period of operation, which began in the 1990s and continues today. Investigators explore the operation of self-regulation processes as learners employ them and relate moment-to-moment changes in self-regulation to changes in outcome measures. The general research model posits a reciprocal relation between self-regulation and achievement outcomes ([Figure 1.1](#), Model 3). Learners use self-regulation processes, monitor their levels of understanding and learning, and adapt processes as necessary in an ongoing manner to promote learning or accommodate to changing conditions. This research model captures both the dynamic and cyclical natures of self-regulation.

This research model requires different methodologies to capture the dynamic nature of self-regulation. New and refined methodologies emerged, broadened with the enhanced capabilities of technology. In addition to surveys and interviews, investigators increasingly employ such measures as think-aloud protocols, observations, traces, and microanalytic methods.

Think-aloud protocols involve learners overtly verbalizing their thinking while engaged in learning (Greene, Robertson, & Costa, 2011). Think-aloud protocols capture learners' verbalized cognitive processing and do not depend on their memories. Verbalizations typically are recorded and transcribed to allow for coding. Verbalizing is itself a task that may prove distracting to some learners who have not received an opportunity to practice, and it is important learners simply say what they are doing and thinking rather than explaining, as the latter can interfere with cognition (Ericsson & Simon, 1993).

Observations of students while engaged in learning can occur through video and audio recordings or by taking detailed notes. Video data can be annotated and audio data can be transcribed and coded to determine the types and extent of self-regulation processes. Observations in classrooms and other settings involving more than one participant allow researchers to determine the role that the social context might play in self-regulation.

Traces are observable measures of self-regulation that students create as they engage in tasks (Winne & Perry, 2000). For example, traces include marks students make in texts, such as when they underline, highlight, or write notes in margins. Traces can indicate students' use of self-regulatory processes such as planning and monitoring. Computer technologies have expanded the range of traces available. Researchers are able to collect measures of learners' eye movements, time spent on various aspects of material to be learned, and selections of self-regulation processes to use with content.

Microanalytic methods examine learners' behaviors and cognitions in real time as they engage in tasks (Cleary, 2011). Assessments administered to individual students may require them to respond to context-specific questions concurrently as they apply self-regulatory processes to tasks. These questions may tap several measures of self-regulation before, during, and after task engagement. Learners' responses may be recorded and scoring rubrics used to code the responses.

A representative study from the period of operation was conducted by Winne and Jamieson-Noel (2002), who collected trace measures of study strategies from undergraduates while they learned about lightning. Trace data were recorded by instructional software as students studied material. Traces recorded students' behaviors such as scrolling through text and opening windows. Students also completed a self-report measure of strategies used, and the trace data were matched as closely as possible to the self-report items such as those assessing planning a method for studying, creating a note, and reviewing objectives. The results showed that students tended to overestimate their use of study strategies, especially for planning a method for studying, highlighting, copying text verbatim into a note, and reviewing figures. For example, students reported having reviewed figures 26% more than traces indicated. At least for certain self-regulatory processes, students may not be cognizant of the frequency with which they employ them.

Research exploring the operation of self-regulatory processes addresses the dynamic and cyclical nature of self-regulation as an event that is subject to continuous change. Although assessments of the operation of self-regulation are more time-intensive than simply administering surveys, they capture processes as they occur and are not subject to forgetting or memory distortions. If measures of achievement outcomes also are collected concurrently with those of self-regulation processes, investigators can plot changes in self-regulation against those in achievement outcomes to track how processes affect outcomes.

Overview of the Handbook

As the preceding discussion makes clear, self-regulation researchers have used a variety of methods in conducting their research. These methods, and the underlying conceptual models that inform them, have led to robust fields of investigation into self-regulation of learning and performance in context (e.g., mathematics, music, technology), as well as studies of individual differences (e.g., age, culture, calibration accuracy) and their role in self-regulation. The chapters that follow represent contemporary and future thinking in self-regulation theory, research, and applications. In this section, we provide brief overviews of the major sections of the book and their associated chapters.

Section I: Basic Domains of Self-Regulation of Learning and Performance

The first section of this volume deals with five basic domains of self-regulated learning and performance: social cognitive, cognitive/metacognitive, developmental, motivation and emotion, and co-regulation and socially shared regulation. Although conceptualizations of self-regulation across these domains overlap to some degree, each chapter provides a unique perspective on self-regulation of learning and performance.

In [Chapter 2](#), Usher and Schunk describe self-regulation from the perspective of social cognitive theory. This theory highlights reciprocal relations between personal factors, environmental variables, and behaviors. Usher and Schunk describe a dynamic, cyclical model of self-regulation comprising three phases: forethought, performance, self-reflection. Importantly they also discuss a model for helping learners develop greater self-regulatory competence, progressing from initially social levels (i.e., observation, emulation) to self-levels (i.e., self-control, self-regulation).

Winne ([Chapter 3](#)) provides a further elaboration of his information-processing theoretical perspective on self-regulated learning. Drawing on prior formulations, he discusses the foundational cognitive processes of searching, monitoring, assembling, rehearsing, and translating, as well as phases of self-regulation. He also elucidates the five aspects of tasks: conditions, operations, products, standards, and evaluations (COPES). He identifies key challenges that learners face when using study strategies, as well as the ways multiple data channels can capture dynamic relations between cognitive, metacognitive, and motivational processes.

Hoyle and Dent present a developmental perspective on self-regulation in [Chapter 4](#). A major advantage of a developmental perspective is that it provides a mechanism for charting both normative and individual trajectories of self-regulatory development. They espouse viewing self-regulation through the lens of dynamic systems theory, which captures not only the dynamic nature of self-regulation but also its being situated in multiple levels of organization ranging from the individual to the broader culture.

Another basic domain encompasses motivation and emotion, the focus of [Chapter 5](#) by Efklides, Schwartz, and Brown. Using their conceptualization the Metacognitive and Affective Model of Self-Regulated Learning (MASRL), they highlight the dynamic interactions among motivation, metacognition, and affect. They focus particularly on metacognitive experiences and show how these prominently figure as antecedents of emotions.

In [Chapter 6](#), Hadwin, Järvelä, and Miller distinguish self-regulated learning from co-regulated learning and socially shared regulation of learning. The latter categories are especially important given the current emphasis

on collaborative learning in education. This chapter underscores the importance of the social context in conceptions of self-regulation, provides an organizing framework and set of definitions for this burgeoning area of research, and outlines implications for educational practice.

Section II: Self-Regulation of Learning and Performance in Context

The second section of the Handbook focuses on the adaptation of self-regulatory principles to investigate their effectiveness in specific contexts. The chapters in this section address the following contexts: mathematics, reading, writing, science, social studies, music, sport, educational standards and student learning outcomes, and teacher education.

Mathematics is a critical area for self-regulation because many students have difficulty with mathematics and effective use of self-regulatory processes can enhance their learning and achievement. In [Chapter 7](#), Mevarech, Verschaffel, and De Corte present a framework that heavily leverages metacognitive processes such as planning, monitoring, control, and reflection. Their chapter discusses how metacognitive pedagogies can assist students' mathematical reasoning and achievement.

The focus of [Chapter 8](#) is on reading. Thiede and de Bruin discuss a self-regulation model relevant to reading that stresses metacognitive monitoring. Their central thesis is that by improving their metacomprehension accuracy, students will improve their study decisions and in turn their reading performance. They review interventions that have the potential to raise the accuracy of comprehension monitoring at the text level.

[Chapter 9](#) covers the domain of writing. Graham, Harris, MacArthur, and Santangelo review two models of writing—a social context model and a writer-in-context model—as well as research on self-regulation in writing. The chapter covers in depth the Self-Regulated Strategy Development instructional approach, which researchers have shown to be highly effective in promoting students' self-regulation in writing, and their writing skills and achievement.

In [Chapter 10](#), Sinatra and Taasobshirazi cover self-regulation in science. They make a compelling case for self-regulation as a necessary component of proficiency in scientific tasks involving inquiry, reasoning, and problem solving. They also discuss self-regulatory connections to the key topic of conceptual change in science, and review research and assessment of self-regulation in science. Importantly, they also discuss the topic of emotion regulation, which is highly germane in science given that many topics are controversial and can trigger negative emotions in learners.

Fostering self-regulation in the social studies is the topic of [Chapter 11](#) by Poitras and Lajoie. They underscore its importance in social studies given that historical learning is dynamic and involves studying multiple sources of information, many of which may be in disagreement. Their chapter discusses how scaffolding can be integrated into technological learning environments to assist learners' development of historical reasoning competencies.

In [Chapter 12](#), McPherson, Miksza, and Evans discuss self-regulation in the context of music learning and performance. Music lends itself well to self-regulation because development of skill takes place over lengthy periods that are characterized by extensive practice and application of cognitive and motivational strategies. They illustrate their points by discussing the results of a 14-year longitudinal study of children and adolescents, as well as intervention studies with intermediate and advanced music learners.

Self-regulation of learning and performance in sports is the focus of [Chapter 13](#). Kitsantas, Kavussanu, Corbatta, and van de Pol utilize a social cognitive perspective and highlight how key self-regulatory processes come into play in sport learning and performance. They also devote a significant portion of the chapter to the role of coaches in the development of athletes' self-regulatory skills, including how coaches create a motivational climate and how that can influence sport learning and performance.

[Chapter 14](#) addresses how self-regulation links with standards-based education. White and DiBenedetto apply a social cognitive theoretical model to show how standards can be criteria that self-regulated learners use to evaluate their goal progress. Although the use of educational standards is common, there is not much research linking them with student learning or how application of self-regulatory processes can facilitate their attainment. An intent of this chapter is to encourage more research in this critical area.

The second section concludes with [Chapter 15](#), where the focus is on teachers; specifically, how they can become better self-regulated learners and how, in turn, they can promote self-regulation among their students. Kramarski describes a model for teacher training and presents strong evidence for the dynamic and reciprocal relation between teachers' self-regulated teaching and students' self-regulated learning. This chapter illustrates the important role of teachers in domain contexts as both models and facilitators of students' self-regulation.

Section III: Technology and Self-Regulation of Learning and Performance

Research on self-regulation and technology includes what kinds of knowledge and skills are needed to successfully utilize technology in the modern world and how technology systems can be designed to teach and foster self-regulation. In this section, chapter authors review the literature on the role of self-regulation in computer-based learning environments, intelligent tutoring systems and teachable agents, digital games, and computer-supported collaborative learning.

In [Chapter 16](#), Moos applies principles of self-regulation to the integration of technology with classroom instruction. He focuses on hypermedia, which contains design features that allow students to actively engage in learning. These design features require that students self-regulate their use, and students' success at doing so can predict how well learners engage in these types of environments. This research has implications for classroom practice because it suggests that the design of technological environments should be consistent with how students best learn in these environments.

Azevedo, Taub, and Mudrick explore real-time cognitive, affective, and metacognitive (CAM) processes that can help to promote self-regulation with advanced learning technologies such as intelligent tutoring systems ([Chapter 17](#)). They also discuss several challenges for researchers who attempt to capture and assess CAM processes. Using real-time measures is important because such fine-grained measures help to show how these processes change as learners engage in learning tasks.

The role of self-regulation in digital games—a rapidly expanding area of research—is addressed by Nietfeld in [Chapter 18](#). Integrating self-regulation in digital games holds great promise for assisting learners who use such games, and self-regulation can be a targeted outcome of educational digital games as well. This chapter presents a model for enhancing the research base. He also makes solid suggestions for how digital games can be meaningfully integrated into instruction to benefit teaching and learning.

The final chapter in this section, by Reimann and Bannert ([Chapter 19](#)), covers self-regulation in computer-supported collaborative learning environments. Collaboration is a timely topic that is drawing much educational interest and there is a clear need for more research on collaboration in technological environments. The authors explain and illustrate key concepts that are at work in collaboration, which involves both individual and group regulation processes, and how group awareness and representational guidance tools can foster these processes.

Section IV: Methodology and Assessment of Self-Regulation of Learning and Performance

This section examines methodological issues in assessing self-regulation of learning and performance such as reliability, validity, diagnostic value, and sensitivity to instruction. The chapters include task-adaptive measures of self-regulatory processes such as self-reports, think-aloud protocols, microanalysis, and case studies, as well

as other techniques common in studies of self-regulated learning and technology such as trace data, temporal or sequential data, and educational data mining.

Self-reports have been the most common form of assessment of self-regulated learning and their frequent use continues in current research. In [Chapter 20](#), Wolters and Won discuss the strengths and shortcomings of self-report questionnaires with particular emphasis on assessment issues such as validity. The authors offer recommendations for how to use self-report questionnaires effectively in self-regulation research.

Think-aloud protocols are the subject of [Chapter 21](#) by Greene, Deekens, Copeland, and Yu. These authors discuss several issues relevant to think-aloud protocols including ways to analyze these data and how they contribute to an understanding of the process whereby self-regulation develops and changes as learners engage in tasks. Think-aloud protocols hold strong potential for capturing, modeling, and instructing self-regulatory processing.

Microanalytic measures ([Chapter 22](#)) constitute another type of real-time measure leveraging both prompted and unprompted self-regulatory process data. Cleary and Callan discuss the utility of using microanalysis and how these measures relate to performance and other types of self-regulation measures. The value of microanalytic measures lies not only in their prediction of performance on multiple tasks but also in their relation to more global and distant outcomes.

Case studies ([Chapter 23](#)) offer another means of assessing self-regulation. Butler and Cartier describe the case study methodology and provide examples of case study research, showing how this methodology aligns well with situated views of self-regulation. They also address the challenges in using case studies and make a strong argument for how case studies can provide unique insights into self-regulatory processes and their operation as students are engaged in learning.

In recent years, the use of trace data has become more prevalent in research. In [Chapter 24](#), Bernacki discusses the potential of such data, which reflect temporal and contextual interactions between learners and their technology-enhanced environments. Traces can capture cognitive, metacognitive, motivational, and affective processes, and they reflect fine-grained changes in how self-regulation operates during learning.

Educational data mining techniques are the subject of [Chapter 25](#) by Biswas, Baker, and Paquette. They focus on various data mining methods: prediction modeling, sequence mining, clustering, feature engineering, and correlation mining. Collectively, these methods have great potential to leverage large datasets to enhance understanding of self-regulatory processes and lead to further theory development.

Section V: Individual and Group Differences in Self-Regulation of Learning and Performance

This section discusses individual and group differences in the self-regulation of learning and performance. The chapters focus on calibration and delay of gratification, resource management, epistemic cognition, young children, special needs, and culture.

In [Chapter 26](#), Chen and Bembenuddy discuss theory and research underlying calibration of performance and delay of gratification—two self-regulatory processes that learners engage in as they monitor their learning and goal progress. These authors discuss in depth the individual and group differences in these two processes, and underscore their educational importance for teaching and learning. These two processes also serve as critical pivots upon which self-regulation processes depend.

Help seeking is a key self-regulatory process, as substantiated by theory and research. Karabenick and Gonida ([Chapter 27](#)) discuss several aspects of help seeking relevant to self-regulation including when help seeking is most adaptive, personal and contextual factors that can affect help seeking, and how it can be promoted. They re-

conceptualize help seeking as a type of resource management that is relevant in both traditional and technology-assisted environments.

Epistemic cognition is the subject of [Chapter 28](#). Muis and Singh present a theoretical model that integrates epistemic cognition and self-regulated learning. Epistemic cognition, or how people think about knowledge, depends heavily upon self-regulatory processes for enactment and management. Muis and Singh discuss how epistemic knowledge and experiences can affect goals, strategies, and task engagement, and in turn, how self-regulatory activities may influence the development of epistemic thinking.

Self-regulation in young children is addressed in [Chapter 29](#) by Perry, Hutchinson, Yee, and Määttä. They outline how self-regulation is needed for successful participation in education environments, and how self-regulation of learning bolsters the results of that participation. The authors show that young children begin developing their self-regulatory capacities before they enter formal schooling, and how differences in self-regulatory functioning predict a variety of academic and interpersonal outcomes in education. They describe in detail interventions that help children develop these self-regulatory competencies.

Self-regulation with learners with special needs is the subject of [Chapter 30](#) by Mason and Reid. Learners with special needs often have difficulty with self-regulation, which results in academic, social, and behavioral problems. These authors summarize research highlighting ways that educators can help students with special needs learn skills and develop self-regulatory processes that can be used over time and on different tasks.

McInerney and King ([Chapter 31](#)) discuss the ways culture has and has not been addressed in self-regulatory research. They note that most research has been conducted in Western educational communities and that the results cannot be simply generalized to other cultures without first determining whether the principles and practices accurately capture self-regulation in those cultures. They argue for examining both the emic (i.e., culture-specific) and etic (i.e., universal) aspects when studying self-regulation and culture, and urge educators to examine whether Western principles and practices are culturally appropriate and meaningful.

Future Directions

As we noted earlier, in the future we expect that continued advancements in theory, research, and practice will be made in the major topic areas of this volume: basic domains, context, technology, methodology and assessment, and individual and group differences. The study of self-regulation of learning and performance in educational contexts is still young and there is much that needs to be investigated.

The chapters in this Handbook suggest some new directions where the field is heading. We do not reiterate these here, but rather we offer three points that we want to underscore as critical needs that cut across multiple subject areas. These points concern context and culture, real-time assessment, and advocacy for self-regulation as an educational skill.

Context and Culture

Early research was primarily conducted in traditional educational contexts (e.g., classrooms, laboratories), in Western cultures, and using standard content areas (e.g., mathematics, writing, reading). As the chapters in this Handbook make clear, the focus of self-regulation research has expanded greatly since that time. Multiple kinds of content have been addressed with learners in diverse cultures and settings.

We recommend continued expansion of research to such areas as internships, work experiences, and mentoring relationships. Many content areas have seen little research; more is needed in the areas of the visual and performing arts, athletics, and vocational programs. Out-of-school contexts are important. We recommend more research on homework and flipped classrooms, and during informal types of teaching and learning

Research is increasing among learners in non-Western cultures. This research must both leverage findings from the research literature while also allowing culture-specific definitions, principles, and practices to emerge. Such work is critical to understanding how self-regulation of learning and performance exists across cultures, and what that means for an understanding of how such processing develops, with and without intervention. Within cultures we recommend an increase in research on student populations that have not received that much attention, such as students living below the poverty line and homeless students. Fully understanding self-regulation requires attention to all who practice it, and attempts to foster self-regulation must take into account the unique circumstances of the target population.

Real-Time Assessment

A second point that we underscore is the need for more real-time assessment of self-regulation. Historically, most studies have used self-report questionnaires. These questionnaires constitute one source of data, but like all assessments they have strengths and weaknesses. Their ease of use and direct assessment of participants' understandings and beliefs are counterbalanced by concerns about participants' accuracy when making judgments pooled across different times and tasks. Such concerns are compounded when questionnaire data are collected only at a single point in time.

A growing emphasis in the field is on more real-time assessments that occur as individuals are engaged in learning. Real-time assessments have several advantages. They show how self-regulation actually operates as learners engage with content. They also, importantly, show how it changes over time and in response to changes in environmental conditions and as a function of changes in learners' judgments, knowledge, and skills. Real-time assessment methods also capture the notion highlighted in this and other chapters that self-regulation is a dynamic process that can change dramatically within and between learning tasks. Researchers and educators need a better understanding of these dynamic processes to revise theories, add to the research literature, and offer useful implications for teaching and learning.

Advocacy for Self-Regulation as an Essential Skill

The current volume makes it clear that self-regulation is an essential educational skill that influences motivation, learning, and achievement. While many educators tout the benefits of self-regulation, we find little evidence that these skills are explicitly being taught to students in a systematic or comprehensive way in formal educational environments. Ideally self-regulatory processing as both a method and an outcome would be incorporated into domain-specific instruction so that students understand how they can help to improve their learning in that domain, and understand how to extrapolate that learning to other aspects of their lives.

Our final recommendation is for greater advocacy of self-regulation as an essential educational skill. An important part of this advocacy will be found in teacher preparation and professional development programs. As teachers acquire content and pedagogical skills (i.e., what to learn), they also can be taught to use self-regulatory skills so that they understand how these skills come into play in the respective disciplines (i.e., how to learn). This will help foster their teaching of these skills to their students, as well as their using them to become better self-regulated teachers. We believe that such advocacy will benefit both teachers and students, and will help to maintain their academic motivation for continued learning.

Conclusion

Research on self-regulation of learning and performance in education has increased dramatically over the past several years. As we discuss in this chapter, perspectives on self-regulation cut across many domains involving social, cognitive, metacognitive, developmental, motivational, emotional, co-regulated, and socially shared regulation processes. Self-regulation researchers have investigated self-regulatory processes in multiple contexts using diverse methodologies. Researchers also have explored the role of different forms of technology as a means

of self-regulation and as a way to improve students' self-regulation. Research on individual and group differences in self-regulation continues to inform all of the other work reviewed in this Handbook.

The range of theoretical developments, research findings, and educational applications discussed in this volume is impressive. Collectively we believe that this volume is an important starting point for the future of research on self-regulation of learning and performance in education. The ongoing goal of this Handbook is to show how self-regulation is a critical component of learning and performance in achievement contexts. We find ourselves much better informed as a result of working on this volume, and we hope that readers find new, intriguing directions for their work as well. We are encouraged by the current state of the field and the bright future that lies ahead.

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2 Social Cognitive Theoretical Perspective of Self-Regulation

Ellen L. Usher and Dale H. Schunk

“Will you or won’t you have it so?” is the most probing question we are ever asked; we are asked it every hour of the day, and about the largest as well as the smallest, the most theoretical as well as the most practical, things.

(James, 1892/2001, p. 327)

This sentiment mirrors the parting message William James offered to schoolteachers at the conclusion of his series of talks on psychology in the late 1800s. For James, the capacity of the individual—when faced with myriad possibilities for and against action—to act or not to act, was the deciding force of human destiny. Over a century later, psychologist Albert Bandura (2016) made the same declaration in a slightly different way: “Through their contributing influence, people have a hand in shaping events and the courses their lives take” (p. 8).

The process of systematically organizing one’s thoughts, feelings, and actions to attain one’s goals is now commonly referred to as self-regulation. In this information-rich, fast-paced world, individuals are presented with many possible paths of thought and behavior, which can sometimes feel overwhelming. Whether we ultimately move in a healthy direction of growth depends on our ability to consider our options, put our stake in the ground, pay attention to where we go astray, and self-direct along the way. This self-regulatory repertoire enables us, at least in part, to shape our own life outcomes, and may be one of the most vital and influential components of our humanity, as James and Bandura asserted.

In this chapter, we offer the social cognitive view of self-regulatory influence in human functioning in general, and in academic functioning in particular, moored in the theorizing of Albert Bandura and Barry Zimmerman. We begin with an overview of social cognitive theory and examine the role of self-regulation within it. We next describe the three subfunctions of self-regulation, the cyclical nature of self-regulation and performance, and the development of self-regulation. We then review research evidence describing unique and combined effects of the cognitive, behavioral, motivational, emotional, social, and environmental components of self-regulation in learning and performance. The chapter concludes by offering directions for future research and implications for educational practice.

Social Cognitive Theory of Self-Regulation

According to social cognitive theory, human functioning is the result of the interacting influence of personal (e.g., biological, affective, cognitive), environmental, and behavioral factors (Bandura, 1986, 2001). What people do, how they feel, and what they think are not simply products of external influence and reinforcements, as behavioral theories have claimed (e.g., Skinner, 1987). Nor are people guided solely by internal hidden drives and impulses, as argued by psychodynamic theories (e.g., Freud, 1923/1960), nor simply by their own free choice, as many humanists have claimed. Personal, behavioral, and environmental factors are co-determinants of the human experience. The directions of causal influence are reciprocal and interactive. In school, students’ behaviors, including their level of self-regulation, are guided by both internal and external circumstances.

The ability to intentionally direct the course of events and circumstances in one’s life, and to choose one’s reaction to them, forms the foundation of human agency (Bandura, 2016). People exercise their agency through several core human capacities (Bandura, 2001). One is the capability to generate new thoughts. By selecting and attending to favorable thoughts rather than unfavorable ones, people can alter their internal environments, even if their

external environments are not optimal. Second, the capacity for forethought offers humans a means by which to plan, set goals, and imagine unrealized futures, all of which guide eventual behavior. Third, and central to self-regulation, is the capacity for self-reaction. When individuals recognize a wrong course of action, they can make needed adjustments. People compare their performance to their own and others' standards and refine their tactics. Finally, humans have developed a capacity for reflective self-consciousness. The ability to examine one's own actions, thoughts, and feelings before, during, and after performance enables people to influence their subsequent thoughts and behaviors. Indeed, at the heart of social cognitive theory is the self-system (i.e., cognitive structures for perceiving, evaluating, and comparing one's self; Bandura, 1978), which serves as a guide to regulate human behavior and functioning. Bandura (2016) has contended that "there is no self-view more personally devastating than self-loathing" (p. 29), and it is likely for this primary reason that self-regulatory processes are activated. Accordingly, it is chiefly the investment of one's self-regard that directs motivation and self-regulation.

Among the most influential of these self-reflective judgments is an evaluation of one's capabilities to reach desired attainments, or self-efficacy. Beliefs in one's personal efficacy to create the life one desires is a critical determinant of self-regulated behavior (Bandura, 1997; Schunk & DiBenedetto, 2014; Zimmerman, 2013). People who view themselves as capable set challenging goals for themselves, monitor their progress, and take appropriate corrective steps to ensure their own success. Learners with high self-efficacy are better self-regulated, think more positively, expect successful outcomes, and persevere when faced with difficulty. On the other hand, those who doubt their own efficacy are less motivated, feel that their efforts are futile, and give up easily (Schunk & DiBenedetto, 2014). In short, self-efficacy "is the foundation of human aspirations, motivation, and accomplishments" (Bandura, 2016, p. 5). We emphasize the important influence of this core belief in self-regulated learning.

Social cognitive theory also recognizes that the environments in which people live are partly under one's personal influence. Environments can be imposed, selected, and created (Bandura, 1986). For example, students spend a great deal of time in the imposed environment of school. Within the same imposed environment, however, students' experiences may vary widely according to their selected environment. By choosing to participate in certain classes, social groups, and activities, students have some leverage over their academic environments. This selected learning environment may have considerable influence over whether a student grows and succeeds or flounders and withdraws. Students can also create their learning environments by means of physical, social, or technological resources (e.g., social media). This self-constructed or self-tailored environment requires a high degree of agentic control.

Just because such students have the potential to exercise agentic capacities does not mean that they do so routinely or in all situations. In fact, many find too much self-control aversive and grow comfortable relegating many tasks to external controls (Bandura, 1986, 2016). Parents and teachers may wish that young people were more proactive in exercising their own agency, but unless students believe they can create more favorable circumstances for themselves by their own thoughts and actions, they may not internalize high standards and self-regulate to meet them. As we explore in the next sections, the development and function of a healthy self-regulatory repertoire requires great energy and cognitive, motivational, and emotional resources.

Self-Regulation Subfunctions

In social cognitive theory, self-regulated actions are developed and initiated as the product of three cognitive subfunctions: self-observation, self-judgment or self-evaluation, and self-reaction (Bandura, 1986; see [Figure 2.1](#)). Self-observation provides necessary information for self-directed change. When learners approach a new task, they must pay attention to their thoughts and behaviors. The capacity for intentional self-awareness is influenced by numerous factors, including one's emotional state, memory reconstruction, and pre-existing self-beliefs. Task demands and prior knowledge also relate to the degree to which one can attend to information relevant for self-improvement. The more complex a task, the higher the cognitive cost in attentional resources and working memory (Hoyle & Dent, 2018/this volume; Sweller, 2010). One's level of self-awareness provides

information needed for diagnosing problems when they arise, disrupting long-held habitual tendencies, and setting realistic standards and goals through self-motivation.

If being aware of one's self were enough to guarantee self-regulatory effectiveness, humans would be relieved of many hours of arduous effort. In fact, whether self-observation leads to changes in behaviors depends on a number of mediating factors. For example, as will be shown in Zimmerman's (2000) model of self-regulated learning, the timing of self-observation, whether before, during, and/or after an event, is important for whether self-initiated change will occur. Similarly, whether one feels that change is controllable or valued can determine whether change is attempted. An adolescent who spends hours gaming online may be aware of his own sedentary lifestyle but may not feel he has much control over his behaviors or value physical activity. One's motivation toward an activity also contributes to self-directed change. In short, self-observation alone is not reliably related to self-regulation (Bandura, 1986).

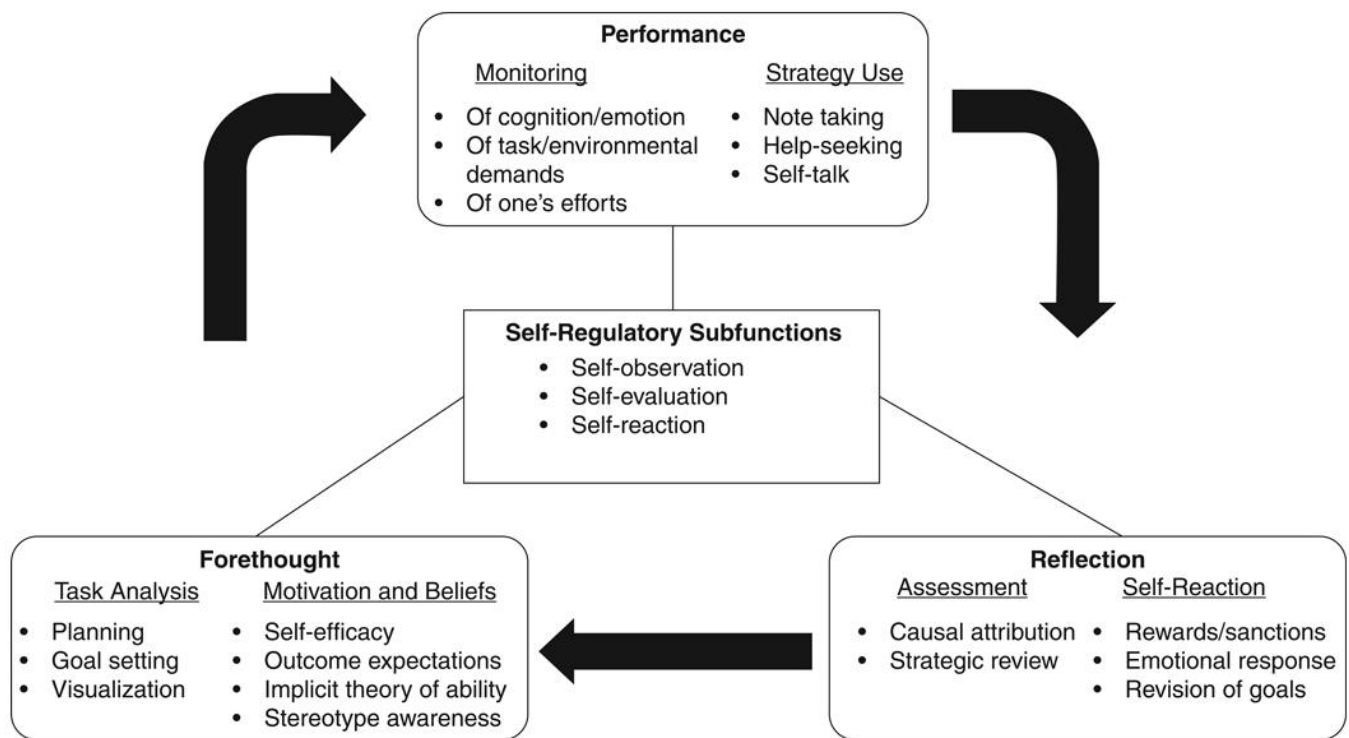


Figure 2.1 Subfunctions and cyclical nature of self-regulated learning

The second self-regulatory subfunction is self-evaluation. People judge themselves and their situations by comparing them to both external and internal standards. Where do those standards originate? There is no doubt that external standards can become the measuring stick against which people judge their thoughts and actions. The performance standards set by schools, parents, and society are conveyed both explicitly (e.g., cut-off scores for certain academic programs) and tacitly (e.g., social recognition conferred for meeting high expectations). Parents and teachers offer direct instruction of certain standards, hoping that children will reach them and even internalize them. Standards also are conveyed indirectly by social models. When a child sees her mom expecting nothing short of perfection, she may set the same self-standard and judge herself harshly.

Whether any performance standard is ultimately internalized depends on a number of factors (Bandura, 1986). When standards taught at home and at school are consistent and explicit, they often are internalized with ease. A teacher who sets clear standards of performance and who follows through with consistent feedback teaches young learners how to evaluate themselves independently. However, the complex social environments in which people live can propose contradictory ways of thinking and living. When these standards—whether imposed, modeled, or self-set—are in conflict with one another, a person may feel confused about how to act. Fortunately, people do

not behave like weathervanes, directed only by prevailing winds (Bandura, 1997). Because of their agentic capacity, they can evaluate themselves against standards that they have carefully weighed, judged, selected, or imagined, which makes self-regulatory influence not only possible but also powerful.

One's own self-modeled performances can also modify personal standards, hence the motivating power of "personal bests." Self-evaluation also depends on the degree to which a given activity is personally valued. Individuals routinely self-evaluate in areas of high personal investment and pay less attention to those they value little (Bandura, 1997). In most circumstances, one's self-set or internalized standards wield more self-regulatory influence because they affect one's self-system. On the other hand, "If adequate self-standards are lacking, people exercise little self-directedness" (Bandura, 1986, p. 363).

Self-regulated thought and action depend on one final subfunction: self-reactive influence. The capacity for reacting to one's thoughts, feelings, and actions enables people to direct their own lives. One way in which they learn to exercise self-reactive influence is to offer themselves tangible rewards contingent on their own desired performances. This is particularly important when external demands are weak or lacking, such as when an author decides to write a book or a runner sets off on a 10-mile course. The promise of a break, free time, or a delicious snack helps them push through difficulty and pursue their goals. The desire to maintain a positive self-regard in pursuit of one's goals can also mobilize self-regulatory power. People work harder and persist longer when their self-satisfaction depends on reaching personal standards (Bandura, 1986). Anticipation of positive self-evaluation can keep a person engaged for hours at a seemingly onerous task.

Cyclical Nature of Self-Regulation and Performance

Zimmerman (2000) proposed a cyclical model of self-regulation that takes place across three phases of learning: forethought, performance, and reflection (see [Figure 2.1](#)). Skilled self-regulators spend considerable time thinking and planning during the forethought phase prior to taking any action. It is in this initial phase that individuals analyze the task ahead and motivate themselves to act by what they believe about themselves and their situation. Task analysis involves considering what will be required for successful action, breaking down complex tasks into manageable components, and identifying the strategies that will be used to accomplish them. Beliefs about one's own efficacy, or inefficacy, to strategize and carry out planned activities influence the types of strategies an individual pursues, which in turn influence performance. Consequently, self-efficacy plays a key role in initiating and guiding behaviors. Unless people believe they have the capability of performing a given task, they will be unlikely to attempt it. People may assess their efficacy for a range of performance tasks during the forethought phase. For example, an adolescent might judge her capability to read and understand a lengthy 19th-century novel for her literature class (i.e., reading self-efficacy), but she might also evaluate whether she can allocate sufficient time and attention to read the long book (e.g., self-efficacy for self-regulation).

Other motivational tools are summoned during the forethought phase. People set goals for their performances that will serve to marshal their attention and energy during the performance phase. Goals can also affect whether students persist and how effectively they plan and prepare for the tasks they must perform (Locke & Latham, 2013). For instance, setting a goal of writing a research paper by the end of the semester might prompt a student to make an appointment with a librarian early in the semester, conduct background reading, and plan time for writing and revising. As we will later discuss, one's goals and reasons for engaging in an activity have implications for how one will manage performances—especially when setbacks occur. People also assess their interest in a topic and their expectations for success, both of which can lead to varying levels of subsequent performance. Forethought also permits people to visualize possible outcomes.

During the performance phase, self-regulation involves monitoring one's thoughts and behaviors within given performance contexts and selecting or modifying one's strategies. Self-monitoring involves observing one's thoughts, feelings, and actions and making adaptations when needed. While performing, people must also monitor changing task or environmental demands. Successful performance often requires the effective use of strategies.

Athletes record their performances and review them to fine-tune their movements; marine biologists maintain careful notes during their observations to document changes in conditions, behavior, and data. Individuals must also determine whether, when, and how to seek help during the performance phase. Some engage in strategic self-talk to get themselves through difficulties. Children's egocentric speech during play serves as a primary regulatory function (Vygotsky, 1935/1978).

After performance, individuals engage in self-regulation by assessing and reacting to their own behaviors. During this self-reflection phase, people review the outcomes of their efforts and the behaviors that led to them. During self-reflection, people search to make attributions (i.e., perceived causes) for what has happened. If the causes are attributed to internal, changeable factors, people are able to consider alternative plans for their next efforts. For example, a student who earns a mediocre grade on a biology exam might attribute her score to inadequate studying approaches and evaluate where her strategies were insufficient. People also assess the effectiveness of the strategies they used. Not only do people assess what happened and why, they also react to their own performances. As Bandura (2016) noted, self-reaction is a powerful factor in human self-regulation and agency. People choose to reward or sanction themselves according to whether their performances met their goals. This often prompts a new behavioral cycle. Emotional responses can also help or hinder self-regulation. For one student, frustration after a challenging task leads to renewed determination; for another, frustration leads to withdrawal of effort. Self-reflection can also involve the reappraisal of efficacy-relevant information that is used to inform and revise self-efficacy perceptions relevant to the particular domain (Schunk & Usher, 2011).

As [Figure 2.1](#) shows, the cyclical nature of self-regulation described by Zimmerman (2000, 2013) emphasizes the social cognitive components that enable humans to exercise agency in their development. The three subfunctions of self-regulation (self-observation, self-evaluation, and self-reaction) are involved at each of the three phases of self-regulated learning.

It is important to keep in mind that one's external environment, mental and physical landscape, and behaviors are all—to a certain extent—under one's direct control through self-regulatory effort. Therefore, regulation does not pertain only to overt behavior. In many circumstances, not to act requires as valiant an effort as to discharge into speech or action. Moreover, people often need to regulate their thoughts and emotions so as to achieve their goals. A multifaceted self-regulatory skill set helps people to navigate the diverse environmental and social contexts in which they spend their lives.

The cycle of self-regulation described above applies to large and small events alike and therefore can take place within minutes, days, or years, depending on the activity (Zimmerman, 2011). Given the complexity of human functioning, each self-regulatory event involves numerous interacting components. We next explore in more detail how people develop their capacity to self-regulate.

Development of Self-Regulatory Competence

Most self-regulation skills do not arise on their own; rather, they must be learned. Schunk and Zimmerman (1997) depicted a developmental model of self-regulatory competence as learners moving through four levels: observation, emulation, self-control, and self-regulation. In the first two levels, the sources of influence are social (i.e., external to the learners), whereas the source of influence becomes internalized during the second two levels. Thus, this sequence is known as social-self progression (Schunk, 1999).

At the observation level, social models such as teachers and peers provide information on how to perform a task and how to engage in forethought, performance, and reflection phase processes. Models also provide self-efficacy information vicariously and through social persuasions; for example, students observe their teacher modeling how to perform a task successfully. Teachers not only demonstrate behaviors but also their self-efficacy to perform them successfully. At the emulation level, students practice the observed behaviors. Self-efficacy is strengthened

by teachers who provide feedback and encouragement. Students are developing self-efficacy as they perform the task the way it was modeled.

At the self-control level, students begin to develop and influence their own sense of efficacy (Schunk, 1999). Although they are internalizing what they observed, they still use the representational patterns of the model to perform behaviors. At the self-regulation level, learners systematically adapt their performances to different environmental and personal conditions and are motivated by their personal efficacy beliefs (Zimmerman, 2000). Now they are capable of initiating the strategies, making adjustments based on situational factors, and evaluating their performance. As learners engage in the three cyclical phases of self-regulation, their skills and self-efficacy develop further.

Although Schunk and Zimmerman (1997) did not contend that this progression is the only means for developing self-regulatory competence, their description provides a social cognitive account of self-regulatory development. It also emphasizes the role of personal agency and learner motivation through the development of self-efficacy in all phases. We next describe these and other components of self-regulation and provide research findings related to their function in self-regulated learning.

Research Evidence on the Components of Self-Regulated Learning

In this section, we offer examples from empirical research that show how various components can be more integral to self-regulation in particular contexts. Six components of self-regulation that can affect student learning and performance have been described by Bandura (1986, 1989, 1997, 2016) and Zimmerman (2000, 2013). Social cognitive theory posits that these components do not act independently but in conjunction with each other when guiding individuals' thoughts and actions. In other words, each component can be the goal of one's efforts, a subgoal of another effort, or both. We provide examples of this interactive process.

Cognition

All self-regulatory acts require a certain level of cognitive engagement. Human cognitive architecture includes long-term memory and working memory, both of which are essential to successful functioning (Choi, van Merriënboer, & Paas, 2014). The nature of the task determines the degree to which cognitive and metacognitive resources are required. When learners confront complex information or novel situations, they must activate relevant cognitive schemas in long-term memory to help them decide on an appropriate course of action. These schemas alleviate the burden on working memory, which is quickly overburdened in unfamiliar performance settings (i.e., situations with high cognitive load). Cognitive events are subserved by executive functions, the mental skills that permit people to manage themselves and their resources by selecting and monitoring their actions and thoughts to attain their goals (see Hoyle & Dent, 2018/this volume). Specifically, self-regulatory success depends on the individual's use of three key executive functions: working memory, inhibitory control, and task-switching flexibility (Hofmann, Schmeichel, & Baddeley, 2012). For example, a student with poor use of inhibitory control might find herself mindlessly following a bad crowd of peers. Blair and Diamond (2008) have explained that, because of the interacting influence of personal, behavioral, and environmental factors, students with better executive function will reap the benefits of being praised more often for their high compliance, produce better academic performance, and have higher motivation. Those with poor executive function will likely experience more difficulty in school.

Learner characteristics (e.g., expertise, age, motivation), task features (e.g., nature of the problem), and environmental features (e.g., physical set up, social composition, climate) interactively influence the degree to which one's cognitive resources are burdened during self-regulation (Choi et al., 2014). When facing a chaotic environment, students can find it difficult to concentrate, regulate their own activities, and minimize intrusive thoughts. This is mitigated by certain learner characteristics, such as self-efficacy and prior knowledge about the

task at hand. During activities that require high cognitive demand, individuals allocate fewer resources to cognitive monitoring and self-regulation (Choi et al., 2014).

Self-regulation also depends on the human capability to think metacognitively, or about one's thoughts, feelings, and actions. One's metacognitive activities can be key sources of self-motivation. By anticipating the outcomes their behaviors will produce and reflecting on previous attempts, people become more or less likely to make plans of action (Bandura, 1989). The need for cognitive self-monitoring may be highest when skills are initially being developed. With more experience, less explicit monitoring is needed. After proficiency has been reached, heightened self-monitoring might in fact impede performance (Mace, Belfiore, & Hutchinson, 2001). Experienced athletes are coached not to interfere with habitual processes via cognitive fiat or over-thinking, so as not to throw off their performance. Artists and writers have similarly emphasized the importance of incubation, or the cessation of cognitive monitoring, at more advanced stages of the creative process (Hao, Liu, Ku, Hu, & Runco, 2015). In this way, self-regulation involves cognitive processes similar to those required for complex problem solving (Zimmerman & Campillo, 2003).

Behavior

The previous section points to the many self-regulatory events that take place covertly. What do overt self-regulated learning behaviors look like? A student's self-regulatory behavioral repertoire can be expansive, including organizing one's physical environment, taking notes, recording one's performances, rehearsing, minimizing distraction, and self-punishing/-rewarding. Although most of these behaviors can take place during the performance phase, some also occur during the forethought and self-reflection phases. Zimmerman (1998) provided examples of underlying self-regulatory processes that are used in diverse domains of functioning (e.g., writing, athletics, academics), which include scheduling one's time, delaying immediate gratification, reviewing one's work, and seeking help from others (for a similar list of self-regulatory control processes in school settings, see Duckworth, Gendler, & Gross, 2014).

Engaging in avoidant or addictive behaviors can undermine one's self-regulatory success. Klassen, Krawchuk, and Rajani (2008) found that undergraduate students who had lower self-efficacy for self-regulation were more likely to procrastinate. Learners with high levels of fear that they will fail to live up to their own or others' expectations tend to engage in a range of self-handicapping behaviors, which enable them to attribute their expected failure to an external, rather than internal, cause (Urdu & Midgely, 2001). Students self-handicap in different ways, such as by withdrawing their effort, making an array of excuses, selecting inappropriate study settings, or engaging in compulsive or addictive behaviors (e.g., online gaming, substance abuse). Meta-analysis of over 25,000 students revealed that self-handicapping behaviors are related to poorer academic performance (Schwinger, Wirthwein, Lemmer, & Steinmayr, 2014).

Motivation

People can typically describe their ideal performances with ease. The runner hopes to run at a certain pace. The applicant knows what will make his essay top notch. Such ideals and aspirations must be combined with what James (1899/2001) called "pluck and will" (p. 144) if they are to lead to significant change. Without the motivational power to initiate and sustain the behaviors necessary, potentiality remains just that. Motivation and positive self-beliefs guide action by focusing learners' attention, influencing their choices, and increasing the perseverant effort needed to solve complex problems and reach challenging goals.

In social cognitive theory, beliefs in one's capabilities to perform desired behaviors and the tasks that subserve them (i.e., self-efficacy) are central to whether individuals will engage in self-regulation (Bandura, 1997). People who believe in their own efficacy are likely to sustain their activities even when faced with challenges; those beset with self-doubt are more likely to recoil when the going gets tough (Schunk, 2012; Schunk & Pajares, 2009). Outcome expectations also influence self-regulatory behavior. When people expect that their actions will bring

about desired outcomes (e.g., good grade, job, reward), they are motivated to implement strategies to ensure those outcomes (Bandura, 1986). On the other hand, expectations of failure or hardship can lead people to give up prematurely. Self-efficacy and outcome expectations, though central to self-regulation, may be insufficient if people see little value in their activities. When students perceive an activity as important, they are more likely to implement strategies to stay the course. Furthermore, activities that are intrinsically interesting and rewarding require less cognitive effort to enact for long periods of time (Renninger & Hidi, 2015).

Learners' reasons for studying and engaging in their academic work, or achievement goal orientations, are also key motivators. When students' reasons for engagement involve increasing their own learning and mastery, they tend to enlist more adaptive self-regulatory strategies and have faith that their competencies are developing (Schunk & Ertmer, 2000). Yeager et al. (2014) found that having a self-transcendent purpose for learning—a reason to benefit others beyond one's self—was positively related to adolescents' persistence and self-control. On the other hand, students whose primary reason for performing well is to surpass others or demonstrate their own competence may be discouraged by challenges and attribute them to internal insufficiencies. This orientation is often fueled by a belief that one's competence is inherent (Dweck, 2006). As noted above, students whose goal is to avoid failure or negative evaluation tend to engage in defensive self-regulatory processes, which, paradoxically, bring about the very difficulties they fear.

Yet another powerful motivating factor comes from individuals' self-set, task-contingent rewards. Offering self-incentives for reaching one's goals can motivate a person to stick to a plan. Indeed, self-incentives have been shown to be more effective motivators than external rewards, such as praise or money (Bandura, 1986). Intrinsic rewards, which offer positive consequences that flow naturally from one's behavior, can also lead to sustained activity, but the self-imposed act of “withholding freely available rewards until self-acceptable performances have been achieved” (Bandura, 1986, p. 366) is a critical feature of regulation by self-reactive influence. Most often people use a combination of intrinsic and extrinsic motivators to get their work done. To the extent that individuals rely on external regulators, however, they are apt to suffer from lower motivation and are less likely to achieve their long-term goals.

Emotion

How people feel about themselves before, during, and after their performances can also influence their self-regulatory engagement. For instance, students' ability to regulate their emotions is related to how well they process information and learn (Pekrun, 1992). Likewise, emotions serve to reinforce both helpful and harmful self-regulatory practices (e.g., Hao et al., 2015). Although emotions are typically salient after performance during the self-reflective phase of self-regulation, they influence all phases of the self-regulatory cycle. Anticipatory feelings before an activity often guide whether and how a person will perform.

The more closely one's personal standards, ideals, and self-worth are linked to the task, the more emotional weight one's performance carries (Bandura, 1997). Acts of self-importance may invoke great fear. In such cases, initiating effort may require overcoming one's fear of failure. Fear can motivate regulatory action too. As Williamson (1992) observed, “Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure” (pp. 190–191). For many individuals, emotions such as inspiration are experienced in proportion to the difficulty being faced. Challenge can thus become the catalyzing force of self-regulation. Perhaps James (1899/2001) was right: “What our human emotions seem to require is the sight of the struggle going on” (p. 133).

Whether people feel satisfied during and after their performances is related to how they will respond. Feelings of happiness and pride, coupled with a sense of personal responsibility, can lead to renewed efforts and higher aspirations. Conversely, shame, depression, anxiety, particularly when people feel that certain factors are beyond their control, can lead to the adoption of self-destructive strategies, such as task avoidance and withdrawal (Pekrun, Goetz, Titz, & Perry, 2002). Affective or physiological blocks often bring about adverse behavioral

consequences by lowering people's coping self-efficacy (Bandura, 1997). However, when people develop skill and confidence in managing stressors, they are less likely to activate distress systems, such as autonomic arousal and depressive rumination (Bandura, 1989).

Social

Human interdependency means that regulation of one's thoughts and activities is socially mediated and socially consequential (Bandura, 1986). The social and ecological contexts in which students live also influence their self-regulatory development. Supportive social networks can help learners withstand challenges that might otherwise overcome them. Exposure to proficient models can offer better strategies for planning, monitoring, and accomplishing one's goals (Zimmerman, 2013). Coping models, those who describe their own effortful process and struggles, can convince observers that they too can succeed with similar effort (Pajares, 2006). For example, by watching others overcome challenges, observers can learn better strategies and gain a sense of their own efficacy. The proliferation of films featuring individuals who overcome great adversity (e.g., *Selma*, *The Revenant*, *Unbroken*) is a testament to the power of social modeling to influence self-efficacy for self-regulation. Seeing a similar peer overcome difficulty through effort can be similarly motivating (Bandura, 1997). Indeed, by their own initiative, people intentionally seek out aspirational models who not only offer self-regulatory strategies but also increase their motivation for self-directed change (Bandura, 2011).

People must also rely on others to help them accomplish their goals (see Karabenick & Gonida, 2018/this volume). Part of an effective self-regulatory skill set is knowing when and from whom one should seek help. Teachers offer scaffolded instruction and feedback designed to help students master the subtasks needed to meet their longer-term goals. Coaches devise plans that build skills while maintaining variety that will engage athletes during practice. Working in larger social groups helps learners set collective goals, monitor progress, share accountability, and work together through co-regulation of effort (see Hadwin, Järvelä, & Miller, 2018/this volume). Parents help their children learn how to surmount challenges by talking through the steps they need to take. Socially mediated regulation in turn becomes internalized and used to regulate actions and thoughts when one is alone.

Making one's standards and goals known to others can create a positive self-regulatory cycle whereby an individual seeks to maintain social approval for meeting self-set standards. Announcing that one is going to write a book of poetry or register for a long-distance running event sets up a social accountability system that can be highly motivating. The self is still the primary agent of change by virtue of setting the initial goals and working to meet them. The cognitive representation of one's social group serves in part as "an approval-contingency" that motivates self-regulation towards desired outcomes (Bandura, 1986).

Another way in which students regulate themselves by social means involves selecting environments that offer advantageous social contagion. Choosing positive social environments can enhance a feeling of collective commitment to shared goals and standards. Many students find it easier to study in a library where others are engaged in deep learning tasks. People may join fitness clubs to expose themselves to models who seem dedicated to healthy self-regulatory routines. Social networks can be selected in similar ways and connective technologies have placed proxy agents at one's fingertips.

Environment

Individuals' self-regulatory thoughts, beliefs, and behaviors are considerably influenced by micro- and macro-level environmental factors (e.g., one's living arrangements, economic status, school climate, and exposure to threats). Successfully navigating through multiple demands on one's time and attention requires considerable self-directedness, metacognitive skill, and self-motivation. Because this requires great effort and cognitive involvement, particularly when tasks are novel and complex, people must often rely on external regulating structures such as deadlines, social pressure, or external sanctions (Bandura, 1986). In academic settings with

high external demands, students have less need to rely on their own self-regulatory skills and may become habituated to external regulation. However, teachers and parents hope that, over time, learners will internalize the standards set for them. Direct instruction can facilitate the development of the self-regulatory subfunctions by helping students gauge their progress relative to an external standard (i.e., via self-observation and self-evaluation; Schunk & DiBenedetto, 2014).

Environmental stressors (e.g., poverty, stereotype threat) can also influence self-regulatory processes. Whether one is able to withstand environmental adversity depends in part on personal characteristics. Whereas some redouble their efforts, others give up or become paralyzed by adversity, which can tax cognitive and emotional resources. Children must rely on their own self-encouragement when external support for their efforts is lacking. A strong sense of one's own efficacy can serve as a buffer in challenging circumstances. In environments where social messages are perceived as threatening, students who must expend more effort mitigating the threatening environment consequently have less cognitive power to focus on regulating their performance on the task at hand (Schmader, Johns, & Forbes, 2008). Emotion regulation in such environments comes at the expense of cognitive regulation of learning tasks.

It bears emphasizing that environmental conditions are but one determinant of human activity. One's behaviors are also determined partly by one's own self-influence (Bandura, 1986). Effective self-regulators use this influence to tailor their environments to help them accomplish their goals. Timers, goal sheets, planners, and self-scheduled reinforcements can become strong self-regulatory allies. Technological tools (e.g., laptops, phones, tablets) can also be creatively used to enhance self-direction and self-monitoring; however, the gadgets designed to better manage our lives also are used to avoid and distract. To be used effectively, technological tools require people to exercise self-directedness and self-observation (Schunk & Ertmer, 1999).

Future Research Directions

We have described the social cognitive foundation of self-regulation, the cyclical nature of self-regulated learning and performance, the development of self-regulatory competence, and the interactive components that influence self-regulation. We now offer several ideas for future research on self-regulated learning. In this section, we highlight the components and phases of self-regulated learning described above that have not been studied as extensively in the literature.

One recommendation is that researchers pay more attention to self-regulation in understudied learning contexts. Much research on self-regulated learning has taken place at four-year postsecondary institutions or with convenience samples of students in largely middle class public high schools. The unique characteristics of understudied learning environments (e.g., charter schools, early childhood centers, vocational training settings, distance education programs) make them ideal for furthering an understanding of how self-regulatory processes operate, especially among diverse populations (e.g., community college students, English language learners, students in rural or high-poverty areas).

A second recommendation is to explore self-regulation in high-technological environments. One might ask whether the devices and online learning platforms increasingly used in learning settings are enhancing the emotional, social, physical, and academic well-being of students and teachers. Many school systems have adopted open-use policies for technology or one-device-per-student approaches, but few studies have included matched controls to test their effects on students' self-regulation (Zheng, Warschauer, Lin, & Chang, 2016). Students are frequently encouraged to self-direct during technologically supported learning (e.g., to gather resources on a topic). Investigating the degree to which guidance is offered to students in such settings could offer insights into helpful social supports for self-regulated technology use. This seems to be a particularly valuable avenue of research (see Moos, 2018/this volume).

Third, feedback has been shown to be effective in many phases of learning (Hattie & Timperley, 2007). More research should be conducted on how various forms of feedback can influence the self-regulatory cycle. For instance, athletes and non-athletes alike wear watches that track their movements, and many feedback devices prompt people to set new goals and enact new health regimes. What would such feedback devices look like in educational settings? Under what feedback conditions do individuals tend to give up or persist? Personal technologies such as “meditation assistants” may be similarly helpful for providing learners with feedback on their cognitive and emotional arousal.

Lastly, future research could aim at illuminating the processes by which individuals adopt certain standards and select certain environments. Bandura (2001) argued that, by virtue of their self-set goals and personal standards, humans are discrepancy creators and not just reactants motivated to resolve the discrepancies in their environment. In other words, once environmental discrepancies are reduced and managed, new challenges and aims are set. Some students set extremely challenging personal goals, whereas others are satisfied with marginal work and effort. These self-set standards are no doubt environmentally situated and context specific. However, learners also select environments where external standards match their own internal standards (Bandura, 1986). What individual characteristics influence these selection processes?

Implications for Educational Practice

In this closing section, we offer several implications from current research about how educational practitioners and parents can support students’ self-regulation. Supporting the motivational antecedents to self-regulated behaviors is one area in which small interventions are likely to reap sizeable benefits. Given the power of a sense of personal efficacy to achieve one’s goals, teachers and parents will do well to focus their efforts on helping students build healthy self-efficacy. They can do this by structuring opportunities for skill development and mastery, which typically serve as the strongest source of self-efficacy (Usher & Pajares, 2008). They can rely on social models who have overcome difficulty through persistent, self-regulated effort. They can provide performance feedback that highlights learners’ capabilities to be agents of their own development and change. These persuasive messages can convince the doubtful of their own power. By attending to students’ feelings and emotions, including adverse physiological arousal, parents and teachers can help students view their emotions adaptively and to surmount negative feelings (Pajares, 2006).

Social cognitive theory suggests that self-set goals and incentives are more powerful in motivating self-regulation than are externally imposed goals and rewards. This has implications for classroom practice. Helping students set goals and personal incentive structures acquaints them with their agentic power and sense of autonomy. New technologies permit people to monitor their goal progress in creative ways. Helping learners internalize as much as possible their plans for action leads to more lasting self-regulatory effects. Apps and programs that are highly customizable may be well suited as tools for self-regulation of learning.

Launching new self-regulatory habits can also be helped by training in executive functioning, which may improve students’ self-regulatory capacity. Blair and Diamond (2008) identified several ways in which teachers and parents can help children’s executive functioning, such as allowing children to engage in role play, encouraging them to make decisions about their own learning, and promoting students’ social and emotional development. By structuring their lessons and their classrooms in ways that scaffold instruction and expose students to appropriate exemplars, teachers significantly reduce the cognitive load of the learning task, thereby permitting students to allocate their cognitive resources elsewhere (Choi et al., 2014).

Although it may be unpopular to say, one key to success is knowing when to give up. As a general rule, learners should be encouraged to put forth effort to pursue their goals, but at some point efforts might be counterproductive to their ultimate aims. Dweck (2015) noted that a number of practitioners, wooed by the idea of promoting a growth mindset, have done so without taking the learner’s long-term development into account. Knowing when

to quit or drop a strategy is also a necessary part of being self-regulated. Adults can help learners identify and let go of old self-regulatory strategies that are no longer working.

School practitioners can help learners frame their self-evaluations and reflective self-assessments in adaptive ways. For example, negative emotions (e.g., anger at one's self) can be redirected toward the task to create a distance between one's self-evaluation and the task to be accomplished. Teachers can also help by looking for blocks in their students' self-regulatory processes and encouraging them to try new strategies. They can assist learners to focus on what they can control rather than on what they cannot. As Bandura (1997) noted, "Focus on the controllable aspects of one's life makes the uncontrollable ones more bearable" (p. 31).

Guiding students toward a self-regulatory repertoire that will serve them well in their lives involves not only teaching useful concepts and skills. Unless students—indeed humans—can pay attention when the time for change is ripe, they will not enact their own self-regulatory powers. William James (1899/2001) was well aware of the precious resource of "voluntary attention," which he referred to as that momentary and effortful affair that is needed to launch new self-regulatory routines. Perhaps this is why in his closing talk to schoolteachers he referred to "the exercise of voluntary attention" as "one of the most important points of training that take place there" (p. 92). This is because self-regulatory habits that are developed early become the patterns that guide people throughout their lives. James estimated that these habitual forces comprise 99.99% of daily life, and the remainder—the 0.01% comprising free will—is where self-regulatory habits are launched. He said that this portion of our voluntary behaviors, "brief and fitful as they are, are nevertheless momentous and critical, determining us, as they do, to higher or lower destinies" (p. 92). Schools, he added, are therefore ideal places for exposing students to many possible ideals or standards for their lives that can inform their willful decisions. Education, therefore, is primarily "a means of multiplying our ideals, of bringing new ones into view" (p. 142).

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3 Cognition and Metacognition within Self-Regulated Learning

Philip H. Winne

This chapter describes the complex fusion of cognition, metacognition and motivation that is self-regulated learning (SRL) and identifies key foci for future research and practice. Following a selective recap of cognition and metacognition, SRL is characterized using two perspectives: Winne and Hadwin's (1998, Winne, 2001) loosely sequenced, recursive four-phase model and Winne's (1997) COPES model that identifies facets of a task wherein learners exercise SRL. Key challenges learners face are developing study tactics and learning strategies that SRL manages, and articulating the role of motivation in SRL. With these topics as backdrop, three goals are highlighted for future research: using data from multiple channels, tracing motivation as a dynamic variable over the timeline of a task and the critical need to better trace metacognitive monitoring and control. A strong recommendation is offered for reconceptualizing practice in ways that support learners as learning scientists who experiment with "what works" as they self-regulate learning.

Theoretical Lenses for Viewing Self-Regulated Learning

Cognition

The origin of the word cognition is the Latin *cognoscere* meaning essentially "to come to know." Coming to know is a process that takes in information—input—and produces information—output. Kinds of information processed in cognition are diverse. Fundamentally, they correspond to kinds of information available to the human senses plus one kind of information humans invented—symbol systems. In school, the most dominant symbol systems are text, mathematics and diagrammatic representations of various sorts.

Cognitive processes that operate on information are commonly named with reference to a result of the operation: encoding creates an encoded form of information; retrieving brings previously encoded information from long-term memory into working memory where it can be operated on further. A short list of commonly described cognitive processes also includes: comprehending, predicting, solving, reasoning and imaging. Much cognition in school and life engages operations that are learned algorithms or heuristics designed to accomplish people's goals. Examples are long division, learning strategies and mnemonics (e.g., first-letter acronyms, the alphabet song) and rules (e.g., i before e except after c). Metaphorically, the mind is programmable. Many operations require information to be in a prepared form. Examples are using an index to a book and proving a geometric theorem using a succession of previously established theorems and axioms.

Learned processes have a typical developmental trajectory. At first, they are quite observable and very effortful. Often, a learner verbally or subvocally describes each component or step before as it is carried out. Transitions across steps or stages in multi-step processes at early stages of learning are tentative, and the intended result of a step is not reliably realized. With practice, steps reliably lead to the intended result, setting a stage to fuse them into a smooth series. As this happens, adjacent steps form subunits that become increasingly difficult to disassemble. After extensive practice, learned processes become automated. Automated processes are carried out rapidly, they reliably produce intended results and typically "run off" without one's noticing. If one tries to disassemble an automated process, the process often shows a dramatic reduction in pace and may even spawn errors.

In contrast to cognition that operates on information by a learned automated procedure, other cognitive operations are basic or "primitive." These are possibly innate to the human cognitive system and they resist analysis into simpler forms. Notwithstanding, learners can engage both learned and basic operations mindfully, with purpose. I proposed a set of five basic cognitive operations: searching, monitoring, assembling, rehearsing and translating (Winne, 1985, 2010a). [Table 3.1](#) defines each of these five basic cognitive operations and provides examples. If I apply one learned cognitive tactic I know, assembling a first-letter mnemonic, this set of cognitive operations can be encapsulated by the acronym SMART.

[Table 3.1](#) Basic cognitive processes

Operation	Description	Examples
Searching	Directing attention to information that meets standards.	Retrieving the chemical symbol for gold (Au). Paging through a chapter to locate a fact.
Monitoring	Identifying whether or the degree to which information corresponds to standards.	Judging whether to use “affect” or “effect.” Checking the steps in solving a problem.
Assembling	Joining previously separate information by identifying a relationship.	Linking items and labeling links in a concept map. Developing a timeline of events.
Rehearsing	Preserving or re-instating information in working memory.	Rotely rehearsing definitions of terms. Practicing typing on a keyboard.
Translating	Transforming the representation of given information.	Graphing the parabola $y = x^2 - 2x + 4$. Paraphrasing a famous quote.

It is often challenging for students (and other thinkers) to thoroughly and reliably observe their cognitive operations. When information about cognition is not directly available or is missing, people typically make inferences about cognitive operations. Ingredients for inferences are mainly: (a) changes in properties of output(s) compared to input(s), (b) time between input event and output events (i.e., latency), and (c) behaviors that can be made observable by supplementing memory and one’s sense impressions with instrumentation: eye tracking gear can record visual searches, highlighting tools permanently identify text that was monitored and judged to have particular attributes (e.g., “That’s important”), and a video can record a search for information when using a book’s index or translating numbers into counts represented by extended fingers.

Metacognition

Turning to metacognition, meta originates in the Greek meaning principally “after” or “beyond.” Its use in English often signifies “about” the category that is modified by “meta.” Meta-X is information about X. In this sense, metacognition is cognition about the information input to or output by cognition, as well as information about the operations that work on information. An important feature of metacognition is that what differentiates it from cognition is not the operations involved. I argue the same fundamental cognitive processes are used in cognition and in metacognition (Winne, 2011).

In other words, the topics of metacognition are qualities of thoughts and thinking. Here is an example of metacognition’s appearance in a learned form of cognition, a basic study tactic. As a learner studies an assigned chapter, each time a term appears in italics, as identified by monitoring for this typographical cue, the learner searches the text for information that matches the common form of a definition (e.g., monitoring for cues like “... is defined as” or “..., meaning”), translates the features provided by the cued information into an example by calling on (i.e., searching) prior knowledge and checks (i.e., monitors) that each key feature is represented in the constructed example. Upon completing this study tactic, the learner metacognitively thinks, “That worked quite well these last few times.” Here, the learner is monitoring qualities of products of the study tactic. Those qualities might describe that the tactic: (a) completes reliably, (b) is not too effortful, (c) can be executed rapidly and (d) boosts confidence in a judgment about how well material is understood. The learner adds to these thoughts, “... and I feel pretty confident it will help me on the test.” This involves recalling meta-features of test items and test taking experiences, such as: (a) knowledge of definitions is often called for, and (b) confidence in test answers is higher for items that ask for definitions when those definitions were studied using the tactic.

Like theories of cognition, theories about metacognition also are diverse. Research has investigated metamemory—what a learner knows about how memory works and factors that influence the retrievability of information (see Thiede & de Bruin, 2018/this volume); metacognition—what a learner knows about cognitive events, including the probability they generate a successful product, the typical pace of particular forms of cognition, factors that affect cognition such as load and vigilance; and meta-emotion—how a person feels about the experience of a particular emotion (see Efklides, Schwartz, & Brown, 2018/this volume).

Nelson and Narens (1990) provided a precise description of metacognition:

- Principle 1. The cognitive processes are split into two or more specific interrelated levels ... the meta-level and the object-level.
- Principle 2. The meta-level contains a dynamic model (e.g., a mental simulation) of the object-level.
- Principle 3. There are two dominance relations, called “control” and “monitoring,” which are defined in terms of the direction of the flow of information between the meta-level and the object-level.

Nelson and Narens’s third principle can be usefully represented in the form of a production system: IF–THEN. For example, IF information at the object level is monitored according to a profile of attributes and is determined to differ sufficiently from a meta-level profile, THEN exercise agency to modify cognition at the object level by searching for a form of cognition that is judged at the meta-level to be more productive. This interplay between cognition and metacognition is the focus of theories and research on SRL (Winne, 1995a, 1995b, 1997, 2001, 2010a).

Self-Regulated Learning

Research on SRL has been vibrant for approximately 40 years (see Winne, in press). Hadwin and I (Winne & Hadwin, 1998; see also Dimmitt & McCormick, 2012) proposed a model of SRL that unfolds over four loosely sequential and recursive phases. In the first phase, the learner searches the external environment plus her memory to identify conditions that may have bearing on a task she is about to begin. This information represents context as the learner perceives it. In phase two, the learner forges goals for working on the task and drafts plans to approach those goals. Phase three is where work begins on the task itself.

Throughout all three of these phases, the self-regulating learner monitors information about (a) how learning was enacted using cognitive operations (e.g., SMART processes), study tactics and learning strategies; and (b) changes in the fit of internal and external conditions to various standards. For example, after mapping external conditions, the learner may judge she has only moderate efficacy and forecasts she will need help. Searching her store of knowledge and judging she is not very well equipped for this task, she becomes slightly anxious and sets a goal to seek help from others. A plan is designed to seek help that is either just in case, e.g., texting a friend to see if he will be in the library during study hall in the afternoon; or just in time, e.g., texting her friend at the moment need arises. Each plan, not yet enacted, is monitored for whether it seems it will sufficiently allay her anxiety. If not, an adaptation may be constructed.

Phase four of Winne and Hadwin’s model of SRL is where learners elect to make substantial changes in their approach to future tasks. This process reflects what Salomon and Perkins (1989) called forward-reaching transfer. Changes learners can make take two main forms: large shifts in standards they use for metacognitive monitoring in a particular context, and significant rearrangements of links between the results of metacognitive monitoring and actions taken (i.e., learning tactics and strategies) conditional on the outcome of metacognitive monitoring. In terms of a production system, this modifies IF A, THEN B to become IF A, THEN C.

Facets of Tasks in SRL: The COPES Model

At every phase of SRL, learners engage in micro, meso or macro tasks. Each task can be modeled using a five-part schema that marks conditions, operations, products, standards and evaluations—the COPES model (Winne, 1997). Conditions are elements the learner perceives could affect work on the task. Internal conditions are characteristics the learner brings to a task, such as knowledge about the topic, study tactics and learning strategies, motivational orientation and epistemological beliefs (see Muis & Singh, 2018/this volume). External conditions are features in the surrounding environment the learner perceives could influence internal conditions of either of two other facets of tasks, operations and standards. Operations work on information, as noted in the description of the basic SMART operations and composite operations, such as study tactics and learning strategies. Every

operation generates products. Some products relate to the goal of the task, for example, ordering by date the French monarchs during the Renaissance or finding the intercept(s) of a quadratic function. Other products are a result of metacognition, such as judging whether it is worth the effort to construct a mnemonic for elements in the actinide series versus just memorizing them. Products are evaluated using standards. The set of standards operationalizes the goal of carrying out operations to produce a particular product. For example, a high-quality first-letter mnemonic (a) includes one letter for each item to be identified, (b) is pronounceable and (c) is memorable (e.g., “A SMART student COPES well with tasks”).

Qualities of SRL

Throughout all the phases of SRL, learners’ motivations and emotions are influential (see Efklides, Schwartz, & Brown, 2018/this volume). These arise automatically as learners engage cognitive and metacognitive processes (Buck, 1985; Zajonc, 1980). Motivational and emotional states play three important roles. First, they are internal conditions the learner surveys in phase one of self-regulated work. Second, standards used in metacognitive monitoring can refer to the presence of, or level of, motivations and emotions. Third, learners can set goals to regulate motivation and emotion in the same general way as they regulate cognition. In this case, motivations and emotions become objects manipulated when learners exercise tactics and strategies via metacognitive control.

A further critical theoretical account about SRL concerns the essence of self-regulation. The learner is in charge. Whatever supports or constraints exist as external conditions and whatever may be the character of an intervention designed to promote elements of SRL, the learner is the decision maker and the actor. Were it otherwise, by definition, regulation would not be self-regulation but other-regulation (see Hadwin, Järvelä, & Miller, 2018/this volume; Winne, 2015).

A corollary of this axiom is that learners engaged in SRL are the principal investigators in a personal program of research. They investigate and mobilize ever more effective tactics and strategies that help to achieve goals. Importantly, the standards they use to judge effectiveness of tactics and strategies are theirs, as are the goals they set. These may or may not match an instructor’s, tutor’s or group mate’s goals.

Each SRL event is a potential experiment. From this perspective, learners are learning scientists. Like “certified” learning scientists, learners gather and analyze data to feed evolving theories about why their approaches to learning are more or less successful. This is challenging scientific work owing to the multivariate nature of the learning environment and difficulties people encounter with scientific reasoning (Winne, 1997, 2010a). Learners need help with at least three main tasks: (a) gathering reliable data about how they enacted learning and associating those data with effects, (b) access to tactics and strategies for learning that can be available to metacognitive control and (c) opportunity to practice newer tactics and strategies to bring them to the status of automated skills. Woven throughout all this, learners need help in applying the scientific method to develop valid interpretations about their experiments in learning.

Research on Cognitive and Metacognitive Processes

Because SRL works at the meta-level to modulate knowledge, skills, motivation and emotion at the object level, this chapter cannot do full justice to the range of research on cognitive and metacognitive processes in SRL. Select topics and select research are included here about effective study strategies and factors bearing on learners’ metacognition.

Are Study Strategies Effective?

Metamemory refers to what a learner knows about processes involved in learning and memory, including beliefs learners have about tactics and strategies for learning. It appears undergraduates, at least, are quite undereducated about these matters. In response to an open-ended question about strategies used to study, Karpicke, Butler and

Roediger (2009) reported the most frequently cited study tactic was reading one's notes or the textbook. McCabe (2011) investigated learners' predictions about the utility of six factors that have general empirical support in learning science as affecting learning: dual coding (i.e., it is generally better to study material presented in multiple modalities than a single modality), animation overload (i.e., it is generally better to study static material), seductive details (i.e., high interest but less relevant details can rob resources from learning key content), the testing effect (i.e., memory is generally improved by testing knowledge vs. restudying it), the spacing effect (i.e., memory is generally better when studying sessions are distributed over time vs. cramming) and the generation effect (i.e., creating a personal representation of content generally improves memory). For the generation effect, 50% of undergraduates correctly endorsed it. Endorsements of the more productive approach to learning for the first five items in this set ranged from 10% to 38%.

While undergraduates may know little about how to study as recommended by evidence from learning science, this can be remedied. A large variety of studies have shown learners can be taught or "pick up" without much training a variety of specific study tactics and learning strategies that benefit learning outcomes in the lab and in authentic settings (e.g., Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). Perhaps the most authentic of these studies is Tuckman and Kennedy's (2011). They taught a diverse group of undergraduates in a large midwestern U.S. university a collection of generic strategies for managing one's studies, taking responsibility for learning, planning and asking questions about learning activities and assignments, and seeking and using feedback about learning, a category loosely matching engaging in metacognitive monitoring and metacognitive control. Two notable features of this study are that the course was lengthy (a semester) and the intervention directly addressed motivational as well as cognitive features of undergraduates' experiences as learners. In comparison to a carefully matched comparison group in this quasi-experiment, students taking the learning strategies course prospered. Odds of continuing to enroll (i.e., retention) were more than six times greater for students who took the learning strategies course. Grade point averages for learning strategies course takers and non-course takers both showed a decline across semesters but learning strategies course takers were statistically identified as having a higher GPA than students in general.

Tuckman and Kennedy's study sparks optimism. The balance of work in this area indicates learners taught learning tactics and strategies experience quite variable but moderately positive results (Donker, de Boer, Kostons, van Ewijk, & van der Werf, 2014; Winne, 2013). Two features of strategy instruction boost chances of benefits: increase opportunities for metacognitive monitoring using standards that focus on both cognitive processes and products, and enhance feedback to address not only products but also cognition and metacognition directly (Schraw & Gutierrez, 2015; Winne, 1985). But learners need additional support. Object-level cognitive processes designed to benefit learning give rise to metacognitive experiences that learners often misconceive, and learners' exercise of metacognitive control based on these misconceptions can undermine learning. Metacognitive knowledge and interpretations of metacognitive experiences are important. The next section examines this topic.

Factors Bearing on Learners' Metacognition About Tactics and Strategies

To oversimplify the complex recursive unfolding of processes and their products that fuel updates across the timeline of a task, consider a snapshot of work at a moment in time—a state. Resources the learner has available in a state of work are the contents of working memory plus whatever information is perceived about the external environment. Importantly, factors that learners scan internally and externally are also fundamentally shaped by memory and its contents, i.e., metacognitive knowledge (see Muis & Singh, 2018/this volume). Everyone, including learners, faces challenges of memory. Those challenges sometimes prevail.

Commonly, learners are overconfident about what they know. As a consequence, they often elect not to restudy content when it would benefit them. Several factors are at play as reviewed by Bjork, Dunlosky and Kornell (2013). First, when material appears easy to grasp, this fluency in encoding appears to mislead learners to forecast that the studied material will be easily recalled. Unluckily, there is only a small correlation between encoding fluency and recall. Second, material that is perceptually emphasized (e.g., by priming memory with keywords or

by styling type font such as italicized terms) is judged easier to learn. It is not. Third, inducing relationships, such as the characteristics of art and artists' names, may be perceived easier when content is presented in blocked fashion, such as all the art by one artist, then all the art by the next artist. Like the false sense of encoding fluency, the ease of inducing relationships when content is blocked also leads learners to judge they have learned better. A mixed presentation produces better outcomes.

The story here is truly meta. Learners observe meta-features about the content they study and their experience as they study that content. What might be considered “obvious” cues about the quality of learning are not inherently probative (see Koriat, 2016). There are remedies, commonly grouped under the apt label of desirable difficulties (Bjork & Bjork, 2011). The general form of a desirable difficulty is to engage the learner in a kind of object-level cognitive processing that the learner might usually avoid because it appears unnecessarily difficult. But there are cases where the very impairment to performance that gives rise to this perception of unnecessary difficulty in the short-term is a benefit to longer-term recall. A prime example is distributed practice where the schedule for reviewing previously studied content spreads out over a timeline rather than reviewing immediately after or very close in time to a first study session. Laboring to recall prior material that is not “at hand” enhances memory for that content (e.g., Roediger & Butler, 2011). But learners prefer material to be blocked or massed, setting a stage for overconfident judgments of retrievability because material they study repeatedly in one session is recognized rather than having to be retrieved. Recognizing material is easier but less productive.

Overall, desirable difficulties engage learners in SMART processing at the object level that otherwise they would metacognitively choose not to carry out. While it is good that learners are metacognitively engaged in monitoring learning experiences, the metacognitive control they exercise, what they choose to do, is often subpar.

Motivational factors are at play beyond a simple preference to avoid what is judged to be unnecessary work. The fulcrum may be hindsight bias and several associated motivational factors (see Bernstein, Aßfalg, Kumar, & Ackerman, 2015). The gist of hindsight bias is a tendency to judge that a previous state was relatively predictable when, at the time that state was occurring, it was objectively not predictable; or vice versa. Hindsight bias is nicely reflected by a less formal label, the “I knew it all along” effect. For example, a learner metacognitively chooses to study material using effortful object-level processes. On later receiving a poor grade, the learner reasons: “No matter how hard I would have studied, the test was so difficult I was bound to fail anyway.” This metacognitively biased attribution to what is afterward perceived an uncontrollable factor—the test—is an interpretation that protects self-worth. But it is a mistake because a poor outcome on the test was not a dependable prediction at the time of studying. Looking through a motivational lens, the learner need not accept blame for unproductive SRL during the study phase. And what blame there is to assign was offloaded to an external uncontrollable factor, the instructor’s unduly difficult test (Weiner, 2010). The upshot is less incentive in future studying sessions to exercise metacognitive control that activates effortful object-level processes.

In sum, metacognitive processes are informed by and constrained by metacognitive knowledge (Winne, 1995b). Knowledge in this sense is broadly interpreted to refer to the contents of memory that supply standards for metacognitive monitoring: beliefs and motivational explanations for results, as well as misconceptions (e.g., Winne & Marx, 1989) and learned tactics and strategies that fuse SMART processes with other knowledge about how to operate on information at the object level. An important implication is that learners engaging in productive SRL need a wide scope of metacognitive knowledge that is both valid and useful in the contexts of their diverse learning activities.

Vectors for Future Research on SRL

Multiple Channels for Observing SRL

Beginning readers are noticeably methodical when they decode a multisyllabic word with a “confusing” cluster of consonants, like “highway.” With extensive practice, this process becomes automated. The accomplished reader is practically unaware of decoding processes. The same is true of metacognitive processes. For a particular

learner, instances of metacognitive monitoring and metacognitive control are commonly “submerged” from the learner’s ready inspection because the learner has developed automated recognition for whether a profile of features matches a standard profile of features. Similarly, the link between a judgment rendered by metacognitive monitoring and the choice identified by metacognitive control may similarly be automated and, thus, escape inspection.

Developing instrumentation to shine light on automated SRL processes has burgeoned in recent decades. The latest work strives to synthesize a “whole picture” of SRL grounded in data gathered in real time across multiple channels such as on-the-spot think-aloud reports (Greene, Deekens, Copeland, & Yu, 2018/this volume), click-stream data generated as learners use features in software (i.e., back buttons, search boxes; (Biswas, Baker, & Paquette, 2018/this volume), and eye gaze data and physiological measures (Azevedo, 2015; Azevedo, Taub, & Mudrich, 2018/this volume). Daunting challenges include: merging data across differing time scales, identifying robust indicators of object- and meta-level cognition and taming significant variability that arises across the timeline of a task and between tasks. Recent work on educational data mining (see Winne & Baker, 2013; Biswas, Baker, & Paquette, 2018/this volume) will be valuable in this work. Success in this methodological sector of research on SRL is essential in order to build a platform of learning science that not only advances the field but allows rigorous tests that can responsibly guide practice.

Motivation and Options

Today’s arena of theories of motivation is vibrant and diverse (Schunk, Meece, & Pintrich, 2014). Each offers perspective about how action and affect arise, and how consequences shape future choices. As noted earlier, cognitive and metacognitive processes in SRL are fundamentally deliberative; this is the purpose of metacognitive monitoring. As agents, learners exercise choices. Even automated routines embed within them motivational features that were deliberative at an earlier phase when the routine was becoming automated.

A significant challenge for research on SRL is characterizing motivation as a dynamic variable across the timeline of work on a task, and across tasks. The vast majority of motivation research samples very, very few states during a task and charts a very punctuated flow across states. Studies that offer temporal measures of motivation capture it at a coarse grain size. Trace methodologies (Winne, 2010b; see Bernacki, 2018/this volume) may offer an approach that fits SRL research. Traces are ambient data (e.g., logs of interactions with a computer) generated as learners do work they would normally do. Traces offer a sturdy platform for making inferences about underlying constructs such as metacognition and motivation. For example, learners who add marginalia to text like an exclamation point (!) or question mark (?) are tracing monitoring the text according to particular metacognitive standards—“This is important” and “This is incomprehensible.” These traces inherently reflect motivation-in-action.

An example is Zhou and Winne’s (2012) study. Among several other features for learners studying text online, they invited learners to click links. The links were phrases matching forms of achievement goal orientation (e.g., “Find more information about this” as a representation of mastery approach goal orientation). Their data showed two important findings: traces of motivational states differed from self-reports of goal orientations, and traces were better predictors of achievement. What needs work is conceptualizing motivation not only as an outcome but also as a standard learners use in metacognitive monitoring. Tracing standards representing motivational stances will be challenging because these standards likely fluctuate within a study session as well as across them.

Providing Opportunity for Metacognitive Monitoring and Metacognitive Control

As described throughout this volume, SRL is complex. At its hub are two expressions of metacognition: monitoring and control (Winne, 2001). Operationally defining metacognitive monitoring can take two general forms. The first and easier form is to observe ambient expressions of metacognitive control and, on that basis, infer meta-cognitive monitoring has occurred. A more complete inference about metacognitive monitoring

requires additional evidence about the standard(s) used when a state was monitored. Suppose a learner annotates text by (a) drawing in the margin of a page a vertical line spanning several lines in one paragraph and (b) writing as a tag next to this line, “evidence?” This 2-part trace operationally reflects an instance of metacognitive control. It supplies sturdy ground for inferring the learner was monitoring the text using a schema for argumentation and identified the marked lines as failing the evidentiary feature of that schema. Research on SRL must provide opportunities for learners to reveal occasions where they exercise metacognitive control by a trace. Ideally, the trace identifies which information was monitored and what standard(s) the learner used in monitoring.

The second and more demanding path for operationally defining metacognitive monitoring affords a richer characterization of SRL at a cost levied on participants measured in time, effort and potentially interest in volunteering to participate in research. It is to train learners in several sets of standards, e.g., a schema for argumentation and a schema for explanation. Then, researchers would observe instances of metacognitive control and examine variance in the tags, e.g., “evidence?” vs. “scope?”

Learners’ exercise of metacognitive control in SRL is evident when learners vary their use of study tactics as a function of conditions at the start of work on a task or as conditions become updated over the course of work on a task. Gathering evidence about variance in metacognitive control within SRL requires, first, the internal condition that learners are approximately equally skilled in using more than one study tactic and, second, that external conditions afford the learner approximately equal opportunities to use any of the tactics. If either feature is absent or biased (i.e., learners are unequally skilled in the several study tactics or the environment biases the product of metacognitive monitoring that sets the stage for metacognitive control), researchers’ evidence of SRL will be truncated or biased. This is not a flaw per se but needs to be acknowledged in reporting research findings.

Implications for Practice

Because expressions of metacognition in SRL are complex, research upon which to base practice may appear piecemeal, failing to paint a whole picture. I recommend teachers and instructional designers conceptualize individual studies as offering heuristics for practices rather than unbending, must-do rules (Winne, 2017b). If this is a reasonable view to adopt for teachers who design instruction for learners, the same follows for learners who design learning for themselves as they practice SRL. A consequence is that learning to learn more effectively, the goal of SRL, will require two-way respect between learners and instructors. Each necessarily must experiment, and each should develop tolerance for well-intentioned yet less-than-optimal success.

The good news is there are promising heuristics for study tactics and SRL. An illustration is Michalsky’s (2013) study of a multi-component approach to studying scientific texts to increase scientific literacy. Learners in grade 10, other than those in a control group, were provided questions about learning in the midst of texts they studied. Questions addressed cognitive-metacognitive or motivational elements in each of four facets of work: comprehending the text, connecting ideas to prior experience, strategies for work and reflecting on the results of exercising metacognitive control. One group received only cognitively plus metacognitively focused questions, a second group received only motivationally focused questions and a third group received both. In addition to achievement data, the researcher gathered both questionnaire data reflecting aptitude-related SRL and think-aloud data reflecting event-related cognitive, metacognitive and motivational features. Embedding opportunities for learners to address metacognitive aspects of learning (i.e., cognition, metacognition and motivation) boosted scientific literacy relative to the control group. An important finding of Michalsky’s study was only the group with all three kinds of embedded questions—cognitive, metacognitive and motivational—elevated state-like views of SRL. As proposed by Panadero, Klug and Järvelä (2016), when students have greater opportunity to become aware of their processing, they have greater opportunity to adapt. In short, as straightforward a technique as explicitly inviting learners to consider how they learn can benefit achievement. But, as discussed throughout this chapter, SRL is a fusion of motivational and cognitive-metacognitive features (Bell & Kozlowski, 2008; Efklides, 2011). Students in Michalsky’s study changed their views of SRL when this fusion was part of their work.

If, as earlier described, learners are learning scientists, designs for instruction that support their research projects will need more than heuristically useful interventions, as illustrated in Michalsky's study. They also need data about their learning that shines light on how they learn, and they need relief from pressures to cover over-stuffed curricula and to succeed at every bit of it in order to afford opportunities to experiment with learning without punishments. I offer several untested suggestions. First, leverage the power of software technologies to gather data about learning as an event (Winne, 2017a). Second, offer learners learning analytics, reports generated using trace and other conventional data (e.g., demographic, self-report, accumulating achievement) about how and what they studied, plus recommendations about how to productively adapt study routines (Winne, 2017b). Convey learning analytics in ways that encourage learners to "try out" adaptations to tactics and strategies they use to learn (Roll & Winne, 2015; Winne, 2017b). When (a) experimenting with learning becomes an accepted curriculum unto itself, (b) learners are motivated and feel safe to experiment with learning (e.g., Marzouk et al., 2016) and (c) excesses of overcrowded curricula where "everyone needs to know all of this" are pruned to make space for experimenting with learning, I predict productive SRL will have a much better chance to flourish.

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4 Developmental Trajectories of Skills and Abilities Relevant for Self-Regulation of Learning and Performance

Rick H. Hoyle and Amy L. Dent

For over a century, leaders in education policy and practice have argued that a primary purpose of formal schooling is teaching students how to learn. This purpose is achieved when students can self-regulate their learning, which transforms the acquisition of knowledge and skills into an active, autonomous process. Being able to do so enables lifelong learning, often considered the ultimate goal of education. Reaching this goal is made possible by self-regulated learning, a multidimensional construct that has moved to the forefront of educational psychology (Boekaerts, 1997; Zimmerman, 1990).

The contributions in this volume make clear the profound implications of learning how to learn. It is thus unsurprising that research on self-regulated learning has proliferated since the publication of the first edition (Zimmerman & Schunk, 2011), further refining its many models (e.g., Hadwin, Järvelä, & Miller, 2018/*this volume*) and measures (e.g., Cleary, Callan, Malatesta, & Adams, 2015). Despite these theoretical and methodological advances, the development of self-regulated learning has received relatively less empirical attention than the relations between its component processes (e.g., Dent & Koenka, 2016). Yet leaders in the field have long recommended looking at self-regulated learning, and self-regulation more broadly, through a developmental lens to chart its course longitudinally (e.g., Aldwin, Skinner, Zimmer-Gembeck, & Taylor, 2011). Although several studies have responded to this clarion call with samples of students from different academic years (e.g., Cleary & Chen, 2009) or developmental periods (e.g., Weil et al., 2013), few have followed the same students across time to capture normative and individual trajectories of the development of self-regulated learning. This chapter provides a theoretical, empirical, and practical overview of this developmental trajectory, focusing on the skills and abilities that underlie it.

Self-regulated learning encompasses an array of constructs and processes that support students' pursuit of learning and performance-related goals. Reflecting this broad understanding, an organizational framework has emerged from the theoretical and empirical literature to identify four primary components of self-regulated learning (Dent & Koenka, 2016; Pintrich, 2000). Metacognitive processes propel students' progress on performance tasks and are closely tied to the phases of self-regulated learning at the center of the two prominent theoretical perspectives: social-cognitive and information-processing. Five frequently identified metacognitive processes are goal setting, planning, self-monitoring, self-control, and self-evaluation (Dent & Koenka, 2016). The cognitive strategies students select and enact during self-regulated learning constitute its second component, which includes the traditional triumvirate of rehearsal, elaboration, and organization (Gagné, Yekovich, & Yekovich, 1993). However, models of self-regulated learning have extended beyond these "cold" cognitive constructs to recognize the need for internal resource management (Dent & Koenka, 2016), which involves regulating "hot" states such as motivation (Pintrich, 1999) and emotion (Eisenberg, Valiente, & Eggum, 2010) during goal pursuit. Acknowledging that contextual factors influence how students learn (Ben-Eliyahu & Bernacki, 2015), external resource management (Dent & Koenka, 2016) includes environment structuring (Zimmerman & Schunk, 2001) and help-seeking (Karabenick & Gonida, 2018/*this volume*). These four components of self-regulated learning are principally distinguished by what they harness, with the role of metacognitive processes to deploy, coordinate, or even counteract students' cognitive, motivational, emotional, attentional, and contextual affordances represented in the other three components. The four components of self-regulated learning encompass a diverse array of underlying skills and abilities that together support its development. Inspired by the principles of dynamic systems theory (Thelen & Smith, 2006), the developmental trajectories of these components of self-regulated learning are the focus of the chapter.

The chapter also considers broader conceptual models from the social psychology of self-regulation. The multiple domains and levels of analysis implicated in these models can clarify how self-regulated learning develops beyond constructs and processes featured in models of self-regulated learning. For example, self-regulated learning can

be described and studied at levels of analysis ranging from biological substrates to behavioral manifestations and interpersonal interactions as self-regulation is in other subdisciplines of psychology. Similarly, self-regulated learning can be viewed through theoretical lenses originating outside educational psychology. Considering self-regulated learning at multiple levels of analysis using the methods and models of different subdisciplines provides a richer, more complete picture of its development than a consideration limited to models and findings focused specifically on self-regulated learning.

The remainder of the chapter begins with a theoretical discussion of how self-regulated learning develops. The highlighted theoretical principles then guide a review of research relevant to the question of how self-regulated learning develops followed by an overview of practical applications.

Theoretical Overview

Two theoretical perspectives—social-cognitive and information processing—have guided much of the research on self-regulated learning. These perspectives offer complementary accounts of how self-regulated learning, and self-regulation more broadly, develops.

According to the social-cognitive perspective of how self-regulated learning develops, students acquire skills and abilities that enable self-regulated learning through observational learning in four phases (Bandura, 1991; Schunk & Zimmerman, 1997). Students first observe then imitate how their social model implements a strategy. Next, students internalize that strategy to an extent that they can implement it independently. This shift from a social to self focus signals the third phase of development, which is constrained by a mental representation of the strategy closely tied to the model's performance. The final phase empowers students to self-regulate the strategy, responsively adapting it to new personal or contextual factors (Usher & Schunk, 2018/this volume). Underlying this social-cognitive account of self-regulated learning is a common assumption of other theoretical perspectives as well; namely, that self-regulation develops through interaction with the social environment (e.g., Boekaerts & Cascallar, 2006).

Although self-regulated learning develops through interaction with the social environment, interaction with the learning material itself is a powerful source of cognitive and metacognitive strategy development. From the information-processing perspective (Winne, 2001, 2018/this volume), self-regulation is a form of expertise that develops as it does in other areas such as athletics or arts: through practice (Ericsson, Krampe, & Tesch-Romer, 1993). In particular, practice allows students to discover more efficient and refined forms of strategies. Experimenting with different strategies and updating metacognitive knowledge about them is how students become better at self-regulating their learning (Winne, 1997).

Whether refined through observation, or practice, the emergence and expression of self-regulated learning is supported by coordinated cognitive mechanisms with their own, often interrelated, trajectories (Paris & Newman, 1990). These mechanisms and the capacities they enable begin to emerge early in life. For example, the basic capacity to inhibit behavior stabilizes by about one year of age (Kagan, 1997). The functional capacity of working memory increases across childhood (Fry & Hale, 1996), which frees capacity for students to consciously monitor and implement cognitive strategies. In early childhood, working memory and other executive functions express as individual differences in temperament, often defined with specific reference to self-regulation (Hoyle & Gallagher, 2015). The features of temperament that support self-regulation generally serve to modulate emotional and motor reactivity (Rothbart & Bates, 2006). Principle among these capacities is effortful control, which primarily involves inhibiting a dominant response in favor of a subdominant response. A related dimension of temperament is reactive control, which is the relatively involuntary influence of approach and avoidance motives. Of particular relevance to the development of self-regulation are the extreme forms of reactive control, namely over- and under-controlled reactivity. Reactive undercontrol manifests as impulsivity, while reactive overcontrol is evident in avoidance tendencies such as shyness (Eisenberg, Eggum, Sallquist, & Edwards, 2010). Although

developmental substrates of self-regulation such as these are relevant for a broad range of human activity and experience, their relevance for self-regulated learning is the focus of this chapter.

The skills and abilities that underlie self-regulated learning can be understood and united through the principles of dynamic systems theory (Thelen & Smith, 2006). These principles help explain the emergence and expression of self-regulated learning as a function of interacting developmental milestones across multiple levels of organization. The two overarching themes in this metatheory provide a useful account of how self-regulated learning processes and strategies come online to together enable students' pursuit of learning or performance goals. First, development can be best understood by considering all of its levels of organization or analysis—from molecular to cultural—and how they interact. Second, nested developmental processes unfold across time and within context. These themes are content neutral and thus flexibly applicable to the development of any dynamic system (Thelen & Smith, 2006).

Self-regulation is perhaps the quintessential dynamic system with its complex, coordinated processes spanning biological substrates to social behavior that build on and mutually reinforce each other across seconds or even years. The many levels and timescales at which self-regulation operates jointly influence its expression and emergence. Some self-regulatory processes (e.g., planning) emerge only after structures and processes underlying them (e.g., executive functions) have developed. Adept self-regulation relies on the development of abilities and their collaboration. For example, although each executive function separately supports self-regulation, together they enable the metacognitive process of planning (Das, Kirby, & Jarman, 1975). Among metacognitive processes, moreover, self-monitoring and self-control work so closely together that they are subjectively indistinguishable (Pintrich, 2000). Consequently, students differ in the degree of developmental readiness to self-regulate their learning based on which cognitive, metacognitive, motivational, and affective processes have become available to integrate and deploy. A growing body of research highlights the critical building blocks of self-regulated learning, their development, and their interconnections.

Research on the Development of Self-Regulated Learning

A summary of the relevance of each process covered in this section for self-regulated learning and, when available, its developmental trajectory is provided in [Table 4.1](#).

Table 4.1 Overview of skills and abilities relevant for the self-regulation of learning and performance

Skill or ability	Developmental trajectory	Relevance for SRL
Temperament:		
<i>Effortful control</i>	Early signs of the requisite attention control between 9 and 18 months. Significant increase in relevant capacities between 18 and 30 months resulting in capacity for effortful control by 3 years of age.	Inhibit a dominant response in favor of a subdominant response, supporting the modulation of emotions during childhood (MP, ERM,IRM).
<i>Reactive control</i>	More research is needed on the developmental trajectory of this ability.	Control of involuntary approach and avoidance motives.
Executive attention:	Incremental development during preschool that lays the foundation for the emergence of executive functions during preschool.	Ability to focus on certain stimuli and ignore others as a prerequisite for goal-directed behavior (MP,IRM,ERM).
<i>Orienting subsystem</i>	Rapid development over first years of life, with different even antagonistic trajectories for attention focusing and shifting through preschool.	Enables students to focus or shift attention toward external stimuli (MP,ERM).
Executive functions:	Rapid development over the first five years of life.	
<i>Updating</i>	Functional capacity of working memory increases across childhood, with slower development of updating working memory.	Working memory capacity enables students to consciously monitor and implement cognitive strategies (MP, CS). Updating enables students to monitor incoming information for its relevance to a goal and modify previous information in light of it, shielding salient goals from competing external stimuli (MP,ERM).
<i>Inhibiting</i>	Basic ability to inhibit behavior stabilizes at 1 year of age. Marked improvement in simple response inhibition before kindergarten transition and in complex response inhibition after it.	Successful self-regulated learning requires inhibiting impulsive, habitual, or otherwise dominant responses that could derail goal pursuit (MP, IRM, ERM).
<i>Shifting</i>	Lagged development of shifting during childhood due in part to its dependence on other executive functions, with significant improvement in mental flexibility toward the end of childhood before reaching adult level in middle adolescence.	Shifting enables students to flexibly switch between tasks or mental sets thus tying it to self-monitoring and self-control, which trigger the process of adapting goal pursuit (MP).
Delay of gratification	Evident at age 4.	Foregoing an immediate reward in order not to disrupt or derail pursuit of a longer-term goal (MP, ERM).
Verbalization	More research is needed on the developmental trajectory of this ability.	Simple verbalization supports rehearsal, while verbal competency supports elaboration (CS).
Associative memory	Basic capacity evident in childhood, with its application becoming less mentally demanding as supporting processes develop.	Facilitates making connections among ideas, as in elaboration (CS).
Metamemory		Supports organization (CS)

Note. SRL = self-regulated learning, here the self-regulation of academic learning and performance; MP = metacognitive processes component of SRL; CS = cognitive strategies component of SRL; ERM = external resource management component of SRL; IRM = internal resource management component of SRL (Dent & Koenka, 2016).

The metacognitive processes involved in self-regulated learning follow a protracted developmental trajectory into adolescence that partially depends on the maturation and coordination of relevant executive functions. Updating or updating working memory enables someone to monitor incoming information for its relevance to a given task and modify previous information in light of it. Updating supports several metacognitive processes, from initial activation and representation of a goal through affect-laden decisions during pursuit of it. The ability to maintain and manipulate information in working memory enables people to shield salient goals from competing external stimuli (Hofmann, Schmeichel, & Baddeley, 2012). Doing so also involves attentional control, which underlies each executive function (Jurado & Rosselli, 2007). For example, the ability to focus attention away from an immediate temptation while maintaining a distal goal in mind facilitates delay of gratification. Inhibiting or response inhibition enables someone to deliberately override a dominant, automatic, or proponent response. Successful self-regulated learning also requires inhibiting impulsive, habitual, or otherwise dominant responses that could derail goal pursuit. For example, resisting the dominant response of falling asleep while finishing a final paper allows exhausted college students to submit their assignment before the deadline. However, failure to inhibit this sleep-deprived response would compromise attainment of that goal. Both updating and inhibiting thus help stay the self-regulatory course, while shifting helps change course when ineffective strategies should be abandoned. Shifting or set shifting enables someone to flexibly switch between tasks or mental sets. Shifting is thus tied to self-monitoring and self-control, which trigger the process of adapting goal pursuit (Hofmann et al., 2012). These connections with executive functions and especially their development demonstrate the principles of dynamic systems theory at play.

The developmental trajectory of single and complex executive functions reflects the maturation of the frontal cortex and its neural substrates, which are susceptible to environmental influences (e.g., Hughes, 2011). As a result, early caregiver interactions and home experiences can profoundly influence children's executive functioning. Whether due to physical maturation or social influences, the development of executive functions and the neurocognitive mechanisms underlying them is rapid during the first five years of life (Garon, Bryson, & Smith, 2008). With new measures capturing these elusive constructs with greater validity in young children, the preponderance of research on executive functions has focused on the formative preschool years. Due to this empirical popularity, coupled with the diversity of measures and dimensions of executive functions, the research on its development is difficult to summarize. However, Garon et al.'s (2008) review of executive functions provides a valuable foundation for doing so.

Garon et al. (2008) argue that the maturation of controlled or executive attention lays the foundation for the emergence of executive functions during preschool. The ability to focus on certain stimuli and ignore others is a prerequisite for goal-directed behavior. This selective attention develops incrementally during preschool, as the anterior attention subsystem increasingly exerts control over the orienting subsystem (Rothbart & Posner, 2001). Developing rapidly over the first year of life, the orienting subsystem allows children to focus or shift attention toward external stimuli. Over the six subsequent years improvements in executive attention mirror development of the anterior subsystem, which enhances processing of visual stimuli through control over the orienting subsystem (Ruff & Rothbart, 1996). Doing so enables both controlled attention focusing and shifting, which show different and even antagonistic developmental trajectories. That is, the ability to focus attention sometimes undermines shifting between stimuli. The negative correlation between these two attentional capacities indicates that they may not be integrated in preschool (Jones, Rothbart, & Posner, 2003), but nonetheless play an important role in the emergence of executive functions during this pivotal developmental period.

Like controlled focusing and shifting, Garon et al. (2008) argue that executive functions do not develop in parallel. Instead, these skills build on each other and the executive attention system unifying them. This development also reflects maturation of the frontal lobe (Anderson, 2002), where both separate executive functions and their integration has been localized. The ability to update information in working memory and retain it there develops later, although the lack of longitudinal data on this executive function compromises inferences about its trajectory

during early childhood. Although not unique to inhibiting, the multitude of measures capturing this construct has presented challenges in charting its developmental trajectory. However, marked improvement in simple response inhibition (e.g., delay an automatic response) has been found before the transition to kindergarten and after it in more complex response inhibition (e.g., hold a rule in mind and respond to it while inhibiting an alternative response; Garon et al., 2008; Hughes, 2011).

In contrast, shifting develops more slowly across early childhood (Hughes, 2011). This lagged developmental trajectory is likely due, in part, to the dependence of shifting on other executive functions. That is, successfully shifting between mental sets requires children to manipulate information in working memory and inhibit the operations that were replaced with new ones. As a result, shifting builds on other executive functions and thus demonstrates later development (Garon et al., 2008). Toward the end of childhood, significant improvements in mental flexibility are apparent (Anderson, 2002), although this capacity might not approach adult levels until middle adolescence (Davidson, Amso, Anderson, & Diamond, 2006). In early adolescence, planning, organizing, and strategic thinking begin to show improvement, which continues throughout adolescence (Anderson, Anderson, & Garth, 2001).

These foundational, higher-order capacities both contribute to and draw on a developing set of cognitive strategies implicated in most models of self-regulated learning.

Cognitive Strategies

A diverse array of specific strategies are involved in the self-regulation of learning and performance. Collectively these strategies are “cold,” deliberative processes; however, they often occur with “hot,” impulse-driven desires and needs. This hot-cold juxtaposition is perhaps most evident in the delay of gratification, which involves foregoing an immediate reward in order not to disrupt or derail pursuit of a longer-term goal (Chen & Bembenuddy, 2018/this volume). Relatively little is known about the development of delay of gratification in an academic context, but classic research on it suggests that this general strategy of self-regulation is evident as early as 4 years of age (Mischel, Ebbesen, & Raskoff Zeiss, 1972). A simple measure of how long preschool children wait before consuming a small treat when promised a larger treat if they delay that immediate gratification predicts academic and social competency in adolescence (Shoda, Mischel, & Peake, 1990). Although specific strategies for delaying gratification in the service of academic goals likely improve with experience, the basic ability to delay gratification is evident before the introduction of formal education.

Cognitive strategies more specific to the self-regulation of learning and performance are rehearsal, elaboration, and organization (Gagné et al., 1993). Rehearsal may take various forms, but a key form for the developing child is verbalization (Schunk, 1986). The general role of speech in self-regulated learning progresses from the directive speech of adults in early childhood, to verbalizations by the child related to enacting behavior through the preschool years, to verbalizations that include inhibition and restraint by the start of school (Luria, 1961). Verbalization is also critical for elaboration, yet it extends beyond the simple ability to verbalize as in rehearsal to verbal competency (Pressley, 1982). Elaboration also relies on associative memory, which facilitates making connections between ideas. Although the basic capacity for associative memory is evident in childhood, its application becomes less mentally demanding as supporting processes develop. As a result, there is a general upward trajectory in the use of elaboration strategies from childhood through adolescence into adulthood (Kee, 1994). The ability to use organizational strategies in the service of self-regulated learning also improves during childhood and adolescence as working memory capacity, metamemory, and basic knowledge increase (Bjorklund & Douglas, 1997). Unlike rehearsal and elaboration, the ability to use organizational strategies appears to emerge rather suddenly, proving highly effective for recall by age 10 (Schlagmüller & Schneider, 2002). It should be noted that self-reported measures of cognitive strategy use indicate that students themselves do not distinguish between rehearsal, elaboration, and organization until they reach high school age or older (Wolters, Pintrich, & Karabenick, 2005). Thus, longitudinal research spanning childhood and adolescence that relies on self-reports tracks the development of general cognitive strategy use rather than strategy-specific developmental trajectories.

Internal Resource Management

Metacognitive processes and cognitive strategies operate against the backdrop of academic emotions and motivation. We refer to emotions and motivation as internal resources, acknowledging that they can either promote or threaten the self-regulation of learning and performance depending on how they are harnessed. When self-regulated learning is promoted by internal resources, students may channel emotions and motivation toward productive activity associated with the task. When self-regulated learning is threatened by internal resources, students may enact strategies to regulate problematic emotions (e.g., frustration, anxiety) or deflect distracting sources of motivation. These potential internal resources must be managed effectively for the metacognitive processes and cognitive strategies of self-regulated learning to be successful at achieving the academic goal.

The development of internal resource management has received relatively little empirical and theoretical attention within the self-regulated learning literature. Although newer models recognize the role of “hot” processes such as motivation and emotion (e.g., Efklides, Schwartz, & Brown, 2018/this volume), research on how students become adept at regulating them during the pursuit of learning or performance goals has not followed suit. Research on the cognitive and social psychology of self-regulation provides a starting point for a conversation about the development of internal resource management.

Like executive functions, the ability to self-regulate emotions is influenced by early interactions with primary caregivers (Blair, Calkins, & Kopp, 2010). Unlike executive functions, however, researchers focused on the development of emotion regulation emphasize these environmental influences more than underlying neurocognitive changes (Hughes, 2011). In particular, early regulation of emotions and behavior is accomplished by others but gradually gets transferred to the child through scaffolded experiences of agency (McClelland & Cameron, 2011). This transfer from other- to self-regulation is considered the main milestone of its early development (Berger, 2011). During childhood, emotion-related self-regulation depends on effortful control, a capacity rooted in executive functions that allows for attentional control, willful activation and inhibition of behavior, and modulation of emotions (Rothbart & Bates, 2006). Longitudinal research spanning preschool into elementary school indicates a central role for emotion-related self-regulation, which influences a range of outcomes associated with school readiness and performance.

Research and theory that integrates motivation into process-oriented models of self-regulation is sparse in other subdisciplines of psychology. Motivation-focused theoretical models and the research they inspired have instead focused on individual differences in motivation presumed to reflect a range of self-regulation competencies. For example, young students’ desire to succeed in school, their satisfaction with school, and their preference for academic challenges predicts academic performance beyond individual differences in self-regulation (Howse, Lange, Farran, & Boyles, 2003). Although these proxies of motivation predict academic performance across elementary school, self-regulation does not emerge as a robust predictor of academic performance until late in that academic stage (Howse et al., 2003). As the importance of online motivation during self-regulation receives greater attention, it will be important to highlight both the role motivation plays in stimulating self-regulation (Bronson, 2000) and the role of self-regulation in generating and sustaining task-related motivation (Sansone & Smith, 2000).

External Resource Management

Like emotions and motivation, forces external to students influence their self-regulated learning. Research in the broader self-regulation literature has begun to focus on the important role of these external resources. That work and work within the self-regulated learning literature is revealing the importance of managing external resources in the service of self-regulation. The primary focus of this research across subdisciplines has been on the potential benefits of other people on individual goal pursuit.

Social psychology research and theory suggest the importance of social support for personal goal pursuit (Fitzsimons, Finkel, & vanDellen, 2015). This work has focused almost exclusively on adults self-regulating primarily with reference to health goals (e.g., Okun & Karoly, 2007). More recent research on parents' role in children's self-regulation indicates that their co-regulation is evident as early as infancy (e.g., Gulsrud, Jahromi, & Kasari, 2010), although that work focuses primarily on parents' support of children's self-regulation as opposed to the reciprocal co-regulation of adolescent and adult dyads. Mutual and reciprocal co-regulation is characteristic of collaborative learning in school and online learning environments (Volet, Summers, & Thurman, 2009). Promising theoretical accounts of co-regulation and other features of self-regulation in social context have been articulated for learning environments (Hadwin et al., 2018/this volume) and more general goal pursuit (Fitzsimons et al., 2015).

Educational psychology theory and research suggest the importance of help-seeking for academic goal pursuit (for a review, see Karabenick & Gonida, 2018/this volume), although only a small subset of this work offers insight into the development of this external resource management. The trajectory of its development—slightly increasing during elementary school before declining after the transition to middle school then improving again across this tumultuous academic stage—reflects the contextual nature of external resource management (Marchand & Skinner, 2007). In addition to the frequency of help-seeking, the reasons for it also change over time: first related to the material and teacher in elementary school before shifting to cost-benefit evaluations in middle school (Newman, 1990). Although help-seeking might seem to undermine rather than support students' self-regulation of learning and performance, it is often motivated by their desire for greater autonomy (Ryan, Pintrich, & Midgley, 2001). For that reason, help-seeking can contribute to the ongoing development of self-regulated learning.

Future Research

Although cross-sectional comparisons offer some insight into the development of abilities and skills related to self-regulated learning, charting their trajectory requires longitudinal research. A major benefit of longitudinal research is the opportunity to map development both normatively and idiosyncratically with new analytic options such as latent curve analysis (e.g., Caprara et al., 2008) and growth mixture modeling (e.g., Chen, Hughes, & Kwok, 2014). These statistical advances allow for person-centered analyses that can identify subgroups of students that differ in the pace or degree of development of specific abilities and skills. Longitudinal research with appropriate spacing of assessments allows for the specification of statistical models that map onto theoretical accounts of development, thereby allowing for rigorous tests of their tenets. Appropriate spacing of assessments coupled with the inclusion of time-invariant and time-varying covariates allows for informative (though not definitive) tests of causal influence. Moreover, longitudinal research can uniquely reveal critical periods of development for underlying abilities and skills that can then inform intervention for students vulnerable to deficits in them.

A key consideration in longitudinal research on self-regulated learning is the availability of developmentally appropriate measures of the constructs and processes expected to change over time. Researchers might draw from the executive functions literature to create more valid measures of emergent self-regulated learning skills among young students, enabling longitudinal research across critical developmental periods and school transitions. Such work is especially important if measures must be administered in some form across several waves of data collection that capture students' changing developmental readiness to self-regulate. In the development of such measures, inherent limitations of self-report measures for young students should be recognized. Alternatives include performance on computerized tasks and trace evidence (e.g., underlining task) of self-regulated learning. Computerized tasks are particularly appealing, because they provide real-time evidence of self-regulated learning and can be adapted to capture increasingly sophisticated uses of strategies and skills (e.g., Greene & Azevedo, 2010). Observation of behavior is promising as well, although validation research would need to establish the meaning of specific behaviors at different developmental periods to ensure that behavioral change is indicative

of change in self-regulated learning. Ultimately, the field would benefit from developmentally appropriate observational measures encompassing the full array of self-regulated learning components and processes.

Although the self-regulation of academic learning and performance is one domain of self-regulation more broadly (Dent & Hoyle, 2016), there is little overlap between their growing literatures. We have drawn on the educational, social, cognitive, and developmental psychology of self-regulation to enrich our dynamic systems account of how self-regulated learning develops. However, a more systematic conceptual synthesis across these subdisciplines would likely benefit their empirical, theoretical, and psychometric understanding of self-regulation. Work on basic executive functions and school readiness (e.g., Eisenberg et al., 2010) is a leading example. Similarly, work on the basic ability to delay gratification and its influence on academic performance (Shoda et al., 1990) suggests an opportunity to embellish accounts of self-regulated learning by drawing on models of this more general self-regulatory capacity. Research on these more general self-regulatory capacities also stands to benefit from this cross-pollination, with the prominent task of academic learning and performance across formal schooling serving as a valuable context for observing basic self-regulation in action.

Translation of Research on Self-Regulated Learning

As the diverse skills and abilities related to self-regulated learning reflect, it is not a unitary construct with uniform development of the many processes and strategies it encompasses. As a result, the timing and focus of attempts to improve them must align with students' developmental readiness to learn how to learn through observation or practice. Accordingly, the two prominent theoretical perspectives on self-regulated learning can inform approaches to instruction and intervention that draw from a multidisciplinary, multidimensional understanding of its development as a dynamic system.

From a social-cognitive perspective, self-regulation develops through interaction with the social environment. For self-regulated learning, the social environment is often the classroom and thus teachers are influential models of self-regulated learning. As a result, teachers who provide plentiful opportunities for students to observe, imitate, internalize, and then autonomously implement strategies should facilitate their development (Paris & Paris, 2001). Tutors and parents are also promising models from whom students can learn how to learn, where both are positioned to provide more tailored modeling of self-regulated learning processes or strategies with which a student is struggling. Yet students must be developmentally ready to learn them. As a result, social models should be mindful of when students become equipped to enact self-regulated learning strategies. Translating the development of self-regulated learning as a dynamic system into actionable, accessible guidelines for social models is thus an important practical step supporting small-scale/everyday opportunities for intervention.

From an information-processing perspective, the development of self-regulated learning occurs through practice. Tasks are the "basic instructional unit in classrooms" (Lodewyk, Winne, & Jamieson-Noel, 2009, p. 2), providing students an opportunity to practice their self-regulation of learning and performance. However, tasks must enable or even require students to enact the strategies and processes involved in self-regulated learning for those tasks to serve as practice. Well-structured tasks restrict affordances for self-regulated learning, thereby limiting students' opportunity to practice it. Conversely, ill-structured tasks embed these affordances and often require self-regulation for successful completion or high performance (Lodewyk et al., 2009). Therefore, ill-structured tasks provide students an opportunity to practice and thus develop self-regulated learning. As a result, according to an information-processing perspective, incorporating more ill-structured tasks in students' coursework would promote self-regulated learning. Moreover, diversifying the strategies and processes necessary to navigate such tasks allows students to practice a wider array of them. However, ill-structured tasks should be introduced when students are developmentally ready to enact the strategies or engage in the processes required of them. For example, a task should not require complex planning before the skills and abilities underlying it have emerged. Once they have, teachers could promote the development of planning by intentionally and systematically varying the degree to which it is required in ill-structured tasks while scaffolding other processes and strategies not yet online.

As research into the broader array of strategies that serves self-regulated learning accumulates, additional practical applications are likely to emerge. In particular, the research we highlighted on internal and external resource management seems ripe for application. Our recommendation for more longitudinal research on self-regulated learning, if followed, would also yield findings that could be translated for practical application. For instance, that research should clarify when students become developmentally ready to learn how to learn and, thus, likely to benefit from interventions targeting different strategies and skills. The translation of findings from research on the development of self-regulated learning into programs and interventions promises the complementary payoffs of better academic outcomes, especially for at-risk students, and better models of self-regulation as they are refined to accommodate the results of evaluations of those efforts.

Note

The authors contributed equally to the writing of this chapter.

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5 Motivation and Affect in Self-Regulated Learning

Does Metacognition Play a Role?

Anastasia Efklides, Bennett L. Schwartz, and Victoria Brown

Introduction

Self-regulated learning (SRL) has been intensively and extensively studied during the past twenty years because it addresses both what people do in real-world learning situations and represents a model of optimal learning. That is, SRL serves as a model of what people actually do in learning situations and also as model of what maximizes learning. In terms of ecological approaches to learning, SRL captures what people do in learning both in and out of educational settings. For example, a musician must monitor her practice to ensure that a piece will be memorized by the time of performance, and a graduate student must monitor his learning until he is sure that he will pass his qualifying exams.

Theoretical models of SRL emphasize the role of motivation in goal setting in learning and the primacy of metacognition in the regulation of cognitive processing. They also acknowledge the role of affect (see Usher & Schunk, 2018/this volume; Winne, 2018/this volume), although the exact ways in which affect impacts SRL is less clearly specified. We assert that affect has major implications for current and subsequent learning activities before, during, or after a learning occasion. Affective responses (i.e., positive or negative affect and discrete emotions; see Pekrun, 2006) are present from the beginning to the end of an SRL event. Moreover, metacognition is also engaged throughout the learning process. Indeed, metacognitive experiences, such as feeling of difficulty or confidence, are a powerful aspect of conscious awareness acting in close connection with emotions. This poses the following question: Does affect exert its effects on the regulation of learning independently from motivation and metacognition?

Traditionally, the effects of emotions on learning are considered in association with motivation. In this chapter we claim that motivation, affect, and metacognition have distinct effects on the regulation of learning behavior. SRL is also informed by the interactions between affect, motivation, and metacognition. These interactions influence engagement with a learning task but also the monitoring and control of cognitive processing and performance. Actually, it is these interactions that reveal the dynamics of SRL.

To complicate the issue, there is mounting evidence that metacognitive monitoring is not always accurate, and control of cognition is not necessarily associated with monitoring (Schwartz & Efklides, 2012). Moreover, there is increasing evidence concerning the interaction of affect and metacognition (e.g., Efklides, 2016). Such evidence suggests that control can be triggered by both cognitive and non-cognitive factors, such as emotion. For example, a frustrated student may forgo his goals, whereas an energized student may seek to exceed hers. Thus, non-cognitive factors such as motivation and affect have implications for the exercise of control—e.g., task selection, effort expenditure, persistence (Efklides, 2011, 2016).

In what follows we shall, firstly, present the Metacognitive and Affective model of SRL (MASRL; Efklides, 2011) that provides the theoretical framework for understanding the interrelations between affect, motivation, and metacognition. Then, we will discuss the evidence on the mechanism underlying the interrelations between affect, motivation, and metacognition. The evidence suggests that there are (a) effects of cognitive states (e.g., fluency) on both metacognition and affect; (b) effects of affect on metacognition (e.g., negative mood increases the reported feeling of difficulty); (c) effects of motivation, such as perceptions of value, on metacognitive monitoring and control; and (d) effects of metacognition on affect and motivation (e.g., metacognitive experiences impact causal attributions and self-concept). This evidence provides the basis for identifying the role of metacognition in the triggering of achievement emotions. Finally, we will discuss the implications of the interactions of affect, motivation, and metacognition for research and educational practice.

The Theoretical Framework

SRL is conceived of as a series of events that ensure goal-directed, deliberate regulation of processing in learning tasks. The SRL process starts with goal setting, which is dictated, in a top-down manner, by the student's motivation, the task itself, and situational demands placed on the student. For example, one student may establish a goal of getting the highest marks in the class, whereas another student may merely wish to earn a passing grade. Once a goal has been set, metacognitive monitoring and control processes operate during task processing to assess and guide the person to that goal. The ensuing evaluation of performance and reflection on performance outcomes set the scene for a subsequent SRL cycle of goal-setting, metacognition, performance, and reflection (see Schunk & Zimmerman, 1998; Zimmerman, 2008). This conception of SRL provides the background for more detailed analysis of the interactions between motivational, affective, and metacognitive processes involved in SRL. These interactions are critical in the MASRL model (Efklides, 2011).

Before presenting the MASRL, and for reasons of clarity, we present some broad conceptualizations of the key terms in the model. First, we use the term affect as a generic term that includes emotions, mood, feelings, attitudes, etc. (see Forgas, 1994; Frijda, 1986). Feelings are the experiential aspect of emotions, but there are also nonemotional feelings (Efklides, 2016), such as metacognitive feelings that have the quality of pleasant or unpleasant but convey information about cognitive states. We use the term meta-cognition to denote monitoring and control of cognition (Flavell, 1979; Nelson, 1996). Metacognition can take the form of metacognitive knowledge (i.e., declarative knowledge or beliefs about cognition, persons as cognitive processors, tasks, strategies, and goals); metacognitive experiences (i.e., feelings and judgments as one works on a task); and metacognitive skills (i.e., strategies for the control of cognition) (Efklides, 2008). The distinct metacognitive forms have differential relations with cognition but also with motivation and affect.

The MASRL invokes two levels of generality to SRL function (see [Figure 5.1](#)). First, there is the Person level. At this level, decisions about learning are made based on relatively stable person characteristics and in terms of the representation of the situational and task demands. For example, a student may make a decision to engage in a learning task and spend a certain amount of time and effort in that task, based on prior knowledge of her performance on similar tasks, metacognitive beliefs in her abilities, motivational beliefs or goals, affect, and control beliefs. Affect is a relatively stable characteristic of the individual, and depending on the knowledge domain, it may have positive or negative valence. Let us take the case of a student who—despite a general deficit in learning new languages—must study really hard because mastering French is important for her career goals. Her affect (e.g., anxiety) towards this task may greatly influence the way in which she works to master her skills in French. Her decisions are based on an initial plan of the way that she will tackle the task based on her aptitude in French, the respective self-concept, motivation (e.g., achievement goals or expectancy-value considerations), metacognitive knowledge regarding learning French, and control beliefs, e.g., if she has control over the resources needed. Thus, at this level, a policy decision is made on the initiation of the relevant actions and effort to be expended on the task. In the example of learning French, the policy decision could be to start the course on French but only for one hour a week and for learning the basics rather than an advanced level. Policy decision means that it can be reviewed in face of evidence from the implementation of the decision.

However, the decision to study French in the above example is implemented at the Task x Person level. At this level, specific task processing takes place (cognition); that is, learning the material in each lesson such as vocabulary, grammar rules, writing, etc. The acquisition of new knowledge and skills is monitored internally through metacognitive experiences and externally by means of feedback or observation of learning outcomes. Monitoring informs as to the need to continue according to plan or to exercise cognitive and metacognitive control. For example, based on monitoring that reveals a weakness in learning verb conjugations, one might decide to do more exercises in grammar. This is the cognitive loop that involves both cognition and metacognition.

There is also the affective loop that monitors and controls the emotional and affective experiences or effort exerted in the learning situation. For example, the student experiences frustration when realizing that progress in learning

French is very slow. The regulation of affect or effort is carried out by the affective loop. For example, our student may downregulate the negative affect by thinking about the benefits she will have when she masters French. In this way, even negative affect may serve a useful function in SRL.

However, because the student has conscious awareness of both metacognitive experiences and affective responses, the regulation of learning can be based on a combination of information from both metacognition and affect. For example, metacognitive awareness of feelings of difficulty or knowledge that she has made errors may lead her to low judgment of learning and to feelings of helplessness. These experiences may then lead her to abandon her goals in the face of these obstacles or, more productively, seek

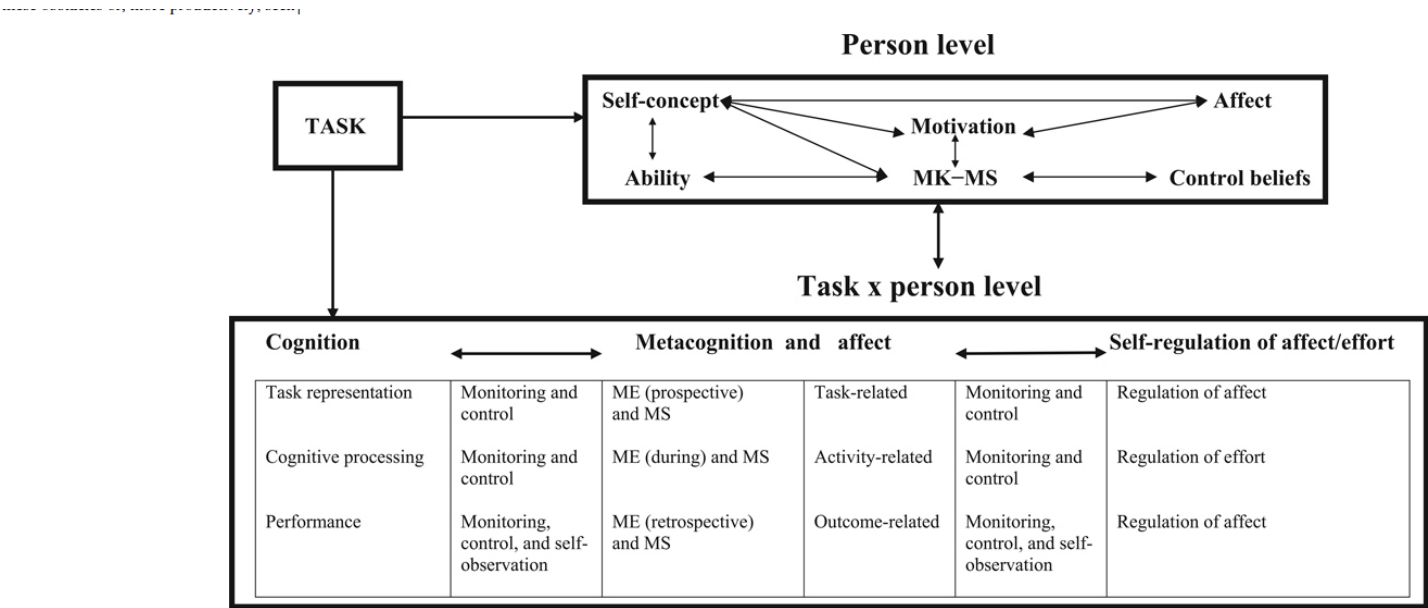


Figure 5.1 The MASRL model

Note: ME = metacognitive experiences; MK = metacognitive knowledge; MS = metacognitive skills

(Adopted from Efklides, 2011)

help from others. Resolving the problems that triggered the excessive feeling of difficulty (e.g., not understanding a grammatical phenomenon) turns the initial negative affect to positive (e.g., joy for understanding the grammatical phenomenon and being able to fill in the correct answer to an exercise). This positive affective state encourages further engagement with the learning task, because processing may be now more fluent, leading to higher judgments of learning and thus leading to a more positive cycle through SRL.

The above example is an illustration of the close relations between motivation, metacognition, and affect in SRL. These interactions are discussed below.

Affect and Metacognition

The relations between metacognition and affect can be much deeper than a rigid traditional distinction of cognition vs. emotion might entail. One way to conceptualize the basis of the relations between affect (e.g., emotions) and metacognition is their common central place in conscious experience. Before we consider how metacognition and affect interact in terms of promoting SRL, we briefly digress into some speculation on the similarity of metacognitive experiences and emotion, in terms of their phenomenological experience, which then may point to a common mechanism to derive action from feeling.

Consider first the phenomenology—that is, how things feel to the individual human mind. Metacognitive monitoring may occur at a non-conscious level (Reder, 1996), but its adaptive role is best manifested in conscious awareness. In a tip-of-the-tongue (TOT) state, we have a distinct feeling that we can recall something that we

presently cannot (Schwartz & Metcalfe, 2011). It is this feeling that makes the person aware that he or she should use some strategy to facilitate retrieval of the non-accessed information. In general, metacognition arises from internal processes that inform us as to whether we know, remember, or can reason successfully about something. Similarly, emotion arises from internal processes that inform us that our current state is pleasant or unpleasant, the nature of that pleasantness, and how strong that experience is (Aizawa, 2010). The feeling part of emotions is necessarily conscious. Both emotion and metacognition are psychological states that arise from non-sensory internal experiences. Thus, we make the claim here that the phenomenology of emotion and metacognition is similar, as they both arise to allow us flexible responding to internal rather than external conditions.

Switching from phenomenology to the underlying neurological roots of emotion and metacognition, we also see the potential for common mechanisms. Neurologically, emotion is associated with areas in the pre-frontal lobes (Arizmendi, Kaszniak, & O'Connor, 2016). In particular, the orbital-frontal cortex and the anterior cingulate gyrus are often found to be critical correlates of emotional experience (Gray, Bargh, & Morsella, 2013). Though any region of the brain may have multiple independent functions and very different functions from very close-by regions, it is of note that the same and spatially contiguous regions are also associated with metacognitive conscious experience (Chua, Pergolizzi, & Weintraub, 2014; Maril, Simons, Weaver, & Schacter, 2005). Many studies show that the anterior cingulate gyrus is important in metacognitive experiences such as tip-of-the-tongue states or the “aha” experience (see Metcalfe & Schwartz, 2016). Thus, this critical area seems to have a role in both metacognition and emotion. Other physiological evidence that connects emotion with metacognition comes from studies using event-related potentials (ERPs) that capture action errors and correct actions. Aarts, De Houwer, and Pourtois (2013) showed that error commission is associated with error-related negativity (ERN/Ne) and correct actions with correct-related negativity (CRN). ERN and CRN encode the perceived emotional significance of actions, and this evaluative process is automatic. That is, erroneous and correct responses have different affective valence.

The monitoring of error or correctness of response, however, is a metacognitive process, and it is reflected in metacognitive feelings such as confidence or awareness of error. Thus, metacognitive feelings and affective responses to error or response correctness are intertwined, and both metacognition and affect inform the person on the outcome of cognitive processing without the need of external feedback. Thus, the neuroscience data point to overlaps between metacognition and emotion.

Fluency, Affect, and Metacognitive Experiences

Another way to look at the relations between affect and metacognition is through the effects of cognitive states on both affect and metacognition. Fluency is the example par excellence. By fluency, we mean the ease or speed of processing material presented to participants (Rhodes & Castel, 2008). Many studies show that more fluently processed material leads to higher judgments of learning (JOLs), that is, participants feel that more easily processed material will be learnt faster or retrieved more quickly than less fluently processed material (e.g., Cleary & Claxton, 2015; Rhodes & Castel, 2008). However, fluency has effects on affect as well. Winkielman and Cacioppo (2001), using psychophysiological measures, showed that fluency is associated with positive affect. This finding is supported by a number of other studies. For example, fluently processed material is rated as more pleasant than less fluent material is (e.g., Monin, 2003). Disfluency, on the other hand, is associated with negative affect (Fritz & Dreisbach, 2013). Much earlier, Mandler (1989) found that when people were exposed to new pictures, they found these pictures to be more pleasant than those they had not seen earlier. Fluency also contributes to discrete emotions. For example, changes of interest during the execution of a task are explained by fluency but also by perceived difficulty—the task should not be too difficult (Fulmer & Tulis, 2013). This means that interest, as an emotion, is influenced by both fluency and perception of difficulty, which is a metacognitive judgment that denotes disfluency.

Summing up, cognitive states such as fluency/disfluency of processing give rise to both affect and metacognitive experiences. However, it might be the case that affect has direct effects on metacognitive experiences and the latter have effects on motivation and affect. These effects are discussed in the following.

Effects of Affect on Metacognitive Experiences

Metacognitive experiences are not only influenced by cognitive processing features such as fluency. They are also influenced by affect. For example, suppose a teacher enters a classroom in a sad mood. Does the teacher's affective state influence students' moods and metacognitive experiences? And are there implications for student effort expenditure or performance? To investigate these questions, researchers induced negative affect and tested the effect on experienced difficulty and mental effort. Specifically, Gendolla and Silvestrini (2011) showed participants masked emotional faces (sad, happy, or angry) and asked them to "do their best" in the task presented. Sad faces led to higher experienced difficulty and cardiovascular effort-related response whereas smiling and angry faces had the opposite effect. Efklides and her associates (Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006; Efklides & Petkaki, 2005), using self-reports, also found effects of induced negative mood (sadness) on feeling of difficulty and self-reported effort. However, the best predictor of effort was feeling of difficulty and positive affect, which suggests that positive affect provides the resources for effort exertion. From an SRL perspective, this would suggest that affect impacts metacognitive experiences but also metacognitive control in the exertion of effort.

Depressed mood also influences confidence about one's response. In a study by Lane, Whyte, Terry, and Nevill (2005), students reported on their anger, confusion, depression, fatigue, tension, and vigor ten minutes before a course exam. They also indicated the grades they had set as goals and their confidence they could achieve it. Students high in depression, unlike non-depressed ones, had low confidence that they could achieve their goal. Positive mood, on the other hand, increased confidence in their thought (also see Briñol, Petty, & Barden, 2007).

The complexity of the relations between affect and metacognitive experiences was also demonstrated by Strain, Azevedo, and D'Mello (2013). They presented participants with audio stimuli of false heart beats (biofeedback) while they worked on a learning task. Participants made prospective JOLs and retrospective judgments of confidence about the correctness of their responses. The faked heart beats were divided into three conditions: accelerated—suggesting high arousal—baseline, or no heart beats (control condition). Learners experienced more positive/activating affective states, made higher confidence judgments, and had better performance on the learning task under the accelerated and baseline biofeedback conditions than they did in the control condition, even though their actual heart rates were not being given. However, the positive effects of accelerated or baseline biofeedback were evident only in the case of difficult questions. This means that participants perceived the accelerated heart beats as indicative of effort and engagement on difficult questions, and this increased their metacognitive judgments.

The evidence on effects of affect on metacognitive experiences is limited but it seems that people, when becoming aware of their affective state, use it as a cue along with other cues that come from the monitoring of task demands, features of cognitive processing, and its outcomes. Such interactions of affect with metacognitive experiences have implications for the exercise of metacognitive control.

Motivation and Metacognition

Motivation in learning can be defined in terms of expectancy-value beliefs (Eccles & Wigfield, 2002), achievement goals (Elliot, 1999), or agenda-based regulation (Ariel, Dunlosky, & Bailey, 2009). Motivation effects on goal setting in SRL are mainly independent from metacognition. However, metacognitive experiences such as JOLs provide information to the student about task demands and the probability of attaining their goals such as learning new material for impending exams. Based on this information the student has to decide whether to focus on learning part or the whole of the material. This decision is made on cognitive grounds but also on the

value of the particular items that have to be learnt. That is, students may often find some information to be more valuable to review or study than others. This may be determined internally by interest or externally by the emphasis placed on certain material by their teachers. For example, students may study one aspect of the material more than others if they think this material will be useful in an essay part of an exam, which may be worth more of the final grade than other parts of the test.

Soderstrom and McCabe (2011) tested this assumption. They attached value points on items to be recalled in a cued recall paradigm. Value points refer to the worth of the item for performance. Participants made JOLs, that is, judgments about the probability that they will recall the list items. It was found that JOLs increased as a function of value but value did not impact performance on cued recall. Moreover, value and relatedness between the words to be recalled (task feature) jointly affected allocation of study time, which is a control strategy. These findings suggest that metacognitive judgments and control of memory are influenced by incentives, such as value. Indeed, in another study, Castel, Murayama, Friedman, McGillivray, and Link (2013) found that participants chose to restudy high-value items more than they selected low-value items for restudy.

Toppino and Cohen (2010) also showed that item point value (i.e., the worth of the item in the final test) influenced metacognitive control, that is, selection of spaced study. Spaced study is an efficient memory strategy that can be employed by students when the material to be learnt is difficult. This study showed that selection of spaced study was more often in items with high value than low value. That is, high-value items were more likely to be studied at greater time distances, whereas low-value items were more likely to be massed. Moreover, value functioned independently of item difficulty. Toppino and Cohen (2010) disentangled value from item difficulty, and it seems that metacognitive control is influenced by value rather than sheer item difficulty.

Although this kind of experimental evidence highlights the potential relations between motivation and regulation of cognition via metacognitive experiences, it is important to bear in mind that value is an appraisal that has affective implications. From this point of view, the effect of value on metacognitive experiences and metacognitive control might reflect effects of affect on metacognition and cognition rather than motivational components of the self-system. To further investigate the relations between motivation and metacognitive experiences we now turn to achievement goals.

Achievement Goals and Metacognitive Experiences

Achievement goals theory (for an overview see Senko, Hulleman, & Harackiewicz, 2011) posits that mastery goals aim at competence promotion, and hence are associated with effort exertion. Moreover, students with mastery goals view errors and failure as part of the learning process. Performance-approach goals aim at demonstrating competence and, for this reason, achievement is very important. Performance-avoidance goals, on the other hand, are more defensive and aim at not showing that one is incompetent. This means that students with mastery or performance-approach goals monitor their learning in progress as well as the outcomes of that learning (e.g., through their meta-cognitive experiences) because this information is critical for continuation of effort or use of strategies for the enhancement of learning and performance. Students with performance-avoidance goals, however, are concerned how others perceive their performance. This entails that extrinsic feedback rather than metacognitive experiences provides information of interest to them.

Efklides and Dina (2007) examined the relationship of achievement goals with metacognitive experiences and affect (interest, liking, anxiety) in junior high school students during math problem solving. They found that mastery and performance-approach goals positively correlated with retrospective metacognitive experiences such as estimate of solution correctness, confidence, and feeling of satisfaction. Performance-avoidance goals did not correlate with metacognitive experiences. Mastery goals correlated with interest and liking of the mathematical tasks, whereas performance-avoidance goals with state anxiety (Dina & Efklides, 2009). Although this kind of evidence is preliminary, it suggests differential relations of achievement goals with metacognitive experiences, but it is not clear if these relations are direct or indirect through the emotions associated with the various goals.

To sum up, motivation can have effects on metacognitive experiences but these effects can be direct or through affect. The next question to be answered regards possible effects of metacognitive experiences on emotions.

Metacognitive Experiences and Emotions

Cognition, Metacognition, and Epistemic Emotions

As already mentioned, fluency has implications for affect and metacognition. Awareness of disfluency and its metacognitive correlate, feeling of difficulty, are important for the regulation of cognition but also for epistemic emotions, such as surprise. Epistemic emotions have as their object knowledge states or knowledge processes. Some of the most representative epistemic emotions are surprise, curiosity, and confusion (Muis, Psaradellis, Lajoie, Leo, & Chevrier, 2015). Touroutoglou and Efklides (2010) showed that feeling of difficulty is associated with higher working memory load or with interruption of processing. Interruption of processing triggers revision processes, and this is effortful. However, interruption of cognitive processing is also associated with surprise. Surprise is experienced when an unexpected and discrepant to prior knowledge event is detected (Topolinski & Strack, 2015). So, for example, while our student is studying her French vocabulary, she may come across a particular word translation (e.g., “computer—ordinateur”). The perceived difficulty is both felt as a feeling of difficulty and as surprise. The role of surprise is to interrupt current processing so that all resources are given to the analysis and processing of the discrepant event. Thus, both feeling of difficulty and surprise facilitate the focusing of attention on events that require evaluation and revision of prior knowledge schemas (Meyer, Reisenzein, & Schützwohl, 1997).

Another cognitive state that has implications for epistemic emotions and metacognition is the lack of information on a topic of interest. Awareness of missing information lowers confidence in one’s answer but also may trigger curiosity. Curiosity is a particularly adaptive emotion because it supports exploratory behavior and search of new information that broadens and enriches one’s knowledge (Berlyne, 1954). Curiosity is driven by the desire to increase the amount of information available at a certain moment or the need to fill in information missing or not easily accessed. Thus, curiosity is associated with metacognitive experiences such as tip-of-the tongue or low confidence that the information is correct (Efklides, *in press*; Loewenstein, 1994).

Metacognitive Experiences and Achievement Emotions

Achievement emotions are defined as “emotions relating to competence-relevant activities or outcomes” (Pekrun, Elliot, & Maier, 2009, p. 116). They form an important part of emotions experienced in academic settings. Why would they be related to metacognition? Metacognitive experiences have, besides the monitoring of cognition function, a self-referential function as well (see also Cosentino, Metcalfe, Holmes, Steffener, & Stern, 2011; Metcalfe & Schwartz, 2016). They convey information about cognitive processing but also about its implications for the self (e.g., disfluency suggests increased probability of error and possibly a lack of ability in relation to a task). Metacognitive experiences provide internal feedback about one’s capability to deal with an achievement or learning situation. Furthermore, by focusing on features of cognitive processing metacognitive experiences also indicate the possible cognitive causes (e.g., fluency/disfluency of processing) of performance outcomes. In this capacity, they point to potential control processes that can remedy or prevent disfluency, such as the use of cognitive or metacognitive strategies. Thus, metacognitive experiences trigger control decisions, update self-concept, and offer the ground for appraisals that give rise to achievement emotions.

Specifically, when entering a learning situations, students make appraisals about their ability to learn and produce a desired outcome. They base their appraisals on their prior experiences with similar tasks, performance outcomes, and attributions about their ability, effort, task difficulty, or luck. Indeed, students persist with learning or quit the attempt, depending on whether they attribute their success to their own efforts or competence (internal causes) or to task difficulty or luck (external causes), whether they feel they are in control of learning, or whether the causes of learning outcomes are stable over time or not. Causal attributions and their underlying dimensions form the basis for appraisals of learning outcomes and discrete emotions (Weiner, 1985, 2014). Evidence connecting

metacognitive experiences with causal attributions was provided by Metallidou and Efklides (2001). They showed that the subjective experience of effort and feeling of difficulty is indicative of lack of fluency and can be attributed to task difficulty or personal incompetence. Confidence in the response produced, on the other hand, boosts attributions of competence.

Self-Concept

Sense of competence is critical for self-efficacy (Usher, 2009) but also for self-concept (Dermitzaki & Efklides, 2000). Self-efficacy captures the person's confidence that they can bring about a certain outcome. Self-concept, on the other hand, is a broader construct that captures one's sense of competence. It includes self-perception, self-efficacy, self-esteem, and what the person believes about other people's perceptions of his or her ability. Self-concept is built based on feedback from others but also on feedback from subjective experiences during an activity. The relation between self-concept and metacognitive experiences was shown by Efklides and Tsiora (2002). Specifically, self-concept predicts and is predicted by metacognitive experiences such as feeling of difficulty, estimate of effort, and confidence. The integration of the positive and negative information about the self as agent in different but related situations informs the self-concept as to our capabilities in a knowledge domain. Then self-concept becomes the basis for prospective metacognitive judgments about task demands in relation to one's self and its resources (Efklides & Tsiora, 2002).

Metacognitive knowledge of the self as a learner (Efklides, 2008) encodes information about how fluently and how correctly we learn in different knowledge domains. This suggests that there are relations between self-concept and metacognitive knowledge of the self. This hypothesis was tested by Efklides and Vlachopoulos (2012) in relation to basic mathematical knowledge and skills. They found that self-concept was related to metacognitive knowledge of the self, particularly knowledge denoting tasks the person believes they are processing fluently. Moreover, self-concept but not meta-cognitive knowledge predicted metacognitive experiences such as feeling of difficulty. This means that self-concept is informed by metacognitive knowledge but has aspects that go beyond it.

The studies showing effects of metacognitive experiences on attributions and self-concept do not directly address effects on emotions. They rather suggest that the effects of metacognitive experiences on achievement emotions are indirect through causal attributions or self-concept. This is in line with Pekrun's (2006) control-value theory of achievement emotions, to which we now turn.

Control-Value Theory of Achievement Emotions

Pekrun's (2006) control-value theory of achievement emotions is the theory most pertinent to emotions, learning, and self-regulation. When students enter a learning situation, there is the acting person (e.g., self), the achievement-related activities (e.g., being in the classroom, studying or doing homework, taking exams), and the outcomes of these activities (e.g., performance, school grades). The learning situation places demands on students' resources, regardless of whether they are cognitive (e.g., aptitude, prior achievements, learning strategies), motivational (e.g., interest, value beliefs, motivation to learn), or volitional (e.g., perceptions of control). Perceptions of control involve students' expectancies about their self-efficacy to achieve a particular outcome (e.g., succeed) or carry out a particular action (e.g., study the exam material efficiently within a given time frame).

Based on the appraisals made, one can experience prospective outcome emotions (e.g., anticipatory joy, hope, or anticipatory relief, anxiety, hopelessness), retrospective outcome emotions (e.g., pride, gratitude, and joy in successful outcomes, or shame, anger, or sadness in failure), and activity-related emotions (Pekrun, 2006). During the activity for the attainment of a goal, there are activating (high arousal) or deactivating (low arousal) activity-related emotions such as enjoyment, anger, frustration, boredom, or relief.

Prior school performance. Prior achievement, academic self-concept, achievement goals, and intrinsic motivation are distal antecedents of achievement emotions, whereas perceived academic control and value beliefs are proximal antecedents of achievement emotions (Pekrun, 2006). Specifically, prior school performance influences subsequent activity-related emotions, such as enjoyment and boredom. Boredom, in particular, has negative effects on test performance, and performance has negative effects on subsequent boredom in an academic course (Pekrun, Hall, Goetz, & Perry, 2014). However, the effect of prior school achievement on enjoyment, but not boredom, is mediated by academic self-concept (Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010). Boredom is mainly triggered by situational characteristics that decrease arousal or violate one's expectations about what is important in a learning situation (see Galla, Plummer, White, Meketon, D'Mello, & Duckworth, 2014).

Self-concept. Metacognition, as already mentioned, is implicated in achievement emotions indirectly via its effects on self-concept. There is, however, evidence suggesting a mediating role of metacognitive experiences between performance and self-concept effects on outcome-related emotions. Tornare, Czajkowski, and Pons (2015) studied students' joy, pride, contentment, worry, shame, and hopelessness after the solution of a math problem. They examined the effect of self-concept, metacognitive experiences such as feeling of difficulty and feeling of success, and performance on outcome-related emotions after controlling for gender and emotions before math problem solving. The interesting finding is that the effect of performance on outcome-related emotions was mediated by metacognitive experiences. Only in the case of hopelessness was there a direct effect of performance. Self-concept contributed to joy, pride, and shame, but the effect was mediated by metacognitive experiences, and particularly by feeling of success. Moreover, metacognitive experiences were significant predictors of all emotions except worry.

Dina and Efklides (2009), on the other hand, showed that metacognitive experiences directly impacted state anxiety. In their study, they provided external feedback to secondary education students regarding their success or failure on mathematical problems they had solved. External feedback was assumed to offer the grounds for outcome-related appraisals and, hence, emotions such as state anxiety. However, Dina and Efklides (2009) found that the effect of external feedback on state anxiety was not significant. Self-concept and mathematical ability did not predict state anxiety. The main predictors were trait anxiety (as expected) and, most importantly, metacognitive experiences. High confidence that the response was correct prevented state anxiety whereas awareness of increased effort contributed to it. Therefore, metacognitive experiences may be implicated in achievement emotions in multiple ways because they provide evaluative feedback on one's performance during the actual task processing.

Achievement goals. Achievement goals are significant distal antecedents of achievement emotions. Specifically, mastery goals positively predict enjoyment, hope, and pride, and negatively predict boredom, anger, and shame. Performance-approach goals positively predict hope and pride, whereas performance-avoidance goals positively predict anxiety, hopelessness, anger, and shame, and negatively predict pride and hope (Daniels, Stupnisky, Pekrun, Haynes, & Perry, 2009; Pekrun et al., 2006, 2009).

Moreover, achievement goals can mediate situational effects on achievement emotions. Specifically, Pekrun, Cusack, Murayama, Elliot, and Thomas (2014) showed that the type of anticipated feedback in a testing situation—be it self-referential, normative, or no feedback—impacted achievement emotions, but this effect was mediated by achievement goals. Self-referential feedback favored test-specific mastery goals, whereas normative feedback favored performance goals, both approach and avoidance. Achievement goals then predicted emotions as reported at the end of testing and before feedback was given.

Yet, during task processing achievement emotions can impact achievement goals as well. Daniels et al. (2009) showed that prospective emotions such as hopefulness and helplessness differentially predicted achievement goals. Specifically, hopefulness positively predicted mastery and performance-approach goals, whereas

helplessness negatively predicted mastery goals at the beginning of an academic course. The possible effect of metacognitive experiences in this change of emotions during task processing is yet to be investigated.

Proximal Antecedents of Achievement Emotions

Perceptions of control. Evidence on the role of perceived academic control in achievement emotions was provided by Perry, Hladkyj, Pekrun, and Pelletier (2001). They found that perceived academic control and action control (unlike preoccupation with failure) are negatively related to boredom and anxiety. They are positively related to achievement and use of SRL strategies such as motivation control strategies, self-monitoring strategies, and effort exertion.

Perceptions of value. Another proximal antecedent of achievement emotions are value appraisals. Value can take various forms (Eccles & Wigfield, 2002). There is intrinsic value (personal interest), utility value (when a task is instrumental for achieving another goal), attainment value (importance of doing well in a task, e.g., for one's self), and cost. Cost is negative value, and it can take the form of effort required as compared to one's resources, the potential of losses in other valued activities, or anxiety over potential failure. Metacognition is implicated in value appraisals particularly as regards to cost. Specifically, feeling of difficulty and awareness of excessive effort are indicators of cost as one works on a task. Take, for example, the remembered utility effect (Finn, 2010). Consider a student who is engaged in a difficult task that requires intensive effort (Task A). Then they are given a second task (Task B) that comprises a similar number of items of similar difficulty as Task A but also a number of extra items of lower difficulty following the difficult ones. At the end of the study period students are asked which task (A or B) they would choose to work on again at a later time. As Finn (2010; Finn & Miele, 2016; see also Hoogerheide & Paas, 2012) showed, students select Task B although the rational decision would be to choose Task A. That students base their decision on the experienced difficulty, and Task B "ended on a high note," that is, less experienced difficulty, suggests that metacognitive experiences inform on the cost of learning and the utility value of tasks.

Further evidence for the role of experienced ease or difficulty of processing in the determination of utility value is the "instrumentality heuristic." Lambroo and Kim (2009) showed that when people pursue a goal they invest effort on whatever means they believe is conducive to the attainment of their goal. Thus, the experienced difficulty and effort are perceived as instrumental for goal attainment. Then, whenever a difficult object is perceived as means for their goal, its difficulty is desirable (i.e., it has value) because it is believed to be instrumental to achieving their goal.

Perceptions of cost, on the other hand, form part of the metacognitive knowledge regarding effort and its outcomes. While working on a task students experience feelings of difficulty, effort in the form of cognitive elaboration and/or physical or mental exhaustion (e.g., headache, depletion of resources, fatigue), and monitor the success or failure in their efforts. Efklides et al. (2006) showed that students have two sets of ideas regarding effort and its outcomes: one that effort and persistence are instrumental for success and one that effort is hard, has negative side-effects, and does not necessarily lead to success. This entails that effort for some students has utility value but for others it has cost, because the probability of success is low. Whether this kind of metacognitive knowledge has implications for achievement emotions has yet to be investigated.

To sum up: metacognitive experiences provide subjective feedback on one's competence, control, and task value. Delimiting the complexity of the interrelations between metacognition, motivation, and achievement emotions, however, is a challenge for future research.

Future Research Recommendations

SRL is a dynamic process that integrates one's learning goal with information from the task and the person's past and current experiences in various learning situations. These experiences include, among others, metacognitive experiences (e.g., JOLs) and emotions (e.g., disappointments due to past failures to learn foreign languages). The evidence presented in this chapter aimed to reveal interactions of motivation, affect, and metacognition (as person characteristics and subjective experiences as one works on a task) in order to broaden and enrich our conception of self-regulation processes. Such a framework has implications for theory but also for educational practice.

In terms of theory, some critical issues future research should address are the following:

SRL is a long-term process. In the real world people have to plan their learning over individual sessions and across college semesters and extended training periods on the job. This contrasts with metacognitive control, which usually is about determining what the next item to study will be—and over the course of minutes, not months. The studies that we have presented in this chapter depict self-regulation at the task level or at larger time frames at the level of course, exams, etc. At this point there is limited research addressing these multiple levels at the same time. More complex and longitudinal designs are needed to answer the question of how task-specific metacognitive and affective experiences—that are momentary and variable across situations—are transformed into more stable person characteristics or emotional states (e.g., hopelessness). Does the person keep track of metacognitive and affective experiences and reflect on them, or is affect encoded in memory implicitly and operates subconsciously, outside of the person's control? Are particular combinations of metacognitive and affective experiences (e.g., feeling of difficulty and frustration) more critical than others (e.g., JOL and surprise)? Is repeated exposure to similar experiences a condition for their long-term effects in SRL or does a single emotional experience (e.g., a negative emotion) suffice for shaping future responses to similar tasks?

Another issue deserving more research regards epistemic emotions. Research on emotions in learning has in the main focused on achievement emotions and less on epistemic emotions. However, epistemic emotions can support or undermine SRL and new learning. For example, curiosity can strengthen exploration of the learning material whereas unresolved confusion can lead to quitting of effort. The question is whether epistemic emotions exert their effects in association with affect (as person characteristic, e.g., attitudes towards a knowledge domain) or momentary task-specific affect (positive or negative) (Efklides, in press) or other emotions. For example, surprise can trigger other epistemic emotions, such as curiosity, or achievement emotions, such as situational interest. In such interactions between emotions metacognitive experiences play a significant role, because they offer information about the value of, and control over, the learning situation. Thus, the question is whether epistemic emotions exert their effects on cognition directly, or indirectly via metacognition or through interactions with other concurrent achievement emotions. To put it more broadly, future research should highlight the interrelations between metacognitive experiences and emotions but also between epistemic and achievement emotions.

Finally, the regulation of metacognitive experiences and emotions is another critical issue for SRL research. A lot of research in metacognition deals with the calibration of metacognitive experiences, which is an implicit process. However, if metacognitive experiences have an affective component then it might be the case that students explicitly up- or downregulate particular metacognitive experiences as a means to regulate their emotions and learning. For example, a student deliberately decreases confidence in the response produced (e.g., by doubting its correctness) in order to increase negative affect and ensure further engagement with task processing because she wants to get the best possible grade in the ensued exam. Downregulation of confidence increases state anxiety or curiosity, and the emotions then provide the energy for further cognitive processing.

Obviously, research on emotions in learning has a lot to offer in the future in relation to both student well-being and learning. Looking at the interactions of emotions with motivation and metacognition is a promising line of research because it can reveal the role of emotions in cognitive processing and its regulation but also the role of cognition and metacognition in the formulation of task-specific motivation and emotions that can be constructive

for learning. This has implications for educational practice and particularly the efficiency of interventions for more effective learning.

Implications of the Interrelations between Affect, Motivation, and Metacognition for Practice

Advances in theory open the way for interventions that can enhance learning. In the past, interventions for the advancement of learning mainly focused on cognition and metacognition. However, the interactions between cognition, metacognition, and affect suggest that there can be interventions targeting emotions that have the potential to support learning as well. For example, Tzohar-Rozen and Kramarski (2013) applied an affective self-regulation program in order to enhance mathematical performance in fifth-grade students and had satisfactory results. They showed that students who were better at affective self-regulation also did better on mathematics performance. Ben-Eliyahu and Linnenbrink-Garcia (2015) studied affective (e.g., reappraisal, suppression), behavioral (e.g., environmental control, planning), and cognitive (e.g., cognitive focusing, metacognition) forms of regulation along with SRL strategies (deep and surface processing, organization, engagement with course work) to predict achievement. All forms of regulation were related to learning strategies, but, in contrast to other results, they found that the links to achievement were less strong. They also found that students self-regulate more in their favorite courses. This means that a positive affective background is essential for investing resources to self-regulation. It also means that part of the teachers' efforts should be addressed to emotions in the classroom, and that emotional regulation supports learning.

Another implication for practice is understanding the change of self-regulation processes from top down to bottom up. SRL models claim that SRL is a top-down process. However, often students use more of a trial-and-error strategy without a clear goal. They base their decision to go on with a task or not on their metacognitive and affective experiences during task processing rather than a pre-specified goal. For example, Koriath and Nussinson (2009) showed that study time in self-paced study is a cue monitored in learning because it is indicative of processing fluency. More time spent on an item is suggestive of greater subjective difficulty (disfluency in memory retrieval). Hence, JOLs tend to decrease with increased study time. Control in this case (e.g., time devoted to learning) is bottom up (data-driven) because it is determined by the ease of processing rather than the goal or time available. The remembered utility effect (Finn, 2010) is arguing in the same direction. For practice this implies that teachers should organize the presentation of tasks in a way that takes advantage of metacognitive and affective experiences of students rather than expecting rational decisions and top-down self-regulation.

A third implication for practice has to do with the regulation of emotions. Regulation of emotions is an ongoing process in life and learning in particular (see Ben-Eliyahu, & Linnenbrink-Garcia, 2015; Strain & D'Mello, 2015; Tyson, Linnenbrink-Garcia, & Hill, 2009). Regulation of emotions can be deliberate and explicit, implicit, or supported by teachers, parents, or peers. One can envisage that metacognitive experiences are implicated in emotion regulation but presently there is no research directly addressing this issue. Despite this, Lambroo and Kim's (2009) research showed that experienced difficulty can be re-appraised as a positive aspect of the learning task.

Evidently, the challenges for practice are high but knowing how effective teachers manage student learning, despite the limitations mentioned above, is a good source of inspiration.

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6 Self-Regulation, Co-Regulation, and Shared Regulation in Collaborative Learning Environments

Allyson Hadwin, Sanna Järvelä, and Mariel Miller

Introduction

Early socio-cognitive conceptions of self-regulated learning (SRL) emphasized individual, cognitive-constructive aspects involved in cognition, behavior, and motivation, as well as social context as a component in the triadic process of self-regulation (Schunk & Zimmerman, 1997; Zimmerman, 1989). More recently, situated perspectives of learning have extended theories and models of self-regulation to highly interactive and dynamic learning situations where shared knowledge construction and collaboration emerge. Self-regulated learning became a cornerstone for exploring more social forms of regulation such as co-regulation and shared regulation.

In the late 1990s and early 21st century, a handful of scholars began to define and explore two social modes of regulation including co-regulation and shared regulation (Hadwin, Wozney, & Pontin, 2005; Järvelä, Järvenoja, & Veermans, 2008; McCaslin & Good, 1996). Since 2000, we have carefully defined and conceptualized three modes of regulation operating in highly interactive and collaborative learning contexts (Hadwin, Järvelä, & Miller, 2011; Hadwin & Oshige, 2011; Järvelä & Hadwin, 2013). Self-regulated learning refers to individual learners taking metacognitive control of cognitive, behavioral, motivational, and emotional conditions/states through iterative processes of planning, monitoring, evaluation, and change. Socially shared regulation refers to groups taking metacognitive control of the task together through negotiated, iterative fine-tuning of cognitive, behavioral, motivational, and emotional conditions/states as needed. Finally, co-regulation refers to the dynamic metacognitive processes through which self-regulation and shared regulation of cognition, behavior, motivation, and emotions are transitionally and flexibly supported and thwarted. Attention focuses on affordances and constraints as mechanisms for shifting regulatory ownership to an individual (self-regulation) or group (shared regulation).

Since then, the field has rapidly burgeoned with interest in social modes of regulation extending well beyond the field of educational psychology to learning sciences, higher education, learning technologies, science education, computer science, and computer-supported collaborative learning (CSCL). Simultaneously a proliferation of terms has emerged for describing and coding regulation, often times divorced from the metacognitive foundations of SRL. This chapter revisits and updates our earlier conceptualizations of social modes of regulation in collaboration (Hadwin et al., 2011) with the aim of: (a) summarizing relevant theoretical ideas, (b) grounding these constructs in their educational psychology foundations, (c) highlighting contemporary research evidence bearing on these ideas, (d) offering directions for future research, and (e) discussing implications for practice.

Relevant Theoretical Ideas

Critical Features of Regulation

Our perspectives of regulation, grounded in educational psychology, build on almost two decades of research and theory development in self-regulated learning (cf. Zimmerman & Schunk, 2011). Therefore, cognition, motivation, and metacognition serve as the bedrock for self-regulated, co-regulated, and shared regulation of learning. Overall contemporary perspectives view regulated learning as a complex cyclical metacognitive and social process involving adaptation of thought, motivation, emotion, and behavior (e.g., Boekaerts, 1996; Zimmerman & Schunk, 2011; Winne & Hadwin, 1998). Six assumptions underlying this statement are essential for accurately defining and operationalizing self-, co-, and shared regulation.

- First, regulation is multifaceted. Regardless of whether the focus is self-, co-, or shared regulation, the processes and products of regulation extend beyond cognition in its purest form. Regulation involves taking control of motivation, emotion/affect, behavior, and cognition. Metacognitive monitoring, evaluation, and control fuel regulated learning, but they are not regulation in and of themselves. Furthermore, facets of regulation (motivation, behavior, metacognition, and cognition) are not isolated during regulation but instead influence one another. For example, metacognitive knowledge generated during group planning has potential to create new emotional conditions informing future collaborative work.
- Second, regulation assumes human agency. Individuals, individuals in teams, and teams themselves have the capacity to make choices and to impose those choices on tasks, situations, and other teammates. Agency has two important implications. First, it recognizes learners have purpose, intent, and goals. Those goals are not necessarily transparent or aligned with task goals or objectives set by others. Inherently, this means exploring learner goals and their alignment with the external task objectives is essential for understanding regulation. Without knowledge of learner intent, inferences about observed strategies, behaviors, motivation, and emotions are limited at best. Second, since exercising human agency is at the heart of regulation, poor alignment between learner and instructor goals should not be equated with poor self-regulation. Learners who hold accurate interpretations of the task at hand and choose to work toward different goals/standards are exercising self-regulatory competence such as when students lower the standards for a task to make it achievable given their current prior knowledge or skill competencies.
- Third, regulation involves cyclical adaptation. Regulation is not a state—it is a series of contingencies over time. For example, Zimmerman and Schunk (2011) model regulation at a macro-level over the broad phases of a task from beginning to end with each phase informing the next. Winne and Hadwin (1998) model regulation at a more precise micro-level with COPEs (i.e., Conditions, Operations, Products, Evaluations, and Standards) building cyclically within and across task events, phases, and episodes. Regardless of grain size, both perspectives emphasize regulation as a temporally unfolding process emerging from, and continuing to shape, future beliefs, knowledge, and experiences. To examine regulation requires collecting data over time and context.
- Fourth, this cyclical perspective acknowledges all regulation draws from personal socio-historical experiences. Learners and teams bring complex knowledge, beliefs, and mental models of self, task, domain, and teams to every learning situation. They build from these complex pasts, meaning learner approaches and decision-making processes are heavily contextualized and personalized by prior individual and group experiences. Although multimodal data can provide rich accounts of learners' observed actions and reactions in the moment, researching regulation also requires an understanding of the beliefs, self-perceptions, and mental models that shape and are shaped by these observed actions and reactions over time and events.
- Fifth, regulation involves adaptively responding to new challenges, situations, or failure, thereby optimizing personal goal progress and standards. Regulation is not what people do automatically when things are proceeding well—the mark of regulation is intent or purposeful action in response to situations and challenges. Adaptation in the face of difficulty cannot be observed any time, any place. Nor is it action without agency or intent. Rather, regulation is strategically enacted when self, task, domain, or social conditions demand it. For example, learners enact positive self-talk when negative self-efficacy lowers task engagement or performance, or when a situation is anticipated to lower efficacy. Learners overtly articulate and set goals when task engagement wanes or procrastination takes over. Regulation involves timely rather than persistent self-monitoring and action. Further, the proficiency with which people toggle regulation on and off creates cognitive capacity for complex processing.

- Finally, regulation is socially situated involving dynamic interplay between learners, tasks, teachers, peers, parents, context, and cultures (Hadwin, 2000; Järvenoja, Järvelä, & Malmberg, 2015). Regulation emerges when learners engage with personally meaningful learning activities and situations infused with (a) personal meaning, (b) outcome utility, (c) task value, and (d) past experiences. In these situations, cultural milieu, relationships, interactions, context, and activities give rise to self-regulation, co-regulation, and shared regulation of learning. We specifically draw from Winne and Hadwin's model of SRL (briefly described below, p. 89) because it acknowledges that the self and socio-contextual conditions shape, and are in turn shaped by, regulatory engagement within and across tasks. In other words, this model acknowledges the situated nature of regulation and can be used to model interaction amongst three modes of regulation: self-regulated, co-regulated, and shared regulation of learning.

Three Primary Modes of Regulation in Collaboration

Our early work proposed three primary modes of regulation in collaborative learning: self-regulated learning, [socially] shared regulation of learning, and co-regulated learning. The following revisions to those constructs more adequately address conceptual and empirical challenges emerging in the past five years.

Self-Regulated Learning (SRL) in Collaboration

SRL refers to an individual learner's deliberate and strategic metacognitive planning, task enactment, reflection, and adaptation in a joint task. It involves individuals taking personal responsibility through iterative fine-tuning of cognitive, behavioral, motivational, and emotional conditions/states as needed. Self-regulation is: (a) deeply metacognitive—monitoring and evaluation drive large- and small-scale adaptation; (b) agentic—personal goals and perceptions serve as standards for monitoring and evaluating; and (c) socio-historically and contextually situated—SRL shapes and is shaped by personal and group-based beliefs and experiences, the environment, and collaborative task engagement.

Importantly, we posit individual self-regulation in the service of the group task is absolutely necessary for optimal productive collaboration to occur. Evidence of self-regulated learning during collaboration is complementary rather than antagonistic to the emergence of shared regulation.

Socially Shared Regulation of Learning (SSRL) in Collaboration

SSRL refers to a group's deliberate, strategic, and transactive planning, task enactment, reflection, and adaptation. It involves groups taking metacognitive control of the task together through negotiated, iterative fine-tuning of cognitive, behavioral, motivational, and emotional conditions/states as needed. [Socially] shared regulation is: (a) transactive—multiple individual perspectives contribute to joint metacognitive, cognitive, behavioral, and motivational states; (b) deeply metacognitive—monitoring and evaluation are shared amongst people to drive negotiated large- and small-scale adaptation; (c) collectively agentic—joint goals and standards are intentionally adopted (informed by, but not necessarily replacing, individual goals) for monitoring and evaluating together; and (d) socio-historically and contextually situated—individual and collective beliefs and experiences create a set of shared conditions continually shaping and being shaped by joint task engagement.

Importantly, shared regulation does not imply dissolving or devaluing of individual regulation in collaboration nor does it equate with collective sameness. Individuals can hold the same goal (collective sameness) without having a shared or negotiated task goal. For example, individuals in a group might assume they are all aiming for the same thing without creating any opportunity to confirm or align goals. What distinguishes socially shared regulation from co-regulation (described below) is the extent to which joint regulation emerges through a series of transactive exchanges amongst group members. Joint beliefs, outcomes, strategies, and awareness intentionally co-emerge rather than being guided or directed by any one person, although they may initially be stimulated by co-regulatory prompts, questions, or statements. Shared regulation implies some sort of elaborative transformation in regulation negotiated between group members. Metacognitive knowledge or processes are not

simply the same across a team, nor guided and supported by one another; rather, SSRL implies jointly evoked regulative acts and jointly emerging perceptions.

Co-Regulated Learning (CoRL) in Collaboration

CoRL refers broadly to affordances and constraints stimulating appropriation of strategic planning, enactment, reflection, and adaptation. Typically co-regulation involves transitional and flexible stimulation of regulation often through interpersonal interactions and exchanges. Co-regulation creates affordances and constraints for productive self-regulated learning and/or shared regulation of learning. This important broadening of our earlier descriptions of co-regulation acknowledges the role co-regulation plays in shifting groups toward more productive shared regulation. It is consistent with empirical findings indicating co-regulatory affordances (such as prompts) are often embedded in episodes of shared regulation (e.g., Grau & Whitebread, 2012). Refining our conceptualization emphasizes co-regulatory affordances, and constraints may be embodied in people's actions and interactions, socio-contextual features of the environment, task design, tools or resources for regulation, or cultural beliefs and practices either supporting or thwarting productive regulation. Through co-regulation, shifts in regulation are made possible, such as fine-tuning cognitive, behavioral, motivational, and emotional conditions/states as needed.

Through this temporary and shifting support amongst group members (a) awareness of each other's goals, beliefs, and progress develop and are shaped by other members of a group, and (b) the active processes of monitoring and regulating can be temporarily offloaded to each other or to tools and technologies. CoRL occurs when regulation of cognition, motivation, emotion, and/or behavior are temporarily redirected or shaped as needed. Co-regulation can be initiated by: (a) the regulator, such as when regulatory support is requested (e.g., asking someone to clarify the task criteria); (b) others, through prompting an individual to engage regulatory processes or practices (e.g., prompting someone to check their notes); or (c) technologies (e.g., a reminder ping to check the time).

To ameliorate misrepresentations in the field, we offer two important clarifications about co-regulation. First, while prompts cue co-regulation, they are not co-regulation in and of themselves because co-regulation implies a shifting or internalization of regulatory processes (Hadwin et al., 2005). Co-regulation is a temporary and shifting support enabling future regulatory uptake by the "co-regulated." Second, co-regulation does not imply a single "more capable other." Rather, it implies regulatory expertise is distributed and shared across individuals and evoked when necessary by and for whom it is appropriate. This latter point sometimes makes co-regulation difficult to distinguish from shared regulation. This is because consistent and productive co-regulation in a group is likely a necessary condition for shared regulation to take hold.

Miller and Hadwin (2015a) demonstrated two varieties of co-regulation emerge in the complexity of collaborative work. First, support can come from one person, multiple team members, or from affordances from the technological environment (e.g., timekeeping or contribution records) or the group as a whole. Second, regulation may be supported or stimulated in one individual or collectively across members of a group such as when a prompt shifts the way each individual looks at the problem. This type of collective uptake in regulation blurs the boundary between co-regulation and shared regulation particularly when it is being coded in conversation alone. Further, by leveraging distributed metacognitive knowledge, skills, and regulatory expertise across individuals, co-regulation stimulates both self-regulatory and shared regulatory processes. Without CoRL, opportunities for shared regulation, group innovation, and successful task completion would be constrained.

Groups working on a common task or project, for which there is collective responsibility, can be conceptualized as social systems comprised of multiple self-regulating individuals who must, at the same time, guide and support regulation as well as regulate together as a collective social entity (Hadwin et al., 2011; Volet, Vauras, & Salonen, 2009). Self-, co-, and shared regulation arise simultaneously and reciprocally over time within physical and social contexts (Hadwin et al., 2011). Co-regulation occurs when affordances or constraints are appropriated by individuals (self-regulation) or groups (shared regulation) to fundamentally provoke strategic monitoring, evaluating, or adapting of motivational, behavioral, cognitive, and/or affective products within and across phases

of regulation. Therefore, co-regulatory affordances (and sometimes constraints) appear within episodes of shared regulation and self-regulation. Once affordances (or constraints) begin to shape strategic planning, task enactment, or adaptation, co-regulated learning is observed. Rather than blurring the boundaries between co-regulation and shared regulation, this perspective acknowledges co-regulation is fundamental in the reification of both self- and shared regulation.

Toward a Model of Regulation in Collaboration

Winne and Hadwin (1998, 2008) characterize self-regulated learning as unfolding over four weakly sequenced and recursively linked phases (cf. Winne, 2018/this volume). In Phase 1: Task understanding, learners construct interpretations or perceptions of the task. In Phase 2: Goal setting and planning, learners draw on their perceptions of the task to set personal goals to attain during the task and make plans regarding how to strategically approach the task to reach them. In Phase 3: Task enactment, learners engage in the joint task, drawing flexibly upon a range of strategies to achieve goals. Processes, progress, and products of each phase are metacognitively monitored and evaluated, leading learners to exercise metacognitive control by strategically adapting task perceptions, goals, and engagement when needed (Phase 4: Large- and small-scale adaptation). This adaptation may occur on the fly to optimize learning in the current task (small-scale adaptation) or may involve larger-scale changes contributing to future tasks (large-scale adaptation). Importantly, project work comprises multiple opportunities to circulate through phases of SRL. Each time a person or group sits down to work, new cycles of regulation are instantiated, each building from the last. From this perspective, phases of regulation evolve, being updated within and across project work sessions.

In teamwork, shared regulation also unfolds over four loosely sequenced and recursive phases. During Phase 1, groups negotiate shared perceptions or interpretations of the collaborative task. In Phase 2, groups draw on their collective awareness of task conditions, contexts, and target outcomes to negotiate shared goals, standards, and plans for the task. In Phase 3, groups coordinate strategic task engagement, collectively and flexibly drawing upon a range of cognitive, socio-emotional, behavioral, and motivational strategies. Strategies are co-constructed and distributed, thereby leveraging individual metacognitive and meta-motivational knowledge and capacities for the greater good of the group. Throughout these regulatory cycles, collective monitoring and evaluation emerge to guide team decision-making and adaptation of collaborative processes, progress, and products, thereby intentionally optimizing learning where needed.

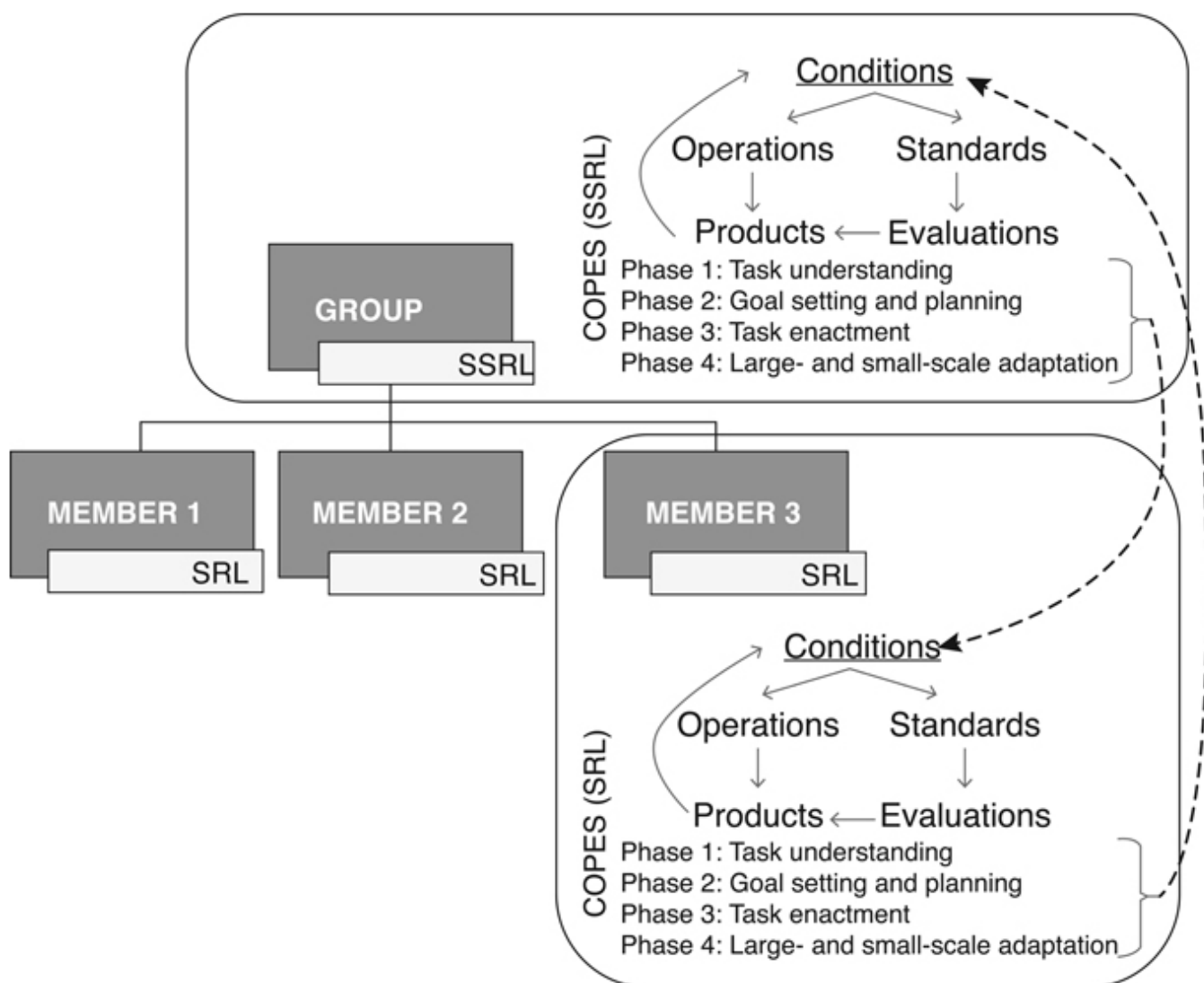
COPES-Based Situated Perspective of Regulation in Collaboration

The COPES architecture (Winne & Hadwin, 1998) provides an ideal framework for conceptualizing regulation at a group level because it emphasizes that choices and outcomes in each phase are inextricably intertwined with dynamic internal, social, and environmental conditions serving as affordances and constraints for regulation (Winne & Hadwin, 2008). Conditions emphasize the situated and socio-historical nature of regulation, recognizing that features of the current situation and a range of past experiences contextualize new situations or learning pursuits.

Three classes of conditions inform regulation during collaboration (Miller, 2015). (1) Self conditions (what I think about me) consist of individual knowledge, beliefs, strengths and weaknesses such as self-perceptions about domain knowledge, task experience, proficiency, efficacy, and affect. During collaboration, self conditions also include perceptions of oneself as a collaborator as well as one's own experience and comfort with a range of possible group roles. (2) Task and context conditions (what I think about the situation) consist of perceptions of external affordances and constraints situated in both the task and task context such as: resources, technologies, time, task difficulty or complexity, group composition or size, and distribution of knowledge or expertise in a group. Task and context conditions are socio-cultural in nature, thereby creating and constraining opportunities for learning and collaboration. (3) Group conditions (what I think about us) are knowledge and beliefs about the groups with whom we work. These types of conditions are very specific to collaborative learning contexts or

teams. Group conditions include beliefs about individuals within the group such as individual's strengths and weaknesses, abilities and proficiencies, as well as knowledge and beliefs about a group as a whole such as group dynamics and norms, group climate, proficiency, or effectiveness. Group conditions are informed by past experiences and observations of current and past groups.

We position the COPEs architecture as a key underlying mechanism in regulation. This is in sharp contrast to Schoor, Narciss, and Körndle (2015), who depicted COPEs as targets for regulation. From our perspective, the COPEs architecture gives rise to a situated perspective of regulation emphasizing regulation embedded within personal, socio-historical, and contextual features of the current situation as well as a range of past experiences and beliefs, together serving as conditions of collaborative interaction and engagement. Products of each phase become the conditions for subsequent phases and cycles of regulation (see [Figure 6.1](#)). In this way, regulation unfolds cyclically and recursively over time with a rich socio-historical database of personal and collective experience and performance developing over tasks, time, and situations. This COPEs perspective acknowledges forward- and backward-reaching effects of regulation as well as the fact that I, We, and You experiences stretch across self-, co-, and shared regulation rather than being contained within them. For example, as one group member's confidence wanes during project work, it results in a shift in the conditions for my own regulation as well as for co-regulation and shared regulation. The changing conditions (my waning confidence and drops in persistence) fundamentally change the COPEs profiles for my own, my peers', and our collective project engagement.



[Figure 6.1](#) Reciprocal relationship between conditions and products at the individual and group level

In 2011, we reviewed the state of the field in terms of social modes of regulation and posed five challenges for moving forward. This section returns to those challenges reviewing the state of the field today by (a) highlighting advancements in the field with respect to those five challenges, and (b) explicating misconceptions and problems arising in the use and operationalization of self-regulated, co-regulated, and shared regulation of learning over recent years. Doing so acknowledges research about the regulation of learning in collaborative learning contexts is not static. Our own conceptualizations continue to develop guided by theoretical discourse and empirical findings in the field. For example, current conceptualizations of co-regulated learning more explicitly acknowledge: (a) the breadth of socio-cultural affordances and constraints shaping and guiding regulation during collaboration, and (b) the role of co-regulatory practices in guiding and supporting regulation of individuals and groups.

Challenge 1: Adopting Clear and Consistent Use of Terminology

The 2011 handbook chapter noted self-regulation, co-regulation, and shared regulation were not consistently defined or operationalized within the literature. We argued for the need to tease apart these constructs. Since then, research about regulation in collaborative contexts has burgeoned across disciplines. Modes of regulation are generally recognized to make unique contributions to successful collaboration beyond domain-specific knowledge construction.

However, the enthusiastic uptake of these constructs is not without problems. A cursory survey of the field uncovered over 25 different terms used to refer to aspects of regulation emerging in social situations across a range of disciplines. Conceptual overlaps in terminology, inconsistent interpretations, and inaccurate representation of concepts have contributed to considerable confusion for research and practice, making it difficult to interpret and synthesize findings across studies. Drawing on our model of regulation and definitions of self-, co-, and shared regulation above, [Table 6.1](#) offers a classification scheme for making sense of the breadth of terms used across studies under five broad categories and definitions including: (1) self-regulated learning, (2) [socially] shared regulation of learning, (3) co-regulated learning, (4) social regulation, and (5) interaction and coordinated action. This classification system highlights some critical themes to consider below.

Category 1: Self-regulated learning (SRL)	
Refers to individual learners taking metacognitive control of cognitive, behavioral, motivational and emotional conditions/states through iterative processes of planning, monitoring, evaluation, and change.	
Self-regulated learning. Strategic, goal-driven, and metacognitive behavior, motivation, and cognition.	DiDonato (2013); Grau & Whitebread (2012); Panadero, Kirschner, Jarvela, Malmberg, & Jarvenoja (2015)
Self-regulation. Regulation of own learning process without intention of influencing others' metacognition, motivation, or emotion.	Ucan & Webb (2015)
Metacognitive regulation. Self-regulatory skills and strategies used by students to actively control and coordinate their learning.	De Backer, Van Keer, & Valcke (2015)
Communal regulation. Self-regulation is embedded in collective society and occurs within a network of socially mediated factors.	Jackson, McKenzie, & Hobfoll (2000)
Self-social regulation. Ability to monitor and regulate one's social interactions.	Patrick (1997)

Category 2: [Socially] shared regulation of learning (SSRL) Refers to group-level deliberate, strategic, and transactive planning, task enactment, reflection, and adaptation. It involves groups taking control of the task together through shared (negotiated), iterative fine-tuning of cognitive, behavioral, motivational, and emotional conditions/states as needed.	
Socially shared regulation (SSRL). Interdependent or collectively shared regulatory processes, beliefs, and knowledge orchestrated in the service of a co-constructed or shared outcome.	Jarvela, Malmberg, 8c Koivuniemi (2016); Jarvela, Jarvenoja, Malmberg, 8c Hadwin (2013); Miller 8c Hadwin (2015a).
Socially shared metacognitive regulation (SSMR). Goal-directed, consensual, egalitarian and complementary regulation of joint cognitive processes.	De Backer, Van Keer, 8c Valcke (2015); Khosa 8c Volet (2014); Iiskala, Volet, Lehtinen, 8c Vauras (2015); Raes, Schellens, De Wever, 8c Benoit (2016).
Socially shared metacognition. Consensual monitoring and regulation of joint cognitive processes.	Molenaar, Roda, van Boxtel, 8c Sleegers (2012); Volet, Vauras, Khosa, 8c Iiskala (2013)
Shared regulation. Group members jointly and equally assume regulation activities for the task.	DiDonato (2013); Ucan 8c Webb (2015)
Collective regulation. Regulation of the group (team) as a collective entity.	Chan (2012); Jarvela, Jarvenoja, and Naykki (2013)
Co-regulation. Group members jointly assume regulation in the task (equated with [socially] shared regulation).	Vauras, Iiskala, Kajamies, Kinnunen, 8c Lehtinen (2003); Volet, Vauras et al. (2009); Volet, Summers, 8c Thurman (2009); Lajoie 8c Lu (2011); Raisanen, Postareff, 8c Lindblom-Ylänne (2016);
Collaborative regulation. Metacognitive activities shared among the group members regulating their collective cognitive activity.	Molenaar et al. (2012)

Category 3: Co-regulated learning (CoRL) Refers broadly to the dynamic metacognitive processes through which self-regulation and shared regulation of cognition, behavior, motivation, and emotions are transitionally and flexibly supported or thwarted. Attention focuses on affordances and constraints as mechanisms for shifting regulatory ownership to an individual (self-regulation) or group (shared regulation).	
Co-regulation (CoRL). Transitional (externally initiated) process towards self-regulated learning and/or shared regulation of learning.	Hadwin 8c Oshige (2011); Jarvela 8c Hadwin (2013); Zheng 8c Yu (2016); Lajoie et al. (2015)
Co-regulation (CoRL). Temporary coordination of self-regulation amongst self and others.	Hadwin, et al. (2011); McCaslin 8c Hickey (2001); Saariaho, Pyhalto, Toom, Pietarinen, 8c Soini (2016)
Other regulation. (More capable) Other temporarily predominates by guiding the joint activity and others' understanding.	Hadwin 8c Oshige (2011); Volet, Vauras, et al. (2009)

Category 4: Social regulation Refers to all modes of regulation in group work or interpersonal interaction including but not limited to: self-regulation, co-regulation, and socially shared regulation.	
Social regulation. General term for regulatory activities on the group level (e.g., co-, other, and socially shared regulation) in contrast to self-regulation.	Grau & Whitebread (2012); Lee, O'Donnell, & Rogat (2015); Molenaar & Jarvela (2014); Schoor & Bannert (2012); Ucan & Webb (2015); Volet, Vauras, & Salonen (2009);
Interpersonal regulation. Social regulatory processes emerging across different systemic levels.	Volet, Vauras et al. (2009); Volet & Vauras (2013)
Socially shared regulation. All social processes groups use to regulate the joint task.	Rogat & Linnenbrink-Garcia (2011)
Co-regulation. All forms of regulation during cooperative or collaborative learning.	Chan (2012); DiDonato (2013)
Collaborative regulation. Regulatory processes students engage in while they are learning collaboratively.	Winters & Alexander (2011)

Category 5: Interaction and coordinated action Refers to interaction patterns, knowledge construction, or regulatory actions without connection to regulatory constructs or targets.	
Facilitative and directive other regulation. Other regulation aimed at guiding versus controlling the group's regulatory processes. Regulatory act/ action in a co-regulatory trajectory.	Rogat & Linnenbrink-Garcia (2011)
Co-regulated learning. Interpersonal interaction geared towards monitoring and managing each other's learning.	Garrison & Akyol (2015); Zheng & Huang (2016); Ucan & Webb (2015)
Group regulation. Group coordinates their efforts and resources in effective ways to achieve common goals.	Kwon, Liu, & Johnson (2014)
Internal and external regulation. Self-regulation vs. regulation by the external setting like scaffolding or scripting.	Romero & Lambropoulos (2011)
Team vs. task regulation. Distinguishing regulation of the collaboration from regulation of the task.	Duffy et al. (2015); Saab, Joolingen, & Hout-Wolters (2011); Janssen, Erkens, Kirschner, & Kanselaar (2012)
Co-regulation (CRL). Joint influence of self-regulated and other regulating agents on students' learning.	Tsai (2015)

The Emergence of Overarching Terms

Terms such as social regulation and interpersonal regulation have emerged as umbrella terms broadly referring to social forms of regulation primarily as a means for distinguishing it from regulation at the individual level (e.g., self-regulation). Adopting these terms emphasizes the importance of group-level regulatory activities such as planning, monitoring, and evaluating in collaborative work. However, the nuanced use of these terms to distinguish CoRL and SSRL from SRL is often misinterpreted to imply self-regulated learning is not a social mode of regulation. In contrast, we have always positioned self-regulated learning as a social process influenced by and influencing social context.

From a situated perspective, individual agency arises as part of a rich social milieu feeding self-regulated learning and growing from it. Conditions have internal and external properties. Products generated during regulation, such as shifts in emotional state, adopting a particular strategy, or exerting effort to reach a goal, become self conditions for individuals, and contextual conditions for collaborators (see [Figure 6.1](#)). In this way, self-regulation is inextricably social. Therefore the category social regulation refers broadly to all modes of regulation (including self-regulated learning) within collaborative learning contexts, social situations, and groups. Importantly, social regulation is not synonymous with socially shared regulation but may subsume SSRL among other things.

The Confusion Over Co-Regulation

Over the past five years, new research approaches, data sources, coding schemes, and analytic approaches have empirically documented modes of regulation and distinguished shared regulation from other modes of regulation (cf. Panadero & Järvelä, 2015). However, reviewing the literature reveals a state of confusion with respect to co-regulation in particular. The term co-regulation has been used to refer broadly to every mode of regulation during collaborative learning (e.g., DiDonato, 2013). It has also been used synonymously with social regulation (e.g., Volet, Summers et al., 2009) to refer to “constant monitoring and regulation of joint activity, which cannot be reduced to mere individual activity” (Vauras et al., 2003, p. 35). Further, CoRL is often misrepresented as an asymmetrical interpersonal interaction (e.g., Ucan & Webb, 2015) whereby group members regulate each other (e.g., Garrison & Akyol, 2015; Volet, Summers et al., 2009) often through prompting and coordinating actions (DiDonato, 2013).

However, we draw heavily from McCaslin’s (2004) initial socio-cultural conceptualization of co-regulation as the process whereby social environment supports the emergence of regulation, recognizing support is distributed amongst people (rather than one more capable other), task, tools, and environment. This view reconciles tensions in the field by acknowledging (a) the transitional nature of co-regulation in supporting or sometimes constraining the emergence of regulation, (b) the role of co-regulation in supporting the emergence of both self-regulated learning and shared regulation, and (c) the distributed nature of co-regulatory support across people and context afford opportunities for joint regulation to emerge. In this way CoRL plays a mediational role for SRL and/or SSRL. Viewing CoRL in this mediational way acknowledges the scaffolding role CoRL can play in spawning more proficient self-regulated learning as well as [socially] shared regulation.

New Terms for Regulatory Sources and Targets

Coding discourse and triangulating across data sources has led to new labels for regulatory sources and targets operating within the three modes of regulation. For example, other regulation has been used to refer to a regulatory act/action in a co-regulatory trajectory whereby regulation is directed or facilitated by others (e.g., peer, teacher, etc.). Recently, Rogat and Adams-Wiggins (2015) compared other regulation that controls (directive-other regulation) versus guides (facilitative-other regulation), finding facilitative-other regulation contributes to more balanced participation and regulatory contributions amongst group members.

From our perspective, other regulation is merely an affordance or constraint for self-regulated and/or shared regulation of learning. It is a coding node in discourse analysis, until it takes on a co-regulatory role by changing or shaping self- or shared regulation. Directive-other regulation can be characterized as a constraint for self- and shared regulation. Co-regulation is born when other regulation occurs and is acted on in terms of individual or shared regulatory planning, monitoring, evaluating, or strategic action targeting behavior, motivation, affect, or cognition.

What Does Shared Mean?

The term shared holds multiple meanings in the literature ranging from: (a) sameness, such as when individual group members hold similar or common goals, plans, and evaluations of the joint work, to (b) co-constructed,

such as when group members jointly negotiate shared goals and plans, and share in the monitoring and evaluating. However, “sameness” (holding the same goal or evaluation), does not imply shared. Shared regulation is co-constructed; it is a mutually reactive, interdependent, and transactive process related to planning, monitoring, evaluating, and controlling learning processes. Negotiated emergent agreement is the goal, rather than implicit or passive agreement occurring when an individual acquiesces or just happens to hold the same idea. Transactivity occurs when reasoning builds on, relates to, and refers to reasoning shared by other group members (Berkowitz & Gibbs, 1983; Teasley, 1997). Transactivity has been associated with successful construction of metacognitive knowledge in shared regulation, particularly when augmented with support in the form of reciprocal peer tutoring (De Backer et al., 2015).

Challenge 2: Regulated Learning Involves Psychological Constructs

The 2011 chapter boldly claimed research is not about any social mode of regulated learning if it is not anchored in specific psychological constructs including: (a) regulatory processes (monitoring, evaluating, and controlling), and (b) regulatory constructs or targets (motivation, cognition, behavior, and emotion). Since the 2011 chapter, promising advances have emerged in research about regulation in collaboration. In particular, it is becoming increasingly common to research multiple targets and/or processes of regulation within a study. For example, Lajoie et al. (2015) examined the role of socio-emotional processes in both metacognition and co-regulation used by medical students learning to deliver bad news. They specifically coded for: (a) meta-cognitive processes—orientation, planning, executing, monitoring, evaluating, and elaborating; (b) positive expressing emotions; and (c) negative socio-emotional interactions. Although one might argue coding of co-regulation in this study emphasized cognitive knowledge construction primarily, the findings advance research about regulation by considering the dynamic relationships between emotions and metacognition in a distributed online problem-based learning environment.

Similarly, Ucan and Webb (2015) examined the roles of both metacognitive and emotion regulation in the emergence and maintenance of multiple modes of regulation (self-, co-, and shared) during seventh grade science inquiry collaborations. Finally, Järvelä, Järvenoja, Malmberg, Isohätälä, and Sobocinski (2016) examined groups’ cognitive and socio-emotional interaction with respect to three phases of regulation (fore-thought, performance, and reflection), illuminating differences in phases of regulation between cognitive and socio-emotional segments of discourse.

At the same time, three problematic trends exist in the research. First, there is a tendency to limit operational definitions of regulation to “cognitive” episodes alone, implying metacognitive knowledge and processes apply exclusively to domain and task knowledge construction. For example, Khosa and Volet (2014) investigated productive group engagement in cognitive activity and metacognitive regulation by coding: (a) high- and low-quality metacognitive regulation (planning, monitoring, and evaluating) in knowledge construction (talking about the domain knowledge) and knowledge production (talking about the task) episodes, and (b) the social nature and function of metacognitive activity (solo or collective). De Backer et al. (2015) investigated how socially shared metacognitive regulation correlates with both collaborative learners’ content processing strategies and the level of transactivity in their discussions. They analyzed students’ content processing strategies (i.e., questioning and explaining), as well as cognitively oriented and metacognitively oriented transactive discussions.

In contrast, metacognitive planning, monitoring, and evaluating should figure prominently as regulatory processes in motivation, emotion, behavior, and cognition. Modeling motivational and socio-emotional states as both conditions and products in learning (cf. Winne & Hadwin, 2008) acknowledges the salience of metacognitive monitoring, evaluation, and adaptation for motivational, affective, and even behavioral knowledge and beliefs. From this perspective beliefs, thoughts, and perceptions are cognitive products (and conditions) in learning regardless of whether they focus directly on task or domain knowledge.

Restricting analysis to cognitive or content episodes exclusively tends to conflate knowledge construction and regulation because only knowledge construction episodes are examined for evidence of metacognitive processes (monitoring, evaluating, controlling) or regulatory modes (self-, co-, and shared regulation). It obscures evidence of metacognitive planning, monitoring, and control of motivation, emotions, or strategic behavior. Finally, and perhaps most importantly, focusing on domain and task segments alone precludes the possibility of interrelationships in regulation across facets (motivation, cognition, emotion, and behavior). For example, shared regulation of task production may arise in response to heightened task anxiety for one group member. Similarly, groups may collaboratively generate a strategy such as making sure everyone shares one idea (controlling behavior), in response to a cognitive evaluation of insufficient course concepts in a group response.

A second potential problem emerging in the contemporary research relates to delimiting regulatory action to specific regulatory constructs or targets (motivation, cognition, emotion, behavior). For example, Kwon et al. (2014) coded interactions for: (a) group regulatory behaviors—discussions involving coordinating members' joint efforts toward common goals; or (b) socio-emotional behaviors—discussions expressing or encouraging emotions. This approach to analysis precludes the possibility of groups regulating socio-emotional factors or conditions. In contrast, regulatory acts should be considered responses to situated challenges (e.g., time, efficiency, difficulty). What is important and different in our conceptualization is the implied interaction between motivation, emotion, metacognition, and strategic behavior in successful learning.

Similarly, a new trend in the research distinguishes between (a) task regulation defined as regulating the cognitive activities during learning, and (b) team regulation defined as coordinating the collaboration between students, such as checking others' opinions. From our perspective, teasing apart team and task regulation: (a) obscures the dynamic interplay between team and task in self-, co-, and shared regulation, and (b) reduces regulation to a change-behavior devoid of critical metacognitive processes (planning, monitoring, evaluating) and psychological targets (motivation, behavior, emotion, and behavior).

Challenge 3: Challenges Provoke Opportunities for Regulation

The mark of successful regulation is strategic adaptation in response to a challenging situation or problem (Winne & Hadwin, 2008). Given the surprising lack of research examining social aspects of learning at key points when challenge is encountered through to when it is resolved, challenge episodes were proposed in the 2011 chapter as critical for segmenting and analyzing data and discourse. Overall, this area has received minimal uptake in the field. For the most part, research about regulation has examined it across full collaborative episodes (e.g., Grau & Whitebread, 2012; Rogat & Adams-Wiggins, 2015; Ucan & Webb, 2015), or at timed intervals (Iiskala et al., 2015; Molenaar & Chiu, 2014) over the course of collaboration, rather than using challenge episodes for segmenting and narrowing observations to periods in which a regulatory response is warranted.

Researchers across our programs of research have collected data about anticipated and perceived challenges and challenge indicators with a goal of identifying specific targeted episodes to observe regulatory responses (Miller & Hadwin, 2015a; Panadero et al., 2015). For example, Malmberg, Järvelä, Järvenoja, and Panadero (2015) used the Virtual Collaborative Research Institute (VCRI) learning environment along with regulation tools prompting (a) identification of challenges hindering collaboration, and (b) planning SSRL strategies to overcome those challenges. Process mining findings indicated: (a) shifts from regulating external challenges toward regulating the cognitive and motivational aspects of collaboration depending on the phase of the course, and (b) temporal variety in challenges and regulation strategies across the time.

Despite limited empirical progress with respect to researching regulation within challenge episodes, at least three promising lines of inquiry provide foundation for the field to continue work in this area. First, groups experiencing positive socio-emotional interactions also engage in more regulatory processes such as planning, monitoring, and behavior than groups who experience negative socio-emotional reactions (Rogat & Linnenbrink-Garcia, 2011).

Findings may indicate active engagement in regulatory processes mitigates socio-emotional challenges, but given inferences are drawn from in-depth case studies of limited groups, further investigation is warranted.

Second, research has begun to identify types of events stimulating regulation and metacognitive processes. For example, Ucan and Webb (2015) found expressing misconceptions or lack of understanding of domain content stimulates co-regulatory processes, whereas expressing uncertainty about a shared idea, seeking consensus, and experiencing contradictory views tended to stimulate shared regulation. Findings such as this focus on the adaptive nature of regulation arising in the context of simulating events.

Finally, research evidence to date points to at least five broad types of challenges experienced by groups across a variety of settings (Bakhtiar, 2015): (1) Motivational challenges tend to center around differing personal priorities such as competing goals, or differing participation levels. Typically these challenges result in declines in effort, engagement, or participation (e.g., Järvelä & Järvenoja, 2011). (2) Socio-emotional challenges refer to challenges in achieving positive climate such as relational problems associated with achieving psychological safety, communicating effectively, and navigating power relationships (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). (3) Cognitive challenges refer to difficulties in achieving shared mental models of the task and domain, or choosing effective solution paths and strategies (Barron, 2003). (4) Metacognitive challenges relate to difficulties monitoring, evaluating, and reflecting on group processes, products, and progress (Janssen et al., 2012). (5) Environmental challenges relate to external conditions surrounding collaborative work such as technology, task complexity and duration, resources, and group composition (Hommes et al., 2013). We posit the occurrence of these challenges demands varying modes of regulatory action and warrants future investigation.

Challenge 4: Regulation as Change Over Time

The 2011 chapter posited that regulation implies adaptation over time; to adequately research regulation, data should be sampled over time both within and across episodes. This area of research has shown tremendous growth over the past few years. In addition to noting increases in regulation over time (e.g., DiDonato, 2013), research has begun to explore patterns in emerging regulation over time. More recently, data mining techniques have been used to examine sequential patterns in regulation over time: (1) Lajoie et al. (2015) examined changes in metacognitive activity across two problem-based learning (PBL) online sessions. They found growth and progression on adaptive adjustments in the PBL group's thinking, based on continuous metacognitive monitoring. They also found a strong connection between co-regulatory actions activating discussion and metacognitive planning, revealing a co-occurrence of metacognitive, co-regulatory, and social-emotional interactions. (2) Schoor and Bannert (2012) explored logfile sequences of social regulatory processes during a computer-supported collaborative learning (CSCL) task. Although they found clear parallels between high- and low-achieving dyads in a double loop of working on the task, monitoring, and coordinating, closer examination indicated the lower-achieving group displayed faster change between categories, despite having similar patterns of regulation. (3) Järvelä et al. (2016) examined temporal sequences for self- and socially shared regulation during CSCL and found: (a) shifts in the types of self-regulation and socially shared regulation of learning as work progressed, and (b) a tendency of individual self-regulatory processes to be salient early in the collaborative process.

Understanding socially shared regulation of learning requires an understanding of the learning context and the evolution of social and regulatory processes over time. Continued advancements in observational data collection techniques as well as analytical methods and tools are necessary for furthering research about the sequential and temporal aspects of regulation. However, pursuing these methods requires care to avoid the reduction of regulation (self-, co-, or shared regulation) to action alone. Regulation is more than what people do and how they do it. Understanding regulation means knowing something about internal perceptions and intent. Social interactions, sequences, and patterns need to be contextualized in larger episodes of activity with attention to individual and collective goals, plans, and reflection to delineate meta-cognitively driven regulatory processes versus extemporaneous patterns of interaction.

Challenge 5: Researching the Co-Emergence of SRL, CoRL, and SSRL

Over the past five years, the field has progressed past naive notions of learning as solely individual or solely collaborative and must now take up the challenge of understanding how these three modes of regulation (self-, co-, and shared) contribute together to successful collaborative learning. For example, Malmberg, Järvelä, and Järvenoja (2016) investigated how temporal sequences of regulated learning events, such as regulation types (self-, co-, and shared) and regulation processes (e.g., planning, monitoring) emerge during different stages of the collaborative learning process. Qualitative content analysis and sequential analysis of videotaped sessions indicated task execution promoted socially shared planning despite co-regulated learning occurring most frequently. Such research indicates different modes of regulation may support one another in relation to task completion.

Panadero et al. (2015) specifically examined the relationship between self-regulated learning, shared regulation of learning, and group performance in the context of a collaborative essay writing task during a multi-media learning course for pre-service teachers. Findings indicated that groups with better individual self-regulators reported higher levels of group regulation in terms of the collective number of shared goals and strategies, and the activation of strategies to regulate challenges. Despite over reliance on self-report measures of self-regulated learning administered once only, findings from this study establish a relationship between individual self-regulation and aspects of socially shared regulation.

Similarly, Grau and Whitebread (2012) examined the relationship between primary children's self-regulated learning (planning, monitoring, control or regulation, and reflection) and social aspects of regulation including: (a) directing the regulation of others (which they labeled co-regulation), and (b) participating in joint regulation of the task (which they labeled socially shared regulation). In addition to observing increases in self-regulation over the semester, they found significant positive correlations between shared regulation and references to relevant knowledge. Importantly, this research attempted to overcome the dichotomy between individual agency and group activity by examining the interrelationships between self-regulated learning and interpersonal elements of regulation characteristic of either co-regulation or socially shared regulation.

Finally, DiDonato (2013) examined self-reported co-regulation as a possible moderator of changes or improvements in self-reported self-regulated learning during collaborative work. The difference between pre-post SRL scores served as a Level-1 individual outcome variable and group co-regulated learning score (midway through collaboration) served as the Level-2 variable in hierarchical linear modeling. Findings indicated self-reported self-regulated learning increases from the beginning to the end of a collaborative interdisciplinary middle school project, but self-reported co-regulation moderated the relationship between SRL and time. In other words, groups with higher co-regulation scores were also more likely to have individuals whose SRL scores increased from the beginning to the end of the nine-week collaboration period. In-depth video analysis of one group indicated the presence of other regulation rotating amongst group members. Further, when one student took the planning lead, producing a well-defined project idea and providing elaborated explanations about why this was a good plan, it seemed to provide a shared platform for individual and collaborative regulation and task completion.

Together these studies demonstrate the importance of drawing on multiple analytical methods to examine the ways multiple modes of regulation operate in support of one another during collaborative learning tasks. Together these studies have taken important steps toward overcoming the dichotomy between modes of regulation and instead examining the interplay between them. Limited findings to date suggest co-regulation may moderate increases in self-regulatory processes over the course of collaboration (e.g., DiDonato, 2013), while proficiency in self-regulation may set the stage for the emergence of shared regulation (e.g., Panadero et al., 2015).

Future Directions for Research

Moving Beyond Discourse Data

Some of the conceptual confusions about modes of regulation have emerged from attempts to operationalize these constructs in specific, often singular data sources. In particular, coding discourse alone for evidence of self-regulated learning, co-regulated learning, and shared regulation may (a) be inadequate for capturing the richness of these dynamic processes, and (b) reduce dynamic constructs such as co-regulated learning processes to sublevel codes such as “other regulation.” SSRL is increasingly studied in CSCL environments where data collection mainly focuses on online interactions or discussion data. This is not enough to understand the cyclical process of regulation nor its multifaceted metacognitive nature. Clarifications and extensions of our conceptualization of three modes of regulation presented in this chapter point to the need for cross referencing empirical data from coding conversations and interactions with data about intent, beliefs, and the transactivity of regulatory interactions, as well as distribution of regulatory expertise over larger episodes of collaborative learning.

Multimodal Data Advancements

Despite advancements in theoretical framing, limited methods exist for making invisible mental SRL processes and accompanying social and contextual reactions visible. Multimodal data refers to data resulting from different data channels and constitutes objective and subjective data tracing simultaneously collecting a range of cognitive and non-cognitive processes (Reimann, Markauslaite, & Bannert, 2014). For example, subjective data (e.g., repeated and contextualized self-reports) reveal a student’s intention to learn and beliefs about her/himself as a learner (McCardle & Hadwin, 2015). Conversely, objective data (e.g., log data, eye movements, physiological responses) provide continuous information about behavioral and mental indicators like confusion, increasing effort, or attention, which are almost impossible to capture otherwise. While multimodal data collection in SRL research is in early stages, triangulation across channels has potential to capture critical phases of regulation as they occur in challenging learning situations (Järvelä, Malmberg, Haataja, Sobocinski, & Kirschner, 2016). However, we caution that accurate inferences about regulation require objective data to be carefully contextualized by subjective data about learner intent and beliefs in the same relative moment. Triangulating Motivated Strategies for Learning Questionnaire (MSLQ) self-reports with fine-grained objective data may not adequately contextualize situated knowledge, beliefs, and intent upon which students operate in regulating their learning.

Technologies for Supporting the Multiple Modes of Regulation

Often learners do not recognize opportunities for engaging and shifting between self-, co-, and shared regulation in collaboration (e.g., Järvelä et al., 2013; Miller, Malmberg, Hadwin, & Järvelä, 2015). As a result, increasing emphasis has been placed on harnessing technology to guide and support regulation. Recently, Järvelä, Kirschner, Hadwin et al. (2016) reviewed emerging tools and their design principles for supporting regulation in the service of effective and efficient CSCL. To date, our collective programs of research have explored the potential of: (a) planning and reflection tools (cf. Miller & Hadwin, 2015a; Malmberg et al., 2015) for prompting and scripting critical individual and group planning and reflection processes, and (b) collective visualizations of individual plans, perceived challenges (e.g., Miller & Hadwin, 2015a, 2015b) and emotional, cognitive, and motivational states (e.g., Järvelä et al., 2016a). Instead of targeting knowledge construction or functional aspects of regulation, these tools support regulation by prompting learners and groups to (a) increase awareness of their own, others’, and their group’s learning processes; (b) externalize their own, others’, and their group’s learning processes in a social plane; and (c) activate key regulation processes, such as setting goals, making plans, and adopting strategies, and monitoring and evaluating (Järvelä et al. 2015; Miller & Hadwin, 2015a).

Moving forward, research is needed to examine (a) the contribution of such tools to the quality of collaborative learning, across different regulatory processes, across social levels over time; and (b) the most effective ways to store and make visible data about “on-the-fly” processes of socially shared regulation which are not available in

other means (Molenaar & Järvelä, 2014). This may take the form of tools dynamically adapting to provide tailored support for self-, co-, and shared regulation, as well as harnessing the potential of learning analytics and regulation for learners.

Examining Outcomes of Regulation

Regulation is effortful, adding to cognitive load and hogging metacognitive resources. For this reason, long-term gains and outcomes associated with developing regulatory proficiencies for teamwork need to be critically examined. To date evidence about learning and collaboration outcomes have been limited. Understanding the impact of modes of regulation on collaborative knowledge construction, productivity, and products is an important target for future research.

Implications and Applications for Educational Practice

The past five years have witnessed substantial development in terms of defining and operationalizing variables and exploring multi-methodological methods for tapping into social modes of regulation. We offer three implications for educational practice.

Supporting Regulation

Shared regulation can be successfully promoted by scripting planning and reflection to: (a) increase awareness of learning processes, (b) externalize learning processes in a social plane, and (c) activate key regulation processes, such as setting goals, making plans, and adopting strategies, and monitoring and evaluating when needed (Järvelä et al. 2015; Miller & Hadwin, 2015b). Emerging evidence suggests regulated learning can complement CSCL and collaborative learning research in theory and practice. Efforts in scripting and prompting regulation can solve some of the well-known problems in collaborative learning (e.g., socio-emotional problems).

Designing for Regulation

Second, our research to date acknowledges the role design and technology have in creating affordances and constraints for the emergence of shared regulation. Järvelä et al. (2016) reviewed a number of CSCL technologies and tools that cue, prompt, script, or support different modes of regulation by design. SRL can also be facilitated or constrained by task and domain characteristics (e.g., Lodewyk, Winne, & Jamieson-Noel, 2009), such as when more structured tasks provide fewer opportunities for students to engage in SRL phases. Designing collaborative learning tasks with optimal challenge and opportunity for assuming responsibility is central for activating regulated learning. Productive collaborative learning takes time to develop, as does socially shared regulation. When collaborating groups work on open tasks, the focus of the shared regulatory activities shifts over time, moving from focusing on external task factors such as time and environment to cognitive-oriented and motivational issues (Malmberg et al., 2015). This means groups need to be given multiple opportunities to collaborate with each other, complemented with guided opportunities to systematically plan for and reflect on their collaborative progress and challenges.

Feedback and Visualization for Regulation

Feedback is essential for regulation. It is important for the development of self-regulation during solo learning tasks (Butler & Winne, 1995) and equally important for the emergence of shared regulation. Feedback tools offer promise for shifting the emphasis away from collaborative productivity (e.g., number of posts, number of words, degree of completion) and toward regulatory processes and targets (e.g., planning progress, goal status, motivational and emotional climate, regulatory challenges). For example, Phielix (2012) designed Radar to enhance awareness of group members' social, motivational, and cognitive behavior, and in turn, support social, motivational, and cognitive group performance. By asking students to rate cognitive, motivational, and social

beliefs in the moment, Radar provides a means to increase group awareness of regulatory states. While Radar alone does not prompt the acquisition and activation of regulatory processes, it can be leveraged to promote SSRL (Järvelä et al., 2016a).

Learning analytics (LA) create opportunities for data-driven analysis of learning activities and can, in turn, be used to provide learners/teachers with visual feedback for optimizing cognitive, motivational, and emotional engagement learning. For example, dashboards can be designed to inform learners/teachers in real time of what they actually do and what is being achieved with the goal to trigger and sustain learning progress (Greller & Drachsler, 2012). Designing LA interfaces and dashboards specifically with regulation in mind may have potential to promote necessary awareness for strategically engaging self-, co-, and shared regulation of learning.

This chapter set out to revisit and update earlier conceptualizations of social modes of regulation in collaboration with the aim of: (a) summarizing relevant theoretical ideas, (b) grounding constructs in educational psychology, (c) highlighting contemporary research evidence bearing on these ideas, (d) offering directions for future research, and (e) discussing implications for practice. We specifically defined three modes of regulated learning and classified current usage of terminology under one of five categories: (a) self-regulated learning, (b) [socially] shared regulation of learning, (c) co-regulated learning, (d) social regulation, and (e) interaction and coordinated action. The literature and definitions presented in this paper provide a solid framework for advancing research about modes of regulation, synthesizing and comparing findings across studies, and leveraging technologies and tools for supporting successful regulation in collaboration.

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Section II Self-Regulation of Learning and Performance in Context

7 Metacognitive Pedagogies in Mathematics Classrooms

From Kindergarten to College and Beyond

Zemira R. Mevarech, Lieven Verschaffel, and Erik De Corte

Theoretical Background

It is well known that the cognitive system depends on higher-order processes that enable it to work efficiently. Since ‘meta’ means ‘beyond’, those higher-order processes are termed ‘meta-cognition’—they are ‘beyond’ the cognitive system. The main meta-cognitive components include planning, monitoring, control, and reflection (e.g., Flavell, Miller, & Miller, 2002).

A good metaphor for the way metacognition operates is the GPS (Global Positioning System). The GPS, also known as Navstar, is a global navigation satellite system that provides information on cars’ locations, road conditions, and driving time. The GPS chooses the best route to go: it plans the route, monitors, controls, and reflects on the driving until the driver reaches the final destination. When an error occurs, the GPS announces it and recalculates the route. The GPS can also alert the driver on obstacles that are on the way, and sometimes suggests how to bypass them. Obviously, the GPS is not needed when the route is familiar to the driver. Similar to the GPS, metacognition also comprises planning, monitoring, control, and reflection processes. It is particularly essential in solving complex, unfamiliar, or non-routine (CUN) problems, but less (or not at all) necessary when the problem is very familiar and can be solved automatically (Mevarech & Kramarski, 2014).

While there is a large consensus that metacognition has a crucial role in activating and regulating the cognitive system, the term itself includes a large number of different processes that sometimes are overlapping or not clearly defined. Furthermore, over the years the concept itself was enlarged so much that currently it includes almost

every process that relates to overseeing and activation of the cognitive system. From the very beginning, Brown (1987) and later on Schraw and Dannison (1994) distinguished between two components of metacognition: knowledge of cognition and regulation of cognition. Flavell, who coined the term ‘metacognition’ in 1979, clarified in 2002 that metacognition includes not only metacognitive knowledge (e.g., knowledge about the task, strategies appropriate for solving the task, and personal characteristics relevant to the task), but also metacognitive skills, such as monitoring and reflection (Flavell et al., 2002). Kuhn in 2000 talked about meta-strategic knowledge relating to knowledge about the what, when, how, and why of using strategies for solving a problem. (The reciprocal relations between cognition and metacognition within self-regulated learning (SRL) are widely discussed by Winne, 2018/this volume.)

Efklides (2006) took another approach. She includes in the metacognitive system also knowledge and regulation of affect (emotions, attitudes, motivation, etc.) which she terms meta-experience (see also Efklides, Schwartz, & Brown, 2018/this volume). Although there is no question that the affective and cognitive systems work hand in hand during learning and problem solving, some theoretical approaches do not consider this meta-experience system as part of the metacognitive system.

It is not surprising that the wide definition of metacognition has raised various questions, many of which are still open. First, there is much confusion regarding the differences between metacognition and SRL. According to Flavell et al. (2002) and many others (see for example the review by Mevarech & Kramarski, 2014) metacognition is a ‘meta’ concept that includes under its umbrella self-regulation (primarily referring to the metacognitive control functions), meta-strategies, metacognitive knowledge, etc. Zimmerman and Schunk (2011) include under SR cognition, meta-cognition, motivation, affect, and behavior. De Corte, Mason, Depaepe, and Verschaffel (2011) combined the two terms by clarifying the components of adaptive competence in mathematics: the ability to apply meaningful learned mathematical knowledge and skills flexibly and creatively in a variety of contexts. According to De Corte et al. (2011) these components are, besides (a) meta-knowledge and (b) self-regulation skills, (c) a well-organized and flexible, accessible domain-specific knowledge base, (d) heuristic strategies for problem solving, and (e) positive mathematics-related affects involving attitudes, emotions, and beliefs. The meta-knowledge component refers to knowledge about one’s cognitive functioning (metacognitive knowledge), as well as knowledge about one’s motivation and emotions. Self-regulatory skills embrace skills relating to the self-regulation of one’s cognitive processes (metacognitive skills or cognitive self-regulation), as well as skills for regulating one’s motivational and emotional processes (meta-volitional skills or volitional self-regulation). Given the above discussion, in this chapter the two terms, metacognition and SR, are used interchangeably, although this choice does not necessarily reflect consensus in the field.

The second open issue denotes the age at which learners can activate and regulate their cognition. While some researchers argue that metacognitive skills are activated only at the age of 10, research of the past ten years shows that these skills emerge earlier than has mostly been assumed before (De Corte et al. 2011).

The third open issue regards the extent to which metacognition is teachable. Most of the current studies provide hard data showing that at all ages learners who are exposed to metacognitive interventions are able to improve their metacognitive skills which in turn affect their mathematical reasoning (e.g., Schoenfeld, 1992; Mevarech & Kramarski, 2014). Studies based on meta-analysis, such as those conducted by Dignath and Büttner (2008) and Hattie (2009), clearly indicate that SR skills can be enhanced as a result of explicitly teaching those skills.

These issues are used as the framework for the present chapter that focuses on meta-cognitive pedagogies that have been proven to be successful in enhancing students’ mathematical reasoning. Below is an overview of the chapter:

- Metacognition, self-regulation, and mathematical reasoning;
- Metacognitive pedagogies and mathematics education;
- Research evidence regarding the effects of metacognitive pedagogies on the mathematical reasoning of kindergarten children, students in elementary schools, secondary schools, and higher education;

- Developing self-regulation skills for word problem solving in primary and secondary school levels;
- Developing self-regulation skills for geometry problem solving;
- The effects of metacognitive scaffolding on students in higher education;
- Self-regulated mathematics learning in ICT environments;
- Future research directions; and
- Implications for educational practice.

Metacognition, Self-Regulation, and Mathematical Reasoning

The relationships between metacognition and mathematical reasoning are well documented in the psychological and educational literature (e.g., Schneider & Artelt, 2010). Researchers have indicated that students of all ages, K–12 and adults, who plan, monitor, evaluate, and reflect on their problem-solving processes solve mathematical problems better than those who do not use (or use less often) these activities (e.g., Stillman & Mevarech, 2010). This phenomenon was observed by using a large variety of off- and on-line measurements, including: questionnaires, observations, interviews, videos, various brain coding techniques (e.g., Magnetic Resonance Imaging, MRI), think-aloud techniques, and analysis of peers explaining the solutions to one another or working in small groups. The earlier studies referred to metacognition as a whole, whereas more recent studies distinguished between the specific components of metacognition, as explained above. In general, studies reported high positive correlations between metacognition and mathematics reasoning, even after controlling for IQ (Veenman & Spaans, 2005). Interestingly, Veenman (2013) and Van der Stel and Veenman (2014) compared the development of IQ to that of metacognition and found different developmental curves for each variable.

Metacognitive Pedagogies and Mathematics Education

The findings reviewed above showing the positive relationships between metacognition and mathematics reasoning led researchers to look for pedagogies for improving students' metacognitive thinking, their reading comprehension, problem solving, higher-order thinking skills, or their knowledge and conceptual understanding, based on metacognitive processes (Zohar & Barzilai, 2013).

Over the years, several metacognitive methods have been designed for the area of mathematics learning, some being followed by intensive research (e.g., Stillman & Mevarech, 2010; Mevarech & Kramarski, 2014; Schneider & Artelt, 2010). Most of these methods were rooted in the seminal work of Polya (1957) and Schoenfeld (1985, 1992). Generally, these methods use self-addressed metacognitive questions and share common stages as suggested by IMPROVE (Mevarech & Kramarski, 1997; see also Kramarski, 2008/this volume).

The acronym of IMPROVE represents the involved teaching steps:

- Introducing the new materials, concepts, problems, or procedures using metacognitive scaffolding;
- Metacognitive self-directed questioning in small groups or individually;
- Practicing by employing the metacognitive (MC) questioning;
- Reviewing the new materials by teacher and students, using the MC questioning;
- Obtaining mastery on higher and lower cognitive processes;
- Verifying the acquisition of cognitive and metacognitive skills based on feedback-corrective processes; and
- Enrichment and remedial activities.

The core component of the IMPROVE consists in training the students to use four kinds of metacognitive self-directed questions:

- Comprehension: What is the problem all about?
- Connection: How is the problem at hand similar to or different from problems you have solved in the past? Please explain your reasoning.
- Strategies: What strategies are appropriate for solving the problem and why?

- Review: Does the solution make sense? Can you solve the problem differently, how? Are you stuck, why?

To demonstrate the effects of metacognitive pedagogies on mathematics reasoning, the following section reviews studies that exemplify the implementation of metacognitive pedagogy in kindergarten, primary and secondary school, and higher education, respectively; it provides research evidence on the impact of the metacognitive pedagogies on the mathematics reasoning of K–12 and higher education students. Finally, the impact of self-regulation (SR) scaffolding in ICT (Information and Communication Technologies) environments is shortly reviewed.

Research Evidence

Implementing metacognitive pedagogy in the kindergarten is not at all self-evident. As mentioned above, studies conducted in the 1980s and 1990s claimed that children younger than 10 years old have limited metacognitive skills because they are in the concrete developmental stage and therefore cannot activate higher-order thinking skills, such as those involved in metacognition. However, in the 2000s, research has started to report other evidence. Veenman, Van Hout-Wolters, and Afflerbach (2006) indicated that children at the ages of 4–5 can estimate the difficulty of a task and have some knowledge of which strategies to use. Whitebread and Coltman (2010) showed that without adult intervention, kindergarten children at the ages of 3–5 spontaneously plan, monitor, control, and reflect on their mathematics activities. Earlier, Mevarech (1995) demonstrated that kindergarten children could activate metacognitive processes when encountered with mathematics tasks. For example, children at this age could identify and explain which information is crucial for solving mathematical problems, and they could also distinguish between mathematics and non-mathematics information provided in word problems.

Based on this research, several intervention studies used metacognitive pedagogies for enhancing kindergarten children's metacognition and mathematical reasoning (e.g., Ginsburg, Lee, & Boyd, 2008). In these studies, the kindergarten teacher scaffolds children's thinking by providing metacognitive hints based on IMPROVE and asks the kids to explain their reasoning. For example, Mevarech and Eidini (in preparation) conducted a study in which the kindergarten teacher read aloud an e-book embedded with metacognitive scaffolding (Shamir and Baruch, 2012). The metacognitive questions were modified to fit the child's age: What does this page tell us? What do you have to do in order to find the answer? Please explain your thinking. Why do you think you have to add/subtract? If the children did not know what to do, the kindergarten teacher went with the children to the previous page and asked them: How did you find the answer here? Then she returned to the next page and repeated the questions. The study indicated that exposing kindergarten children to metacognitive pedagogy highly enhanced their metacognition and mathematical reasoning. The experimental group could better explain their reasoning, used richer mathematical language, and improved their problem-solving skills more than the control groups.

Developing Self-Regulation Skills for Word Problem Solving in Primary and Secondary School Levels

De Corte and Verschaffel (2006) designed an innovative learning environment, 'Skillfully Solving Context Problems (SSCP)', for fifth graders' acquisition of adaptive competence in mathematical problem solving. As mentioned in the first section of this chapter, self-regulatory skills constitute a crucial component of adaptive competence.

The SSCP learning environment focused on cognitive self-regulation skills. It consists of a series of 20 lessons taught over a four-month period, and aimed at the acquisition by the students of a self-regulation strategy for problem solving consisting of five stages:

- I build a representation of the problem;
- I decide how to approach and solve the problem;

- I do the necessary calculations;
- I interpret the outcome and formulate an answer; and
- I control and evaluate the solution.

A set of eight heuristic strategies was embedded and taught in the first and second stages. For example: draw a picture of the problem situation, or distinguish relevant from irrelevant data. Acquiring this problem-solving strategy involved (1) becoming aware of the different phases of a competent problem-solving process (awareness training), (2) becoming able to monitor and evaluate one's actions during the different phases of the solution process (self-regulation training), and (3) gaining mastery of the eight heuristic strategies (heuristic strategy training).

To elicit and support in all students constructive, self-regulated, situated, and collaborative learning (De Corte & Verschaffel, 2006), the environment was designed—in narrow cooperation with the teachers of the four participating classes and their principals—based on the following three pillars that embody those characteristics of productive learning.

- A varied set of complex, realistic, and open problems that lend themselves well for the application of the self-regulation skills and the heuristics that were intended to develop in students.
- Creating a learning community through the application of a varied set of activating and interactive instructional techniques, namely small group work, whole class discussion, and individual assignments. Throughout the lessons, the teacher encouraged the students to reflect upon their cognitive and self-regulation activities. This support was gradually faded out as students became more competent in solving problems, and consequently regulated more and more their own solution activities.
- Establishing an innovative classroom culture through the introduction of new social norms with respect to learning and teaching problem solving. Typical aspects of this classroom culture include: (1) stimulating students to articulate and reflect upon their solution strategies and beliefs about problem solving; (2) discussion about what counts as a good problem, a good response, and a good solution procedure; (3) reconsidering the role of the teacher and the students in the learning community.

The teachers were intensively prepared for supporting the implementation of the learning environment. The effects of the intervention were evaluated using a pretestposttest-retention test design with an experimental group consisting of four fifth-grade classes ($n = 86$) and a control group of seven comparable classes ($n = 146$). A wide variety of data-gathering instruments was applied: word-problem-solving tests, a standardized mathematics achievement test, an attitude questionnaire, interviews, and video-registration of some lessons.

The findings indicate (see also De Corte, 2012) that the intervention had a significant and stable positive effect on the experimental pupils' skills in solving math problems (in comparison with a control group). The positive effect was stronger for the high-ability students, but also the low-ability ones benefited significantly from the intervention. The learning environment had also a significant, albeit small positive effect on students' pleasure and persistence in solving problems and on their math-related beliefs and attitudes. The results on a math achievement test revealed a significant transfer effect to other parts of the math curriculum (measurement, geometry): the experimental students performed significantly better on this test than the control group. There was a substantial significant increase in the experimental students' spontaneous use of heuristic and self-regulation skills (orienting, planning, monitoring, evaluating).

Studies by Mason and Scrivani (2004) and by Panouara, Demetriou, and Gagatsis (2010), in which an SSCP-based learning environment for problem solving was used also with fifth graders, yielded similar major findings. Altogether these studies show that innovative learning environments in which self-regulation skills for solving math problems are learned by using interactive instructional methods in a new classroom culture can significantly increase students' competence.

Interestingly, the basic principles underlying the interventions applied in those studies converge with the characteristics of the effective learning environments that derive from recent meta-analyses of teaching experiments: (1) train in an integrated way cognitive, metacognitive, and motivational strategies, using thereby a variety of teaching methods; (2) pay explicit attention to the usefulness and benefits of strategies; (3) create opportunities for practicing strategies and provide feedback about strategy use; (4) create an innovative classroom culture that stimulates SRL, especially reflection (Dignath & Büttner, 2008; Dignath, Büttner, & Langfeldt, 2008; Veenman et al., 2006).

Studies on the effects of metacognitive pedagogy on secondary school mathematics achievement reveal similar findings to those conducted at the lower levels of education. The positive effects were evident not only on 'traditional' mathematics achievement tests, but also on math literacy which is largely emphasized in recent years. PISA (Programme for International Student Assessment of the OECD) defines mathematical literacy as:

The capacity to identify, understand and engage in mathematics as well as to make well-founded judgments about the role that mathematics plays in an individual's current and future life as a constructive, concerned, and reflective citizen.

(OECD, 2003, p. 20)

Metacognitive pedagogy is particularly beneficial for promoting students' mathematical literacy because it trains students to activate higher-order cognitive skills which are crucial for solving math literacy tasks. Research findings indicate that tenth graders who solved math literacy tasks via IMPROVE significantly outperformed their counterparts who solved the same literacy tasks for the same duration of time without the metacognitive prompts. Interestingly, fine-tuning analysis of students' performance on the math literacy test indicated that the effect size was larger on the 'application' compared to the 'computation' components (Mevarech & Lianghuo, in press).

To conclude, two meta-analyses (Dignath & Büttner, 2008) based on 49 studies at the primary school level and 35 at the secondary school level that analyzed the effects of SRL on reading and mathematics achievement reported an average effect size of 0.69. For both school levels, higher effect sizes were observed when the training was conducted by researchers instead of regular teachers. Moreover, higher effects were attained in the scope of mathematics than in reading/writing or other subjects. The main conclusion of these meta-analyses was that SRL can be fostered effectively at both primary and secondary school levels.

Developing Self-Regulation Skills for Geometry Problem Solving

Although geometry is an integral part of the mathematics curriculum, surprisingly only a few studies explored the relationships between metacognition and achievement in geometry or the effects of metacognitive pedagogy on students' achievement in geometry. Kai-Lin (2012) explored the extent to which the use of metacognitive strategies that relate mainly to reading comprehension affects students' comprehension of geometric proofs. He found that good comprehenders tended to employ more meta-cognitive reading strategies for planning and monitoring and more cognitive reading strategies for elaborating proof compared with moderate comprehenders who in turn employed these strategies more often compared with poor comprehenders.

While Kai-Lin (2012) explored the relationships between cognitive and meta-cognitive reading strategies on comprehension of geometry proof, Mevarech, Gold, Gitelman, and Gal-Fogel (2013) examined the immediate and delayed effects of meta-cognitive scaffolding implemented via IMPROVE on eighth-grade students' achievement in geometry. In this study, the learning unit was trapezoids: definitions, proofs, and computations. The study indicates that although prior to the beginning of the study the IMPROVE group scored significantly lower on the pretest than the control, after the intervention the IMPROVE students outperformed the control group on the immediate test that was administered at the end of the intervention, as well as on the delayed posttest administered two months later. Similar findings were reported by Hurme and Järvelä (2005) and Schwonke, Ertelt,

Otieno, Renkl, Aleven, and Salden (2013), who studied the effects of metacognitive scaffolding implemented in ICT environments on geometry achievement.

Research on the impact of metacognitive pedagogy on students' achievement in geometry is only at its beginning. The studies reviewed above were implemented in different countries with or without computers, and focused on different geometry units. These studies showed that in spite of the contextual differences, the impact of the metacognitive scaffolding on achievement in geometry was significant.

The Effects of Metacognitive Scaffolding on Students in Higher Education

Schoenfeld (1985) is one of the first researchers who tried to promote mathematics reasoning in higher education students by using metacognitive scaffolding. He started by working with his students who majored in mathematics at the mathematics department in Berkeley University. Observing his students, Schoenfeld was surprised to see how many difficulties the students experienced when they had to solve mathematics problems, and how poorly they coped with the difficulties. Based on Polya's book *How to Solve It* (1957), Schoenfeld suggested a set of metacognitive self-addressed questions that have been widely used in many of the metacognitive pedagogies that were developed since then. Schoenfeld students adopted those metacognitive self-addressed questions which largely promoted their mathematical reasoning. Since the seminal work of Schoenfeld (1985), many other researchers modified those methods to be used either in higher education mathematics classrooms (e.g., Mevarech & Fridkin, 2006) or in other topics (e.g., Choi, Land, & Turgeon, 2005).

Research in the area of metacognition has devoted special attention not only to higher education students who studied mathematics, but also to the promotion of math teachers' SR in both pre- and in-service professional development courses (e.g., Mok, Lung, Cheng, Cheung, & Ng, 2006; see also Kramarski, 2018/this volume). All these studies provided evidence on the essential role of metacognitive scaffolding in supporting teachers' self-regulation in mathematics learning and teaching. Pre- and in-service teachers who experienced metacognitive pedagogies when they themselves participated in professional development courses outperformed the control groups who studied 'traditionally' with no exposure to metacognitive pedagogies. Furthermore, math teachers who were exposed to metacognitive pedagogy during professional development courses were more inclined to implement in their classrooms what they have learned in the course compared to their counterparts who studied 'traditionally' with no metacognitive scaffolding (Mevarech & Shabtay, 2012).

Self-Regulated Mathematics Learning in ICT Environments

As reviewed in the previous subsections, researchers have reported that learners of different ages trained in learning to monitor and control their own cognitive processes for mathematics problems and learning mathematics do better than untrained learners. However, research that focuses on metacognition and self-regulation in mathematical learning has been usually carried out in non-computer-based environments. Yet, the very nature of ICT and its widespread use in the educational systems raises additional challenges for mathematics educators in general, and researchers of math metacognitive pedagogies in particular (see also [Section III](#), this volume). An essential question refers to the extent to which ICT can replace the teacher or only support his/her teaching.

Another question regards the role of metacognition in learning with ICT. Since computerized tools are very friendly and in a way 'invite' users to 'push-the buttons-and-see-what-happens', quite often trial-and-error is the common mode of use in ICT environments, and the learners have a hard time reflecting on the solution process, regulating their learning, or planning ahead. Thus, the provision of metacognitive scaffold becomes a 'must', rather than a 'nice to have' condition.

Furthermore, even those who believe that ICT provides only an extraneous (effective) tool, they still puzzle over how to embed metacognitive pedagogies in these environments: Would the teacher implement the metacognitive scaffolding or would those SR prompts be part of the software? What kinds of SR prompts are appropriate for

these environments and for what age group? And what are the best settings/contexts for scaffolding SR in ICT mathematics environments? This subsection shortly addresses these issues.

During the last decade, researchers have started to use various computer-based tools to stimulate and support different aspects of self-regulated mathematics problem solving and learning, and, in doing so, to enhance learners' mathematics achievement. In relation to mathematics education, computerized tools can be classified into four broad categories:

- Domain-specific ready-made tools such as Computer Algebra System (CAS) Dynamic Geometrical Supposer, Graphical Calculator; in this category, the teacher provides the SRL prompts while students work with the ready-made software;
- Math-specific computerized tools designed to assist specific difficulties, such as those encountered in solving word problems; in these studies the metacognitive scaffold is embedded within the software allowing the students to choose it during the problem-solving process (Jacobse & Harskamp, 2009; de Kock & Harskamp, 2014), or offering metacognitive scaffolds that fit the solution phases in which the student stays (Kapa, 2001, 2007);
- General e-communication tools, such as intelligent cognitive tutor systems (Aleven & Koedinger, 2002), multimedia, or math e-books (e.g., Shamir & Baruch, 2012); and
- Learning settings based on ICT, such as distance learning, forums, mobile learning, etc.

In all categories, whether or not the SR scaffold was embedded in the software or offered by the teacher, the nature of the SR support was similar, slightly adapted to the students' age, mathematics domain, or the specific ICT tool.

Jacobse and Harskamp (2009) and de Kock and Harskamp (2014) used the following metacognitive prompts: read and analyze ('I read carefully'), explore ('I know the type of problem'), plan ('I make a plan'), verify ('I check my answer'), and ('What did I learn?'). Aleven and Koedinger (2002) utilized self-explanations as an effective scaffold during the use of an intelligent cognitive tool. Choi et al. (2005) and Okita (2014) assumed that having students ask each other scaffolding questions and asking students to explain to others how to solve math problems within ICT environment is an efficient metacognitive tool.

It should be noted that ICT embedded within metacognitive pedagogies is used at all levels of education, from kindergarten through primary school (e.g., Jacobse & Harskamp, 2009; de Kock & Harskamp, 2014) to secondary school and beyond (e.g., Kapa, 2001, 2007). This is not surprising given the advanced technologies that could be designed to fit the needs of each age group and the mathematics topics studied.

Although there are tremendous differences between the ICT features that help the learner to navigate within a learning environment, and although these tools differ in the nature and the kind of self-regulatory support implemented either by the teacher or by the computer, most studies have provided empirical evidence for the value of these scaffolds aimed at supporting metacognition or SRL in the domain of mathematics.

Teong's (2003) investigation was one of the first to demonstrate the influence of a computer-based environment on students' mathematical word problem solving. Forty 11–12-year-old low achievers were subjected during four weeks either to a regular version of a computer-based environment for word problem solving (control group), or to a version enriched with CRIME—an acronym for the word-problem-solving stages: Careful Reading; Recall Possible Strategies; Implement Possible Strategies; Monitor; and Evaluation (experimental group). Instruction in the experimental group was based on the cognitive-apprenticeship principles as developed by Polya (1957), Schoenfeld (1992), and Verschaffel et al. (1999). The study adopted a two-phase design combining an experimental design focused on the analysis of students' mathematical achievement test data, and a case-study design using the analysis of collaborative think-aloud protocol data. Results of the word-problem-solving pre- and posttests revealed that experimental students outperformed control students on their ability to solve word problems.

The data from the case studies showed that the experimental low achievers developed the ability to ascertain when to make metacognitive decisions, and elicited better metacognitive decisions than the control lower achievers. However, they needed some time for internalization to occur before the positive benefits of metacognitive training could prevail. The study also provided evidence that self-regulation influenced by metacognitive training in a cognitive-apprenticeship computer-based environment can play an important role in contributing to low achievers' word problem solving.

In many of the above-mentioned studies, data were collected under rather strictly controlled conditions and by the researchers themselves. However, as already mentioned above, meta-analyses of the effects of metacognitive studies in elementary and secondary education have made clear that the general impact becomes much smaller once teachers instead of the researchers start to work with the program (Dignath & Büttner, 2008). So the question remains whether such metacognitive computer programs will also improve students' problem-solving and/or self-regulation skills without the supervision of researchers in a (more) natural class setting.

De Kock and Harskamp (2014) examined in a quasi-experimental study the effectiveness of a computer program in such a naturalistic setting. During 10 weeks, 280 fifth-grade students of the experimental condition practiced with a program that offered metacognitive hints derived from the program of Jacobse and Harskamp (2009), while also working in their mathematical textbooks. Meanwhile 110 students of the control condition worked in their textbooks for the 10-week period but had no access to the computer program. Data analyses from a rich set of assessment instruments revealed that the experimental group was better capable of analyzing and solving the word problems than the control group; the experimental group also had better self-monitoring skills. Log-files revealed, however, that the hint usage in the experimental group was higher in the first lessons compared to the final lessons. Overall, the results indicate that this computer program is suitable for implementation in classroom practice without giving up the use of a textbook, and promotes students' mathematics achievement compared to merely learning with textbooks.

Future Research Directions

The review of the above studies, whether implemented in kindergarten, primary school, secondary school, or higher education, and whether employed in ICT environments or without using computerized tools, indicate that learning environments that offer metacognitive scaffolds such as those suggested by IMPROVE (see also Kramarski, 2018/this volume) have the potential for successfully supporting learners of various ages and ability levels in solving mathematics problems. As mentioned before, in most cases the metacognitive pedagogies were based or built on a theoretical model of the problem-solving episodes of Schoenfeld (1985) ('read and analyze the problem', 'explore possible solutions', 'plan a solution', 'monitor the implementation', and 'evaluate the outcome') or a closely related model. Yet, there are still many open questions that merit future research, and some are described below.

- Although mathematics is considered to be one discipline, it includes various domains: arithmetic, algebra, geometry, calculus, probability, topology, statistics, and many others. Each domain is based on different principles, topics, and solution methods. Yet, the studies that investigated the relationships between mathematics and metacognition have focused mainly on arithmetic and algebra word problems. Little is known at present on the extent to which metacognition is activated when solvers are confronted with other mathematics domains. Furthermore, it is possible that the metacognitive pedagogies described above have to be modified to fit the various mathematics domains.
- While the above review indicates positive effects of ICT embedded within meta-cognitive pedagogies on mathematics achievement of students at various age groups, in most cases the overall research design and/or specific methods used in these studies do not allow us to derive grounded conclusions as to what elements or aspects of the computer-based environment are exactly responsible for the obtained positive effects.
- Teachers play an important role in promoting students' metacognition (Dignath & Büttner, 2008). The issue of how to train teachers to implement meta-cognitive pedagogies is not self-evident. The studies reviewed above provide evidence on the essential role of metacognitive scaffolding in supporting teachers' self-regulation in

mathematics learning and teaching. It seems that 'learning-by-doing' applies also for professional development programs. Pre- and in-service teachers who experienced metacognitive pedagogies when they themselves participated in professional development courses outperformed control groups who studied 'traditionally' with no exposure to metacognitive pedagogies (see Kohen & Kramarski, 2012, and Mevarech & Shabtay, 2012, for pre- and in-service, respectively). Yet, none of these studies followed the teachers in their classrooms in order to observe the implementation of the metacognitive pedagogies learned in the courses. This is an essential issue with wide theoretical and practical implications.

- Longitudinal design experiments are definitely needed in order to understand the development of metacognition and mathematics reasoning. Van der Stel and Veenman (2014) conducted a study in which middle school mathematics students were observed during two to three consecutive years. It would be interesting to follow students who are exposed to metacognitive pedagogies for a longer period of time.
- Most of the research that studied the effects of metacognitive pedagogy on mathematics reasoning was implemented on a small scale using the pre-post or pre-post-delay design. Large-scale studies on these issues are urgently needed.

Implications for Educational Practice

Our cognitive system has its limitations: we can only remember a certain amount of information, we have difficulties solving complex, unfamiliar and non-routine (CUN) problems, and we do not have enough cognitive resources to devote to learning new concepts (Hattie, 2009). To overcome some of these limitations we need effective strategies that enable us to activate and regulate effectively our cognitive processing power:

We learn by employing effective and flexible strategies that help us to understand, reason, memorize and solve problems; learners must know how to plan and monitor their learning, how to set their own learning goals, and how to correct errors; sometime prior knowledge can stand in the way of learning something new, and students must learn how to solve internal inconsistencies and restructure existing conceptions when necessary; and learning takes considerable time and periods of practice to start building expertise in that area.

(Hattie, 2009, p. 246)

There is much consensus that these SR skills can be taught, and effectively used in solving mathematics problems with or without ICT tools. This means that teachers have to be familiar with these metacognitive pedagogies, explicitly apply them in their classrooms, and then provide ample opportunities for students to practice the SR and metacognitive strategies. When students have to solve CUN tasks, it is the quality of their metacognitive skills rather than their intellectual ability that will determine the learning outcomes. When computerized tools are implemented, the applied metacognitive skills and the features of the program make the difference. These findings apply to all levels of education, from kindergarten to high school and beyond, showing what mathematics education can become with the support of mathematics SR and meta-cognitive pedagogies. However, as argued by De Corte and Verschaffel (2006) at the end of their intervention study, a crucial condition to attain positive effects is that the teachers are intensively scaffolding and supported in implementing such metacognitive-oriented learning environments. This is not surprising. Indeed, the effective and sustained implementation of innovative learning environments places high demands on the teachers and requires substantial changes in their traditional roles and practices.

A crucial question regards the basic conditions needed for metacognitive instruction to be successful. One of the most important conditions is explicit teaching of the metacognitive skills within the content area followed by intensive practicing. Teachers and students have to be aware of the SRL strategies and they have to know what, when, how, and why they should activate those strategies during problem solving. Modeling or teaching the metacognitive strategies implicitly is simply not enough. To promote metacognitive awareness, teachers can construct environments that are conducive to the use of metacognitive learning. Such environments include cooperative learning, or peer interactions in ICT or non-ICT environments where students can 'naturally' activate metacognitive processes during the discourse with their peers. Under these conditions, metacognition and SRL

are teachable and have significant impact on teachers and students (e.g., Dignath-Van Ewijk, 2016; Shabtay, Michalsky, & Mevarech, 2016).

The fact that the effects of metacognitive pedagogies were found in a large number of countries calls for international collaborations on studying, designing, and implementing metacognitive pedagogies in mathematics classes as well as in other domains. The major conclusion that derives from this chapter is that metacognitive pedagogies have the potential of improving the learning and performance of students and teachers alike, in K–12 classes and beyond, and for various mathematics topics. However, the implementation of self-regulation pedagogies on a large scale and their longitudinal contributions to mathematical learning, thinking, and reasoning are still open for future research.

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8 Self-Regulated Learning in Reading

Keith W. Thiede and Anique B. H. de Bruin

Reading is a basic skill that many consider a fundamental building block to all other learning (Melby-Lervag & Larvag, 2014). Reading proficiently requires both decoding skills and comprehension skills. Self-regulation plays an important role in guiding comprehension; comprehension is greater for students who better regulate their reading practices than for those who do not (e.g., Thiede, Anderson, & Theriault, 2003; Zimmerman, 1990). In particular, students must monitor and control their reading to effectively comprehend texts (e.g., Cromley & Azevedo, 2007). This chapter provides a model of self-regulated learning that highlights the importance of accurate metacognitive monitoring and effective use of monitoring to guide study decisions in learning. In this chapter, we review approaches used to improve the accuracy of metacognitive monitoring and validate models of self-regulated learning by showing the crucial role that monitoring and regulation have played in improving reading comprehension.

Relevant Theoretical Ideas Underlying Self-Regulated Learning in Reading

Many models of self-regulated learning describe learning as an interaction between metacognitive monitoring and regulation of study (e.g., Ariel, Dunlosky, & Bailey, 2009; Butler & Winne, 1995; see Winne, 2018/*this volume*). For instance, as a student reads with a goal of comprehending a text, she monitors her progress toward full comprehension. If her monitoring indicates that she has not yet comprehended the text, she will likely reread the text until her monitoring suggests that the material has been mastered (or perhaps seek help in understanding the text; see Karabenick & Gonida, 2018/*this volume*), at which time she will stop reading. Accurate metacognitive monitoring is crucial to effective regulation (Winne & Perry, 2000). If the student does not accurately monitor comprehension, she could misdirect rereading efforts or stop reading before the text is fully understood. By contrast, if the student accurately monitors comprehension, she will effectively regulate study and improve comprehension (e.g., Rawson, O’Neil, & Dunlosky, 2011; Thiede & Anderson, 2003; Thiede, Redford, Wiley, & Griffin, 2012). Therefore, it is important to find ways to improve the accuracy of comprehension monitoring, called metacomprehension accuracy.

Measuring Metacomprehension Accuracy

Before describing the literature on self-regulated learning in reading, it is important to understand how metacomprehension accuracy is measured. Glenberg and Epstein (1985) developed a procedure for measuring metacomprehension accuracy. They had participants read a series of short texts. Participants then judged their understanding of each text, and then answered an inference question for each text.

Metacomprehension accuracy describes how well a person’s judgments of comprehension relate to test performance. As noted by Dunlosky and Thiede (2013), accuracy can be described in two distinct ways. One is the degree to which the magnitude of the judgments is related to the actual magnitude of test performance. This kind of accuracy has been called absolute accuracy, often reported as confidence bias (i.e., average predicted performance minus average actual performance computed across texts). The other concerns the degree to which the judgments discriminate between different levels of performance across items. This kind of accuracy has been called relative accuracy, reported as the intra-individual correlation between predicted and actual performance computed across texts. It is important to note that the two kinds of accuracy are theoretically orthogonal. [Table 8.1](#) presents predicted and actual performance of four students. Student 1 has perfect absolute accuracy (no bias: average predicted performance across texts = average actual performance), and has perfect relative accuracy (the rank order of predicted performance across texts = actual performance). Student 2 is consistently over-confident and has poor absolute accuracy, but has perfect relative accuracy. Student 3 is over-confident on Texts 1 and 2, but this is balanced by being under-confident on Texts 4 and 5—and across all the texts has perfect absolute accuracy. By contrast, Student 3 has perfectly inaccurate relative accuracy—the rank order of predicted

performance is the exact opposite of actual performance. Finally, Student 4 has both poor absolute and relative accuracy.

[Table 8.1](#) Illustrations of the relation between absolute and relative accuracy

<i>Performance</i>	<i>Student 1</i>		<i>Student 2</i>		<i>Student 3</i>		<i>Student 4</i>	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
Text 1	7	7	7	4	7	3	7	0
Text 2	7	7	7	4	7	5	7	2
Text 3	6	6	6	3	6	6	6	3
Text 4	5	5	5	2	5	7	5	4
Text 5	3	3	3	0	3	7	3	4
<i>Accuracy</i>								
Absolute	0		+3		0		+3	
Relative	+1.0		+1.0		−1.0		−1.0	

Thus, students' ability to calibrate performance and discriminate between well-understood and less-understood texts may be aligned in some instances and misaligned in others. Perhaps more important, variables that influence one kind of accuracy may not influence the other. For instance, domain knowledge has been shown to influence absolute accuracy but not relative accuracy (Griffin, Jee, & Wiley, 2009). Therefore, to avoid confusion, it is important to be clear whether one is examining absolute or relative accuracy. For the remainder of this chapter, we will focus on relative accuracy.

Factors That Influence Metacomprehension Accuracy

To understand the factors that influence metacomprehension accuracy requires theories of both metacognitive monitoring and comprehension (Weaver, 1990). For instance, Rawson, Dunlosky, and Thiede (2000) used the cue-utilization framework of metacognitive monitoring (Koriat, 1997) and the construction-integration model of comprehension (Kintsch, 1988) to identify ways to improve metacomprehension accuracy. The cue-utilization framework suggests that metacognitive judgments are inferential in nature. That is, people do not have direct access to their memory and comprehension processes; therefore, they have to base their metacognitive judgments on whatever cues they have available about the content of their memory and comprehension processes. The accuracy of metacomprehension judgments is then determined by the degree to which the cues used to judge comprehension are diagnostic of performance on a test of comprehension.

Theories of comprehension, like the construction-integration model (Kintsch, 1988), help identify the cues that will be diagnostic of performance on tests of comprehension. According to this model, readers construct meaning from texts at several levels: a lexical or surface level, a textbase level, and a situation model level. The lexical level, containing the surface features of the text, is constructed as the words and phrases appearing in the text are encoded. The textbase level is constructed as segments of the surface text are parsed into propositions, and as links between text propositions are formed based on argument overlap and other text-explicit factors. Deeper understanding of the text is constructed at the level of the situation model, which involves connecting text information with the reader's prior knowledge and using it to generate inferences and implications from the text. One's situation model largely determines performance on tests of comprehension (McNamara, Kintsch, Songer, & Kintsch, 1996). Thus, getting people to base their metacomprehension judgments on cues related to their

situation model rather than their textbase should increase the predictive accuracy of judgments (Rawson et al., 2000; Wiley, Griffin, & Thiede, 2005).

Recently, van Loon, de Bruin, van Gog, van Merriënboer, and Dunlosky (2014) developed a technique to compute cue diagnosticity (i.e., the degree to which cues are predictive of subsequent test performance) and utilization (i.e., the degree to which cues are related to metacognitive judgments). In their study, they found that differences in metacomprehension accuracy were explained more by differences in cue utilization than cue diagnosticity. Examining cue diagnosticity and utilization could provide crucial information about how interventions influence metacomprehension accuracy.

Thiede, Griffin, Wiley, and Anderson (2010) also showed that metacomprehension accuracy was influenced by the cues used to judge comprehension. They had college students complete the standard metacomprehension procedure. They read a set of five texts, judged their comprehension of each text, and then completed a test over the material covered in each text. However, just after making the metacomprehension judgment for the last text, students were asked to report the cues used to judge their own comprehension.

A list of 30 cues that students reported using to judge comprehension were collapsed into five cue types: (A) the ability to explain meaning; (B) ability to recall information about the text; (C) prior knowledge of a topic; (D) interest in the topic of the text; and (E) use of features of the text including difficulty, ease of processing, length, and specific vocabulary. Many of the self-reported cues have been studied as potential factors affecting metacomprehension judgments. For instance, research has shown that metacomprehension judgments are influenced by prior knowledge/domain familiarity (Glenberg, Sanocki, Epstein, & Morris, 1987; Griffin et al., 2009; Maki & Serra, 1992), text features such as the perceived readability of texts (e.g., Dunlosky, Baker, Rawson, & Hertzog, 2006; Rawson & Dunlosky, 2002) or whether a text is narrative or expository (e.g., Maki, Shields, Wheeler, & Zacchilli, 2005), and one's ability to recall information about a text (e.g., Baker & Dunlosky, 2006).

Thiede et al. (2010) showed that metacomprehension accuracy is also affected by cue use. In particular, metacomprehension accuracy was greater for students who relied on comprehension-based cues (i.e., their own ability to understand or explain the text) than for students who relied on other cues. Metacomprehension accuracy was worse for students who relied on surface-feature cues than for other students. Thus, it is important to direct students to use diagnostic cues in judging comprehension.

Interventions designed to improve metacomprehension accuracy have attempted to focus readers on cues related to the situation model when judging comprehension. Some of these interventions increase the salience of valid cues by asking readers to retrieve information about the texts prior to judging comprehension. Others increase the salience of valid cues by asking readers to encode the texts in a specific way to enhance construction of the situation model for a text. We will review these two approaches in turn.

Improving Metacomprehension Accuracy by Retrieving Information Prior to Judging Comprehension

Glenberg et al. (1987) proposed the modified-feedback hypothesis to account for meta-comprehension accuracy. This hypothesis states that metacomprehension judgments are influenced by one's ability to retrieve information at the time of the judgment. Based on the modified-feedback hypothesis, the standard procedure for examining metacomprehension was altered to include a retrieval attempt prior to judging comprehension. For instance, after reading a set of texts, participants could be asked to write a summary of each text, and then participants would judge their comprehension and complete a test for each text.

According to the cue-utilization framework of metacognitive monitoring (Koriat, 1997), as the person contemplates how well a text was understood, he or she may rely on a variety of cues to make this judgment. Retrieving information about texts may allow a reader to evaluate the quality of cues used to retrieve information

about a text. That is, when judging comprehension, the person may reflect on how successfully he or she had retrieved information. Accordingly, a text may receive a high rating of comprehension if the person had been able to retrieve a great deal of information about the text during the retrieval attempt. By contrast, a text may receive a low rating of comprehension if the person struggled to retrieve information about the text. Assuming availability of information during the retrieval attempt is related to availability of information for testing, then using the retrieval of information as a basis for meta-comprehension judgments should improve metacomprehension accuracy because the basis of the judgments should be highly related to test performance.

Accuracy of metacomprehension judgments may be affected by when the retrieval attempt occurs. Activation theories of text comprehension (e.g., Fletcher, van den Broek, & Arthur, 1996) may help explain why. According to these theories, spreading activation occurs during reading; thus, more information is active in working memory shortly after reading than after a delay (i.e., when activation has decayed). When retrieving information immediately after reading, a person may have access to a highly active mental network. Accordingly, the person may have access to information in short-term memory (STM) even for a text that was not well understood. That is, for less-understood texts, the person may have extraneous information activated during reading or information contained in the text that is active in STM. However, this information in STM may not be accessible after the mental network has decayed at the time of the test of comprehension. The key is a person may have access to information during this retrieval attempt even for texts that were not well understood, so the process of retrieving information of well-understood texts versus less-understood texts may seem quite similar immediately after reading; therefore, the retrieval attempt may produce a set of homogeneous cues for judging comprehension that may not help discriminate well-understood texts from less-understood texts. Moreover, these cues may not be indicative of test performance given that the test occurs after a delay; therefore, one might predict poor metacomprehension accuracy when the retrieval attempt occurs immediately after reading.

When the retrieval attempt occurs after a delay, activation of the mental network for a text may have decayed and a person may have access to only that information retrievable from long-term memory (LTM). Thus, for a less-understood text, the person may have little to draw on when retrieving information; whereas, for a well-understood text, the person may retrieve much more information; therefore, retrieving information after a delay may produce a set of heterogeneous cues for judging comprehension that may highlight differences between well-understood texts and less-understood texts. Moreover, these cues are likely to be highly indicative of test performance because both these retrieval attempts and tests occur after a delay and are based on retrieval of information from LTM, which may produce higher levels of metacomprehension accuracy.

Improving Metacomprehension Accuracy by Promoting Construction of the Situation Model

Another strategy that has been used to improve metacomprehension accuracy is to increase the salience of valid cues by asking readers to encode texts in ways that promote construction of the situation model for texts. For instance, while reading a text, a student could be asked to construct a concept map for the text, which is a graphic representation of the underlying structure of the meaning of a text. Constructing concept maps can be an effective organizational strategy that helps readers formulate the connections among concepts in a text (i.e., the situation model) (Weinstein & Mayer, 1986). More important to improving metacomprehension accuracy, instructions that promote the formulation of the situation model during reading should also increase the salience of the situation model for judgments of comprehension. Thus, when judging comprehension, the reader may have access to cues that provide a sense of the quality of his or her situation model for a text. Again, given cues and tests of comprehension are related to the situation model of texts, utilizing these cues should improve metacomprehension accuracy.

Research Evidence Showing the Efficacy of Interventions to Improve the Accuracy of Comprehension Monitoring

Empirical evidence shows both delayed retrieval attempts prior to judging comprehension and encoding instructions designed to promote construction of the situation model improve metacomprehension accuracy. We briefly review this literature below.

Delayed Retrieval Attempts Improve Metacomprehension Accuracy

Providing a retrieval attempt prior to judging comprehension has been shown to improve metacomprehension accuracy. That is, after reading a series of texts, students are instructed to retrieve information about each text; after the retrieval attempt students then judge their comprehension of each text, and take a test for each text. Researchers have used a variety of retrieval tasks including writing a summary, generating a list of keywords, and constructing a diagram of texts. These retrieval tasks have been hypothesized to increase the salience of cues related to the situation model of each text at the time of judging comprehension (e.g., Anderson & Thiede, 2008). As these cues are predictive of performance on tests of comprehension (e.g., Wiley et al., 2005), utilizing these cues improves metacomprehension accuracy.

Writing Summaries

Instructing students to write summaries of texts has been shown to improve comprehension by helping students build relations among concepts contained in a text as well as link these concepts to prior knowledge (e.g., Wittrock & Alesandrini, 1990). Others have suggested that summarization improves comprehension by helping readers to focus attention on the more important information of a text (e.g., Anderson & Ambruster, 1984). Others have suggested that summarization improves comprehension by promoting self-testing during reading (e.g., Brown & Day, 1983; Palinscar & Brown, 1984), which may signal comprehension breaks and invite readers to initiate fix-up strategies to repair breaks in comprehension (Winne & Hadwin, 1998). Summarizing texts also improves comprehension by improving metacomprehension accuracy and increasing the effectiveness of self-regulated study (Thiede & Anderson, 2003).

Thiede and Anderson (2003) evaluated the effect of writing summaries on meta-comprehension accuracy. They compared metacomprehension accuracy across three groups. A control group read a set of texts, judged comprehension of each text, and then completed a test of each text. An immediate-summary group read a text then immediately wrote a summary for the text. After reading and summarizing each text, they made metacomprehension judgments and completed a test for each text. A delay-summary group read all six texts, they then wrote summaries for each text. After reading and summarizing all the texts, they made metacomprehension judgments and completed a test for each text. Consistent with the theory outlined above, metacomprehension accuracy was greater for the delayed-summary group than for the other groups.

Using a repeated-measures design, Anderson and Thiede (2008) showed that summarizing texts improved metacomprehension accuracy for both typical college students and at-risk readers. To gather information about cue use, Anderson and Thiede also asked participants to describe the cues used to judge comprehension in each condition. These data were analyzed by Thiede et al. (2010) and showed across all conditions that metacomprehension accuracy was affected by cue use, and that at-risk readers more frequently relied on less valid cues (i.e., cues related to the surface features of a text) to judge comprehension than did typical readers.

Generating Keywords

Generating summaries improved metacomprehension accuracy; however, generating summaries for each text is quite time consuming. Thiede et al. (2003) evaluated the efficacy of a less time-consuming retrieval task. Instead of summaries, they had students generate a list of five keywords that captured the essence of each text.

Metacomprehension accuracy was greater for the delayed-keyword group than for the immediate-keyword group or the control group. Chen (2009) also showed generating delayed-keywords improved metacomprehension accuracy for college readers. This finding has also been extended to younger children (de Bruin, Thiede, Camp, & Redford, 2011).

Thiede, Dunlosky, Griffin, and Wiley (2005) evaluated why delayed generation of keywords improved metacomprehension accuracy. They systematically manipulated the lag between reading and keyword generation, as well as the lag between keyword generation and judging comprehension, and found that introducing a delay between reading and keyword generation was crucial to improving metacomprehension accuracy. That is, generating keywords after a delay from reading, when textbase information for a text had faded from memory (Kintsch, Welsch, Schmalhofer, and Zimny, 1990), produced a robust positive effect on accuracy. They suggested generating keywords after a delay produced more valid cues for judging comprehension, which improved metacomprehension accuracy.

Completing Diagrams

Van Loon et al. (2014) evaluated the effect of completing an informational diagram of cause-and-effect relations on metacomprehension accuracy. Students read short texts describing cause-and-effect relations. Then they were shown a diagram of the cause-and-effect relation described in a text with key information deleted from the diagram. Participants in diagramming groups, both immediate and delayed, were instructed to provide the missing information. Metacomprehension accuracy was greater for the delayed-diagramming group than for the immediate-diagramming group or a no-diagramming group. The authors attributed the improved metacomprehension accuracy to better utilization of diagnostic cues in making metacomprehension judgments.

In sum, retrieving information about texts prior to judging comprehension improves metacomprehension accuracy; however, only when retrieval occurs after a delay (i.e., when surface features of a text have had an opportunity to fade from memory), not when the retrieval attempt occurs immediately after reading. A variety of retrieval tasks have been used (e.g., writing summaries, writing a list of keywords, and completing causal diagrams) to improve metacomprehension accuracy. The literature suggests the effects on metacomprehension are robust; retrieval tasks have improved accuracy for typical and at-risk college students, as well as for students as young as 6th grade, but may not be effective with students as young as 4th grade (see de Bruin et al., 2011).

Focusing on Constructing the Situation Model During Reading Improves Metacomprehension Accuracy

Another approach shown to improve metacomprehension accuracy is to provide instructions for reading texts that promote construction of the situation model. By promoting construction of the situation model during reading, cues associated with the situation model should become more salient at the time of judging comprehension, which should increase metacomprehension accuracy.

Concept Mapping

A concept map is a graphic representation of the underlying structure of the meaning of a text. Constructing concept maps can be an effective organizational strategy, which helps readers formulate the connections among concepts in a text (Weinstein & Mayer, 1986). Concept mapping can be particularly helpful for less-able readers (Nesbit & Adesope, 2006). Thiede et al. (2010, Experiment 2) examined whether concept mapping improves metacomprehension accuracy for at-risk readers.

They found that metacomprehension accuracy was greater when participants constructed concept maps than when they did not. Redford, Thiede, Wiley, and Griffin (2012) showed concept mapping also improved metacomprehension accuracy among 7th grade students. Interestingly, a group of students given already-constructed concept maps to examine during reading had accuracy no better than a control group. Thus, the act

of generating the concept map appears to be crucial to improving meta-comprehension accuracy. Redford et al. (2012) speculated that the act of generating a concept map increased the salience of cues related to the situation model, which influenced metacomprehension judgments and improved accuracy.

Self-explanation

Chi (2000) developed a self-explanation paradigm as a technique to improve reading comprehension. As students read a text they explained to themselves the meaning and relevance of each sentence or paragraph to the overall text. They asked themselves how new information was related to previously information. Such explanation-based reading tasks have been shown to focus readers on their situation-model (Chi, 2000). Griffin, Wiley, and Thiede (2008) hypothesized that self-explaining would help students connect ideas within a text and would focus students on cues related to the situation model when judging comprehension, thereby improving their metacomprehension accuracy. Consistent with the prediction derived from this hypothesis, Griffin and colleagues showed accuracy was greater for a group of college students who self-explained as they read than for a group who read the texts twice, and who had equivalent study time as the self-explanation group, and a control group who read the texts once.

Test Expectancy

Another way to focus students on cues related to the situation model is to give them experience with tests that assess deep comprehension (e.g., inference tests; see Wiley et al., 2005). Building expectations for a particular kind of test influences how texts are encoded and how students monitor learning (Thomas & McDaniel, 2007). For instance, Thiede, Griffin, and Wiley (2011) manipulated test expectancy by giving college students a set of three texts and tests. Half the participants read texts and were tested on their memory of facts contained in the texts; the other participants were tested on comprehension using inference tests. After completing three practice texts to build expectations for a test of memory or comprehension, participants read a new set of texts and predicted their performance on tests.

Results showed that metamemory accuracy (i.e., the correlation between metacognitive predictions and performance on tests of details contained in texts) was greater for the group expecting memory tests than for the group expecting inference tests. By contrast, metacomprehension accuracy (i.e., the correlation between metacognitive predictions and tests of inferences inferred from texts) was greater for the group expecting inference tests than for the group expecting memory tests. These results suggest test expectancy can influence how students monitor. Moreover, when focused on reading for deep comprehension, participants can accurately predict performance on tests of comprehension. Thiede et al. (2012) found test expectancy, influenced by school curricula, produced similar effects on monitoring accuracy for 7th and 8th grade students.

In sum, interventions that promote construction of a situation model for a text during reading improve metacomprehension accuracy. These interventions help define the purpose of reading and appear to focus readers on valid cues for judging comprehension. These interventions have included elaborate encoding tasks, such as constructing a concept map for a text, but also have included simply defining the learning to be assessed on tests. The literature suggests the effects on metacomprehension are robust; interventions that promote development of a situation model have improved accuracy for typical, at-risk college students, and younger students.

Research Evidence Showing the Importance of Monitoring Accuracy and Effective Regulation on Learning

As noted in the opening paragraphs, many models of self-regulated learning describe learning as the interaction between metacognitive monitoring and regulation. In the context of reading, accurate monitoring of comprehension is crucial to effectively regulate study, i.e., selecting appropriate materials for additional study. Therefore, much of the research on metacomprehension has focused on improving metacomprehension accuracy.

Far less research has been directed toward understanding how students use their monitoring to regulate their study (Metcalf, 2009); however, recently more research has focused on how students regulate their study.

Several models describe how students regulate their study across items and make decisions about when and what to restudy (for a review see Dunlosky & Ariel, 2011). The discrepancy-reduction model (e.g., Dunlosky & Hertzog, 1997) suggests that as part of the learning process students set a desired goal for learning material. As they study, they monitor how well the materials have been learned and use this information to determine whether the current state of learning meets or exceeds the desired state of learning. Students then use that information to make study decisions, such as choosing to terminate study only once the discrepancy between the current state and the desired state of learning reaches zero.

As the discrepancy between the perceived degree of learning and the desired degree of learning is greater for materials that are more difficult to learn than for materials that are less difficult to learn, a prediction derived from the discrepancy-reduction model is that materials that are more difficult to learn will be selected for restudy more than materials that are less difficult to learn. Much of the data on allocation of study time is consistent with this prediction (for a review see Son & Kornell, 2008). Perhaps more important, allocating study time based on a discrepancy-reduction rule appears to optimize the effectiveness of study time and lead to higher levels of learning (Tullis & Benjamin, 2011).

There is some evidence that students experience difficulty when translating monitoring into study behaviors (Sussan & Son, 2014). However, the extant research suggests that students are fairly adept at using their monitoring to select less learned material for restudy. For instance, de Bruin et al. (2011) showed that 4th, 6th, and 7th graders all chose to restudy less-learned texts over better-learned texts. Anderson and Thiede (2008) also showed that at-risk readers chose to restudy less-learned texts over better-learned texts. Thus, although interventions are needed to improve metacomprehension accuracy, regulatory skills appear to be in place at an early age; children as young as Grade 1 allocated more study time to more-difficult items than to less-difficult items (Dufresne & Kobasigawa, 1989). This suggests that improving metacomprehension accuracy will produce more effective regulation of study, which should in turn improve comprehension.

Thiede et al. (2003) provided the first empirical evidence showing metacomprehension accuracy affects overall comprehension. They showed that metacomprehension accuracy was significantly better for a group of students who generated keywords at a delay than other groups. This superior metacomprehension accuracy led to more effective regulation of study. The delayed-keyword generation group of students applied a discrepancy-reduction rule and chose to restudy texts that were less learned over those that were better learned. More important, after rereading the selected texts, overall comprehension was significantly better for the delayed-keyword group than for the other groups. Thiede et al. (2012) showed that improving metacomprehension accuracy helped 7th and 8th grade students to make better decisions about which texts to restudy, which in turn produced better overall comprehension; for other studies linking monitoring accuracy to more effective regulation and greater overall comprehension see Rawson et al. (2011).

These data provide strong support for the importance of metacognitive monitoring in learning. Improving monitoring accuracy increases the effectiveness of self-regulated learning, and improves learning. Research has now uncovered a number of ways to improve metacomprehension accuracy, which promote better comprehension. If these techniques become widespread, it could improve educational outcomes. That said, there is still work to be done.

Future Research Directions

The studies reviewed have focused to a great extent on learning from written information only. Texts often contain illustrative information, such as pictures, photographs, diagrams, or drawings, and these features influence metacomprehension. For instance, Serra and Dunlosky (2010) found that introducing diagrams in text led to

higher judgments of comprehension and higher performance on a comprehension test of the text. Follow-up research, however, showed that higher judgments of comprehension were also made when uninformative pictures were added to texts, but these pictures did not improve test performance. Ackerman and Leiser (2014) showed that the adverse effect of illustrations on monitoring were limited to lower-performing students. By contrast, higher-performing students profited from the uninformative illustrations, possibly because they expended greater effort to make sense of the uninformative information. More research is needed to better understand why illustrations and diagrams produced what Jaeger and Wiley (2014) called “seductive details” and led to poor monitoring, especially for low-performing students.

Increased use of technology and digital media has shifted learning from texts on paper to learning from text on screen. A fundamental question is: to what extent does reading texts on paper versus on screen affect metacognitive monitoring and regulation of learning? Ackerman and Goldsmith (2011) revealed better calibration of judgments of comprehension when students read texts on paper versus on screen, although no difference on a comprehension test of the texts between the two presentation modes was found. When students studied the texts at their own pace, the improved calibration associated with studying on paper gave way to improved regulation of learning and increased test performance. Given that the study of texts in real-life education is typically self-paced, these findings indicated students need additional support to prevent miscalibration and poor regulation of text study when studying text on screen.

Implications for Educational Practice

Self-regulation of reading requires accurate monitoring of comprehension and effective regulation of study. The good news is even young students allocate more study time to more-difficult materials than to less-difficult materials, which is effective regulation (Tullis & Benjamin, 2011). Thus, teachers need not intervene to improve regulation. The bad news is that inaccurate monitoring of comprehension is ubiquitous. Even college students struggle to accurately differentiate well-learned texts from less-learned texts. Thus, teachers have an important role to play in improving monitoring accuracy.

The cue-utilization framework (Koriat, 1997) suggests the key to accurate metacognitive monitoring is focusing readers on cues that are predictive of test performance. Therefore, teachers need to be quite mindful of what they want students to learn and take great care to construct tests that assess that learning. Then they need to explicitly describe the nature of tests and help students identify cues that are predictive of performance on tests.

Perhaps the best way to improve metacomprehension accuracy is to emphasize the importance of deep comprehension and deemphasize simply extracting facts when reading, by constructing tests that assess deep comprehension. Students adjust their reading and monitoring to meet the demands of the test. The test expectancy research shows that when students know tests will emphasize their ability to connect ideas across texts, they will read to make those connections and accurately monitor this level of learning (e.g., Thiede et al., 2012). Thus, as long as students know what teachers are testing, they will use cues that help them accurately monitoring the learning for a particular kind of test.

Teachers can also emphasize deeper comprehension and help develop students’ monitoring skills by engaging in tasks that facilitate construction of an elaborate situation model for a text. For instance, teaching students to construct concept maps when reading is just one task that helps students connect ideas across a text. Showing how concept maps map onto comprehension tests may help students identify valid cues for judging comprehension, and may increase the likelihood that students use those cues for judging comprehension. Thus, this activity should help students learn techniques for improving metacomprehension accuracy.

Teachers should engage in practices that improve their own self-regulated learning skills and those of their students (see Kramarski, 2018/this volume). They should promote self-testing (i.e., retrieval attempts) as a way of improving monitoring accuracy. Teachers can provide students with opportunities to write summaries or create

cause-and-effect diagrams, which should help students assess their understanding of materials. Showing how summaries or diagrams map onto tests of comprehension should help students identify valid cues for judging comprehension. If students use these cues, metacomprehension accuracy should improve.

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9 Self-Regulation and Writing

Steve Graham, Karen R. Harris, Charles MacArthur, and Tanya Santangelo

Writing is a complex and difficult task, and not surprisingly it takes many years to become a competent writer, and even more time for expertise to develop. While there has been slightly more than a century of scientific research examining writing and its development, much of the empirical research in this area has occurred during the last 50 years (Nystrand, 2006). This research has examined a variety of different topics ranging from the identification of effective practices to teach writing, the socio-cultural conditions surrounding writing, cognitive processes and skills important to writing development, methods for assessing writing performance, and the relation of writing to other language skills, to name some of the more prominent topics under consideration (MacArthur, Graham, & Fitzgerald, 2006, 2016).

An important part of this research effort, especially since the mid-1980s and forward, has involved the role of self-regulated learning processes (also referred to as self-regulation strategies or techniques; these terms are used interchangeably in this chapter) in students' writing. We focus on this area in this chapter. First, we discuss the emergence of self-regulated learning perspectives in writing and the importance of self-regulation in the writing process, and examine theoretical perspectives and models of writing that provide a basis for writing research in this area. We then examine research supporting the importance of self-regulation in writing with school age students. This analysis focuses on research supporting discrete self-regulation processes for writing (e.g., goal setting) as well as those examining the use of multiple self-regulation strategies while writing. Recommendations for future research are considered next, followed by implications for instruction. In the Implications for Practice section, we present an example of an effective multi-component writing intervention that emphasizes self-regulation procedures (i.e., Self-Regulated Strategy Development; Harris & Graham, 1996).

The Role of Self-Regulation in Writing

Early models of writing describe it as a linear and somewhat simplistic activity (e.g., Rohman, 1965), but more contemporary models recognize that writing involves a complex array of cognitive, linguistic, affective, behavioral, and physical process set within a larger socio-cultural context (e.g., Bazerman, 2016; Graham, in press; MacArthur & Graham, 2016). Modern theoretical frameworks emphasize that writing is a recursive, strategic, and multi-dimensional process involving (a) planning what to say and how to say it, (b) translating ideas into written text, and (c) revising what has been written. Furthermore, theories and models of writing either explicitly or implicitly acknowledge the critical role of self-regulatory processes in writing (see for example Hayes & Flower, 1980, later revised by Hayes, 1996, and Zimmerman & Risemberg, 1997). While it is beyond the scope of this chapter to review all pertinent models of writing that emphasize the role of self-regulation in writing, we examine an influential model that placed self-regulation at the center of writing, and another model that greatly expands on this earlier conceptualization.

The Zimmerman and Risemberg Model

Based on a theory of social cognitive learning (Bandura, 1988), Zimmerman and Risemberg (1997; [Chapter 2](#)) proposed a model of writing that described the “self-initiated thoughts, feelings, and actions that writers use to attain various literary goals, including improving their writing skills as well as enhancing the quality of the text they create” (p. 4). In this model, self-regulation occurs when a writer uses personal processes to strategically regulate their writing behavior or the environment. Writers manage the composing process by bringing into play three general classes of self-regulatory strategies. These include strategies for controlling: their actions, the writing environment, and their internal thoughts and processes. Writers employ these strategies as they write, and they monitor, evaluate, and react to their use. This allows them to learn from the consequences of their actions, as self-regulatory strategies that are viewed as successful are more likely to be used in the future and those that are not successful are less likely to be retained. Additionally, a writer's sense of efficacy may be enhanced or

diminished depending upon the perceived success of the employed strategies. In turn, self-efficacy can influence intrinsic motivation for writing, the use of self-regulatory processes during writing, and eventual literary attainment.

Learning is determined by personal processes as well as behavioral and environmental events. For instance, a student's success on a writing assignment is determined by personal perceptions of competency, but also affected by environmental factors such as encouragement from a teacher as well as behavioral events like the use of a self-evaluation strategy to determine if all aspects of the writing assignment are completed as intended. Similarly, the environmental manipulation strategy of arranging a quiet place to write involves intervening behavioral actions, such as closing the door and turning off the radio. The continued use of this strategy, however, depends on the writer's perceptions of its effectiveness in creating a suitable place to compose.

When describing the role of self-regulation in writing, Zimmerman and Risemberg (1997) identified a variety of strategies that writers use to exert deliberate control over the process of composing, the writing environment, and their own behaviors and thoughts. These self-regulation strategies are presented in [Table 9.1](#).

Although Zimmerman and Risemberg's (1997) model did not take into account many important aspects of writing, such as the interaction between self-regulation and other processes involved in writing, like working memory or text transcription skills, it provided an important contribution to how writing is conceptualized (Graham, 2006). It offered an explicit explanation of how writers exert deliberate control over the act of writing. Even though writing is commonly viewed as a difficult and demanding task, requiring extensive self-regulation and attentional control (Kellogg, 1993; McCutchen, 2000), the details and implications of how writers manage the composing process received only cursory attention in prior models (Graham & Harris, 1997).

[Table 9.1](#) Writing self-regulation strategies and examples from Zimmerman and Risemberg (1997)

Goal setting/planning —establishing rhetorical and content goals and tactics to achieve them
Seeking information —gathering information pertinent to the writing topic
Record keeping —making notes
Organizing —organizing notes or text
Transforming —visualizing a character to facilitate written description
Self-monitoring —checking to see if writing goals are met
Reviewing records —reviewing notes or the text produced so far
Self-evaluating —assessing the quality of text or proposed plans
Revising —modifying text or plans for writing
Self-instructions —statements about what needs to be done, dealing with difficulty
Rehearsing —trying out a scene before writing it
Environmental structuring —finding a quiet place to write
Time planning —estimating and budgeting time for writing
Self-reinforcing —going to a movie as a reward for completing a writing scene
Seeking social assistance —asking another person to edit the paper
Self-selecting models —emulating the writing style or tactics of a more gifted author

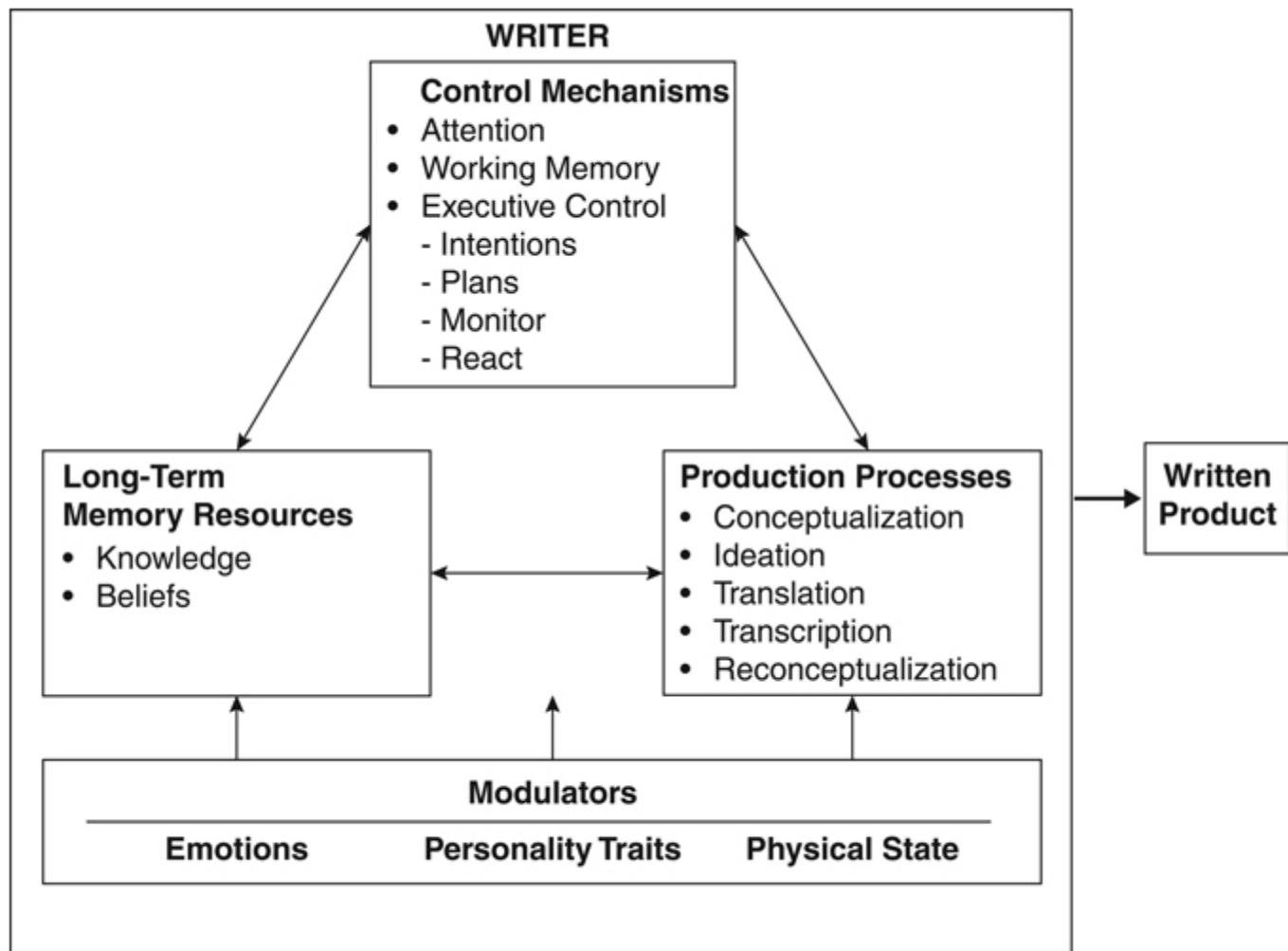
Graham (in press) developed a model of writing that merged both socio-cultural and cognitive perspectives (see also Hadwin, Järvelä, & Miller, 2018/this volume; Usher & Schunk, 2018/this volume). The model describes the act of writing as an inherently social activity, situated within a specific context (i.e., community) composed of individuals with different cognitive resources and motivational dispositions for writing. The creation of a specific piece of writing is bound by both the community in which it takes place and by the capabilities and inclinations of the individual writers who create it. This can involve one or more writers.

Similar to Zimmerman and Risemberg (1997), the model developed by Graham (in press) also stresses that the writer exerts deliberate control and agency over the meaning making process in writing. This newer model places greater emphasis though on the context in which a particular piece of writing is crafted, emphasizing that the way writing is conceptualized within a particular community further shapes its form and nature. Even so, the writer has to make a multitude of decisions that drive and shape what is created. These decisions range from deciding to engage in a particular writing task to determining how much effort to commit to it, what cognitive resources to apply, what writing tools to use, and how to orchestrate these cognitive resources in order to produce text (Graham & Harris, 1997).

According to Graham (in press), these decisions are fueled by the perceived value, utility, and interest in the writing task under consideration; emotional reaction to it; motivations for engaging in it; knowledge about the topic; expectations for success; dispositions for approaching new tasks; beliefs about the value of the community in which the writing task is undertaken; and one's identity and one's role, identity, and success in said writing community (see also Efklides, Schwartz, & Brown, 2018/this volume; Hadwin et al., 2018/this volume). In turn, these values, expectations, and identities fuel effort and provide the impetus for drawing on available cognitive resources, including but not limited to specialized knowledge about writing, the topic under consideration, the presumed audience, writing tools to be used, and knowledge about the purposes and practices of the writing community in question. These cognitive resources are used to carry out various text production processes (i.e., conceptualization, ideation, translation, transcription, and reconceptualization).

In Graham's (in press) model, the writer's use of these resources are initiated and coordinated through three control mechanisms (attention, working memory, and executive control) used to regulate attention; the writing environment; tools for writing; and the processes involved in producing text (e.g., conceptualization, ideation, translation, transcription, and reconceptualization). These control mechanisms also regulate the motivational beliefs, emotions, personality traits, and physiological factors that influence the writer as well as the social situation in which writing takes place (extending Zimmerman & Risemberg's (1997) description of self-regulation in writing). [Figure 9.1](#) provides a schematic diagram of the cognitive mechanisms involved in writing according to this model.

The control mechanisms envisioned by Graham (in press) enable writers to make decisions about what is composed and how; to direct, maintain, and switch attention as needed to meet these writing goals; to regulate multiple aspects of composing including writers' thoughts, beliefs, emotions, and behaviors as well as the use of writing tools, interactions with collaborators, and the arrangement of the writing environment; and to monitor, react, and make adjustments for all of these actions.



[Figure 9.1](#) Cognitive mechanisms in Graham (in press)

[Table 9.2](#) Examples of self-regulation strategies used to regulate various aspects of writing (Graham, in press)

Writing assignment—change the assignment so it is more interesting
Writing community—modify a typified way that the writing community carries out writing activities
Writing environment—restructure the writing environment so that it is conducive to success
Social situation—choose whom to work with, how the writing task is to be distributed
Writing tools—choose what tools to use, what features of a tool to activate or switch off
Production processes—setting rhetorical goals, creating an advanced plan, self-vocalizing while crafting sentences, setting writing aside for a day before making revisions
Attention—monitor and record amount of time spent writing
Motivation—self-reinforcement, goal-oriented talk
Emotions—purposefully controlling excitement, counting to 10, self-reminders that getting frustrated is not helpful
Personality traits—create a strategy to manage time more effectively, purposefully encourage others to contribute
Physical readiness—make sure that you do not come to the writing task sleepy or hungry

The control mechanism of attention allows writers to choose where attention is or is not focused, working memory provides a limited and temporary storage system where information is held and acted upon, and executive control involves the processes of setting goals (formulating intentions), initiating actions to achieve them (plan), evaluating goal process and impact (monitor), and modifying each of these as needed (react).

Graham (in press) indicates that these control mechanisms not only direct and regulate writers' thoughts, behaviors, and production processes involved in writing, but are further used by the writer to direct and manage work within the writing community (see [Table 9.2](#) for examples of self-regulation strategies used by writers). In

fact, Graham puts self-regulation in writing more squarely in context than the previous Zimmerman and Risemberg (1997) model, extending self-regulation to managing the community in which writing takes place, the social situation surrounding writing, and the tools used to create text. It also places more explicit emphasis on writers' regulation of emotional, motivational, personality, and physiological states.

Research Supporting the Importance of Self-Regulation in Writing

Planning and Revising

Graham (2006) examined whether the writing research literature provided support for the contention that self-regulation processes are important to writing. If self-regulation shapes writing and its development, he argued that it is reasonable to expect that: (a) skilled writers are more self-regulated than less skilled writers, (b) developing writers become increasingly self-regulated with age and schooling, (c) individual differences in self-regulation predict individual differences in writing, and (d) teaching self-regulation strategies improves the writing performance of developing writers. He specifically examined whether this was the case for two critical aspects of self-regulation in writing: planning and revising.

For planning, Graham (2006) found that the evidence supported all four of the tenets specified above. In the studies reviewed, skilled writers were more planful than less skilled writers, as the former devoted much more attention to planning when writing than novice or beginning writers. Developing writers became more sophisticated planners with schooling and experience (e.g., planning notes became more conceptual and superordinate). Writers who planned more produced higher quality text than writers who overtly planned less, even when time spent writing was controlled. Teaching developing writers how to plan had a strong and positive impact in improving the text produced by developing writers.

For revising, three of the proposed tenets were supported. Skilled writers spend more time revising than less skilled writers, and the former are more likely than the latter to make substantive revisions to their text. Revising behavior also changed with schooling and experience, as older writers tend to revise more often, revise larger units of text, and make more meaning-based revisions. Further, teaching developing writers how to revise improved the quality of their revisions and the text. The only assumption not met involved the relationship between individual differences and writing performances. Revising behavior was unrelated to overall writing performance until high school or later.

In summary, the evidence reviewed by Graham (2006) generally supports the contention that the self-regulatory processes of planning and revising are important to writing and its development. As we shall see next, the use of other self-regulation strategies, individually or in combination, can enhance writing too.

Meta-Analysis

Santangelo, Harris, and Graham (2016) conducted a meta-analysis to determine which self-regulations strategies specified in the Zimmerman and Risemberg (1997) self-regulation model of writing were supported by empirical research. Unlike Graham (2006), they focused on just one of the four tenets described in the previous section. They reasoned that if a particular self-regulation strategy or procedure was important to writing and its development, teaching it (or putting into place procedures to prompt its occurrence) should improve the writing performance of developing writers. More specifically, they examined whether teaching or applying a specific strategy in four or more studies resulted in a statistically significant average weighted effect greater than zero. Studies were limited to true- and quasi-experiments with developing writers in grades 1 to 12. Their analysis represents a strong assessment of the importance of each of the tested self-regulation strategies, as it examines if a causal link exists between the self-regulation procedure and writing performance through the use of experimental research methodology.

Self-Selected Models

Santangelo et al. (2016) located seven studies assessing the effectiveness of self-selected models as a means for improving text quality. Self-selected models involve the writer trying to emulate an exemplary model of writing. These studies included 1,217 students in grades 4 to 12, where developing writers examined model pieces of writing to help direct what they did in their own compositions. This included analyzing and seeking to emulate different types of text materials, such as published books, teacher constructed samples, or peer written compositions. Self-selected models had a positive impact on text quality in all studies. The average weighted effect size of 0.30 was statistically significant, showing that emulating text produced by others improved text quality.

Goal Setting

The impact of goal setting was also supported in eight studies that included a total of 429 students in grades 4 to 8. Most studies involved goals related to drafting text (e.g., include at least three reasons to support your point of view and at least two likely refutations), but three studies involved revising goals (e.g., add three new ideas to your essay). Goal setting had a positive impact on improving writing quality in all eight studies, resulting in a statistically significant average weighted effect size of 0.73.

Self-Evaluative Standards

This was examined in 12 studies with 1,326 students in grades 2 to 12. In virtually all of these experiments, students' self-evaluation and revision processes were guided by the use of standards (e.g., rubric or scoring guide) and/or a strategy. A positive impact on improved text quality was obtained in 11 studies, producing a statistically significant and average weighted effect size of 0.51.

Mental Imagery

Four studies involving 293 students in grades 3 to 6 examined the impact of teaching students to use mental imagery to facilitate writing performance. In the four studies, students learned to use mental imagery to promote general creativity or enhance sensory description. Mental imagery instruction enhanced writing quality in all four studies, yielding a statistically significant average weighted effect size of 0.76.

Planning and Revising

Like Graham (2006), Santangelo et al. (2016) examined whether teaching developing writers strategies for planning, revising, or both improved the quality of students' text. The impact of such instruction involved 38 studies with 3,268 students in grades 2 to 10. The Self-Regulated Strategy Development model (SRSD; e.g., Harris et al., 2009) was used in 25 of the 38 experiments (we will return to this model later). Teaching students strategies for planning and/or revising text enhanced writing quality in all 38 studies, producing a statistically significant average weighted effect size of 1.06. Moderator analysis showed that the SRSD studies obtained an average weighted effect size of 1.14, whereas other methods of teaching planning and revising averaged an effect size of 0.59.

Santangelo et al. (2016) also located 13 studies involving 1,216 students in grades 2 to 12 where students were prompted to engage in planning activities prior to writing. This included students generating, gathering, and/or organizing writing content in a variety of ways, such as through drawing, using different types of graphic organizers, watching videos, and reading relevant materials. All studies produced a positive effect, resulting in a statistically significant average weighted effect size of 0.55.

Six studies examined the difference between teaching planning strategies with and without additional self-regulation procedures (i.e., goal setting, self-evaluation, and self-monitoring). These studies included 317 students in grades 2–6, and positive effect was reported in all six studies, yielding a statistically significant average weighted effect size of 0.50.

Summary

The analyses by Graham (2006) and Santangelo et al. (2016) provide compelling evidence that self-regulation is important to writing and its development. These two reviews show that teaching or using a variety of self-regulation strategies enhances the text produced by developing writers. The review by Santangelo and colleagues further shows that these writers' performance can be improved even more when multiple self-regulation procedures are applied. As we shall see next, "think-aloud" studies offer some additional support for this thesis and provide some caveats as well.

Think-Aloud Studies

One means of studying self-regulation in writing is to ask writers to "think aloud" while composing (see also Greene, Deekens, Copeland, & Yu, 2018/*this volume*). Analysis of the resulting verbal protocols provides researchers with a window into the cognitive and psychological processes involved in writing, including the use of self-regulatory strategies. Rijlaarsdam and his colleagues (see Rijlaarsdam et al., 2012, for a summary) have used this methodology to examine the composing process of developing writers. They found that self-regulation as well as other cognitive processes revealed through students' verbalized thoughts while composing accounted for considerable variance in the quality of students' text.

To illustrate, these researchers (Breetvelt, Van den Bergh, & Rijlaarsdam, 1994, 1996; Van den Bergh & Rijlaarsdam, 1996) used think-aloud procedures with 15-year-old students to examine the occurrence and timing of 11 cognitive activities during writing. Some of these activities, such as revising and goal setting, were self-regulatory, whereas others such as reading the assignment were decidedly less so. They found that 87% of the variance in the quality of students' writing was accounted for by these 11 categories, when the time at which the activity took place was included in their analyses. Consequently, no cognitive activity, including self-regulatory procedures, appeared to be individually beneficial during the whole writing process (divided into thirds). Instead, some activities contributed positively or negatively depending on when they occurred (as do combinations of specific activities). For instance, if a writer is revising frequently at the start of a writing project it can indicate he or she is experiencing startup difficulties, whereas if it occurs towards the end of the project it can signal that the writer is making final adjustments to align goals and text.

They further found that the function of a cognitive activity can change depending upon when it occurs. For instance, the self-regulatory process of revising plays a different function when a writer is experiencing start-up trouble (i.e., beginning over and over again), than it does when a writer is revising a fluently produced first draft. Moreover, the verbal protocols produced evidence that writers tell themselves what to do from time to time while writing, suggesting that the choice of which cognitive activity to employ is partly under their control and requires attention (Breetvelt et al., 1994).

The think-aloud studies by Rijlaarsdam and colleagues (2012) provide additional correlational evidence that self-regulatory strategies are important to writing, but they also reveal several important caveats. They generally occur in combination with other cognitive activities, and when these activities occur and in what combination are critical to writing success. In the next section, we address the instructional implications of these findings as well as providing a model for how to teach writing self-regulation.

Critical Research Needs

We would like to highlight three critical research needs involving self-regulation and writing. First, as noted at the beginning of this chapter, contemporary models of writing, at least cognitive ones, typically include self-regulation as an important aspect of writing and its development. Unfortunately research directly testing if self-regulation is an essential element in these models is lacking. For example, based on Alexander's (1998) model of domain learning, Graham (2006) contended that self-regulation, knowledge, motivation, and foundational writing skills such as handwriting, spelling, typing, or sentence construction are important of writing success and catalysts for writing development. Graham and Harris are currently testing a model of writing based on this thesis, collecting multiple measures for each construct (e.g., self-regulation) and examining if each construct accounts for additional unique variance in writing outcomes once variance due to reading skills, gender, and the other constructs (e.g., knowledge, motivation, and skills) are controlled. Preliminary analyses show that self-regulation accounts for additional variance in the quality of students' writing. Additional research is needed to replicate studies such as theses and extend testing to other models of writing where self-regulation is considered a central element.

Second, the role and impact of many self-regulation procedures in writing has not been adequately investigated. While there is evidence to support self-regulatory strategies involving planning, goal setting, revising and self-evaluation standards, self-selected models, and mental imagery, most self-regulatory procedures in writing are under-investigated. This includes greater study of strategies for regulating the writing assignment, the community in which writing takes place, the writing environment, the social situation surrounding writing, the tools used to create writing, attention, specific aspects of the writing process (e.g., self-speech to direct the writing process), as well as the emotional, motivational, and physiological state of the writer.

While much has been learned about how writers use self-regulation strategies when writing, the study of the longitudinal development of self-regulation in writing from childhood to adulthood has not been adequately addressed (almost all available studies involving cross-sectional studies are studies focused on a single age or grade). We also need to know more about how and when in the writing process these strategies are most likely to be successful and in what combination. Additionally, our understanding of how students who experience difficulty with self-regulation (e.g., students with learning disabilities, attention deficit hyperactivity disorders, and emotional behavioral difficulties) apply or do not apply such strategies when writing is incomplete (see Mason & Reid, 2018/this volume). Consequently, longitudinal research is needed to track the development of self-regulation in writing and to gain a better understanding of how and when these strategies are employed when writing by different groups of writers. Like Rijlaarsdam and colleagues (2012), we further need to conduct research to determine how self-regulation strategies can be used together to support students' writing and their development as writers.

Finally, more instructional research is needed on how to teach students to use self-regulation to enhance their writing performance. This should include longitudinal research examining the effects of such instruction across multiple years (typically maintenance is collected about one month from the end of instruction; Graham, Harris, & McKeown, 2013). We further need to conduct instructional research to determine what dose of self-regulation instruction is needed to result in improved writing performance, how such instruction should be combined with other aspects of writing instruction (e.g., the balance between writing, skills instruction, and self-regulation instruction), and what combinations of self-regulation strategies enhances developing writers' short-term and long-term writing performance. All of this needs to be done more frequently with writers across all grades of school and beyond (including in the work place), and it should occur across different types of writing.

The types of research described above require the use of multiple methods, including both quantitative and qualitative procedures. Much needs to be done, making it a very fruitful area of research for both beginning and

seasoned scholars. We next consider the implications of self-regulation research in writing for practice, highlighting an especially effective method for promoting students' self-regulated writing.

Implications for Practice

Theoretically and empirically self-regulation is important to writing and its development. The most obvious educational implication from this assertion is that teachers/mentors need to help developing writers acquire the self-regulation skills needed to be a successful writer. This can be done by teaching/promoting the use of individual self-regulation skills for writing or by teaching/encouraging developing writers to use multiple self-regulation skills. It is important to note that the concept of a developing writer can apply to people of all ages. Writing development for an individual is uneven and varies depending upon the task (Bazerman et al., in press). Thus, an adult may be skilled at writing reports for work, but in need of much greater development as a creative writer if his or her goal is to write a first-rate work of fiction. As a result, even older writers well beyond school age may benefit from efforts to help them become more self-regulatory and strategic when writing certain kinds of text.

As writers develop, they must learn how to regulate an increasing array of processes, beliefs, behaviors, and thoughts (Graham, in press; Zimmerman & Risemberg, 1997). These must be used in combination with other cognitive processes and applied at the right time and in the right combination (Rijlaarsdam et al., 2012). While it can be beneficial to teach individual self-regulation procedures to developing writers, students make greater progress when they are taught how to use and successfully coordinate the use of multiple strategies (Santangelo et al., 2016).

SRSD: An Approach for Teaching Multiple Self-Regulation Strategies for Writing

To illustrate how multiple self-regulation procedures can be taught to developing writers, we present an evidence-based approach to writing where students are taught strategies for self-regulating the processes of planning, drafting, and/or revising text as well as self-regulation strategies for managing these strategies, the process of composing, and their thoughts and behaviors. This approach is referred to as Self-Regulated Strategy Development (SRSD; Harris & Graham, in press; Harris & Pressley, 1991). It is not the only validated approach to teaching self-regulation strategies to developing writers (see also Deshler & Schumaker, 2006; Englert et al., 1991), but it has been tested in over 100 studies, making it the most scientifically tested approach to writing currently available (Graham et al., 2013).

These available studies have demonstrated that SRSD is particularly potent, as it produces significantly greater effects than non-SRSD interventions. For example, Graham et al. (2013) found the average weighted effect size for SRSD was 1.14 for writing quality, compared with 0.59 for all other strategy instructional approaches. Moreover, SRSD has consistently resulted in significant and meaningful gains in five main aspects of students' performance: (a) genre elements included in writing, (b) quality of writing, (c) knowledge of writing, (d) approach to writing, and (e) self-efficacy (Graham et al., 2013; Harris et al., 2009). Improvements have been documented in students' use of planning and revising strategies, and these improvements have been consistently maintained for the majority of students over time, although some students need booster sessions for long-term maintenance. Many students have shown generalization across settings, teachers, and writing media.

Not only has SRSD proven to be an effective strategy for teaching typically developing writers, but it has resulted in improved writing performance in students with learning disabilities, enhancing the quality and structure of these students' narrative and expository text (Graham et al., 2013; Rogers & Graham, 2008). Similarly, there is a small body of studies demonstrating that SRSD enhances the writing of students with attention hyperactivity disorders (e.g., Lienemann & Reid, 2008), emotional behavioral difficulties (e.g., Lane et al., 2008), Asperger syndrome and autism spectrum disorder (Asaro & Saddler, 2009; Delano, 2007), and mild mental retardation or cognitive impairment (e.g., Guzel-Ozmen, 2006).

There are five critical characteristics of SRSD instruction (Harris et al., 2008; Harris, Santangelo & Graham, 2008). One, knowledge about writing, writing strategies (genre specific and general), and self-regulation strategies are explicitly taught and developed. Two, students are viewed as active collaborators who work with the teacher and each other during instruction. Three, instruction is individualized so that the processes, skills, and knowledge targeted for instruction are tailored to students' needs and capabilities. Goals are adjusted to current performance for each student, with more capable writers addressing more advanced goals. Instruction is further individualized through the use of individually tailored feedback and support. Four, instruction is criterion based rather than time based. Five, SRSD is an on-going process in which new strategies are introduced and previously taught strategies are upgraded over time (Harris et al., 2008).

Six stages of instruction are used to introduce and develop writing and self-regulation strategies in the SRSD approach (i.e., develop and activate background knowledge, discuss it, model it, memorize it, support it, and independent performance). Throughout the stages, teachers and students collaborate on the acquisition, implementation, evaluation, and modification of these strategies. These stages are briefly presented here; they can be reordered, combined, revisited, modified, or deleted based on individual students' needs.

Finally, procedures for promoting maintenance and generalization/transfer are integrated throughout the stages of instruction in the SRSD model (Harris & Graham, 1996, in press; Harris et al., 2009), including: identifying opportunities to use the writing and/or self-regulation strategies in other classes or settings, discussing attempts to use the strategies at other times, reminding students to use the strategies at appropriate times, analyzing how these processes might need to be modified with other tasks and in new settings, and evaluating the success of these processes during and after instruction. Other teachers and parents can also support use of the strategies at appropriate times in other settings. Booster sessions after initial instruction, where the strategies are reviewed and discussed and supported again if necessary, are important for most students in terms of maintaining and generalizing the strategies.

Develop and Activate Background Knowledge

Background knowledge and preskills that students need to successfully understand, learn, and apply writing and self-regulation strategies are developed in this stage; for some students, this continues through stages 2 and 3. Reading, analyzing, and discussing model texts and poor texts is typical in this stage. This is also an appropriate time to help students identify whether their writing performance is hindered by negative self-statements (I'm not good at this), and show them how to utilize those positive self-statements (I can do this if I use the strategy and take my time).

Discuss It

In the discussion acquisition stage, teachers and students continue to talk about what good writers do when planning, composing, or revising. Genre-specific elements or parts (e.g., a good topic sentence) that make writing effective and fun to read are noted. Teachers and students discuss the strategy to be learned and establish its goals and benefits. Teachers and students explore how and when the strategy can be used, laying the foundation for generalization by not limiting the discussion to the current classroom or task at hand. The importance of student effort is emphasized to enhance motivation and facilitate the development of positive, adaptive attributions. Students make a commitment to learn the strategy and act as collaborative partners in this endeavor. Teachers may (this can be skipped or moved to a later point if appropriate) have students examine and graph their current performance (e.g., counting how many elements of opinion essays were included in essays written before SRSD instruction); this is done in a positive, collaborative manner with emphasis on changes that will soon be realized through strategy use. This is also a logical point to introduce goal setting. Students are taught how to set personal, individual, and specific goals for (a) learning the strategy, (b) using the strategy, and (c) maintaining strategy use.

Goals are revisited frequently during other stages. Materials supporting strategy use (e.g., mnemonic charts with strategy steps and graphic organizers for planning notes) and materials for supporting self-regulation (e.g., self-monitoring graphs) may be introduced at this stage or later.

Model It

Modeling is critical to effective SRSD instruction. The teacher models aloud, demonstrating how and when to use the writing and self-regulation strategies throughout the writing process. The teacher models how to set specific goals for the writing task, self-monitor performance, and self-reinforce. Self-instructions for problem definition (“I need to write an opinion essay with eight parts”), focusing of attention and planning (“First, I need to pick an idea”), strategy implementation (“I know what to do, I do the first strategy step”), self-evaluation (“Did I include all strategy parts?”), coping (“I can do this, I know the strategy!”), and self-reinforcement (“Wow, I like this part of my essay!”) are used by the teacher while modeling. After modeling, the teacher assists students in developing a short list of selected personal self-instructions to be used before, during, and after writing (for greater detail, see Harris & Graham, 1996, in press). These self-instructions are recorded on a sheet of paper for use throughout instruction. Some students may need to have a strategy modeled multiple times; collaborative modeling and use of peer models can be used as appropriate.

Memorize It

Memorizing actually begins in the first stage, as students participate in fun and engaging activities to help them memorize the strategy steps (and corresponding mnemonics), the meaning of each step, and their personalized self-statements. At this point, teachers need to be sure that students have memorized these and understand their importance before moving into the next stage.

Support It

Initially, teachers support, or “scaffold,” students’ use of the writing and self-regulation strategies as they compose together. Students gradually assume responsibility for the writing and self-regulation strategies; prompts, interaction, and guidance are faded over time with each individual student as he or she demonstrates independent and effective use of the strategy. Students self-monitor the use of the writing strategy by determining the number of genre elements (additional goals can be set and monitored as well) they have included in their composition, comparing this to their goal, and graphing their performance. Students are encouraged to revise their graphic organizers and drafts to meet goals as needed. Students progress through this stage at different rates. Throughout this stage, the students and teacher continue to plan for and initiate generalization and maintenance of the strategies. This stage typically is the longest of the six stages for students who have significant writing difficulties.

Independent Performance

To demonstrate independence, students are provided opportunities to use their writing and self-regulation strategies without teacher support or prompts. Booster sessions, where the strategies are reviewed, discussed, and supported again, can be used as necessary over time to maintain the strategies. To establish generalization, students should be given the opportunity to use the writing and self-regulation strategies they have learned in novel settings, with different teachers, and with other appropriate writing tasks.

Available SRSD Materials

In closing the chapter, we provide a list of resources for implementing SRSD. This includes detailed lesson plans and support materials presented in Harris et al. (2008) and in Mason, Reid, and Hagaman (2012); see also Harris and Graham (1996) and Graham and Harris, 2005. Multiple online interactive tutorials on SRSD are available at <http://iris.peabody.vanderbilt.edu/>. Our website for a study of SRSD at grades 1 to 3, Project Write, includes

lesson plans and support materials for story and opinion essay writing strategies designed for the early elementary grades: <http://kc.vanderbilt.edu/projectwrite>. A detailed discussion of what SRSD is and is not can be found at: <https://www.youtube.com/watch?v=gI7cx8Zxvoc>. Finally, non-profit websites devoted to professional development in SRSD can be viewed at www.thinkSRSD.com and www.SRSDonline.org.

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10 The Self-Regulation of Learning and Conceptual Change in Science

Research, Theory, and Educational Applications

Gale M. Sinatra and Gita Taasoobshirazi

Introduction

We live in a paradoxical time: one of great scientific advances, and also one of entrenched skepticism towards science. The current rate of new scientific discovery is unprecedented in human history. At the same time, Americans have shown resistance to accepting stem cell replacement therapy (Ho, Brossard, & Scheufele, 2008), genetically modified foods (Heddy, Danielson, Sinatra, & Graham, 2017), vaccinations (Kata, 2012), and climate change (Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2012). Some have suggested that there is even an attack on the concept of truth itself, leading a philosopher of science to warn “we have reached a watershed moment, when the enterprise of basing our beliefs on fact rather than intuition is truly in peril” (McIntyre, 2015). We view the need for scientifically literate and self-regulated learners as critical in today’s society where citizens must routinely make decisions regarding their health and wellbeing that require an appreciation of complex socio-scientific issues.

We begin by discussing key components of self-regulated learning, including cognition, metacognition, epistemic cognition, emotion, and motivation. Scientific tasks such as inquiry, problem solving, and reasoning require the self-regulation of these components. Then we explore how motivated and intentional conceptual change contributes to developing self-regulated learners. We argue that knowledge change is often needed for developing scientific understanding and that conceptual change research provides a useful framework for exploring self-regulated learning. We review research evidence on self-regulated learning in three areas from our own research: climate change, evolution, and physics. We discuss current measures of self-regulation in science and then close with directions for future research and for supporting self-regulated learning in science.

Relevant Theoretical Ideas

Self-regulated learning has been described as consisting of three key components including metacognition, cognition, and motivation (e.g., Winne & Perry, 2000). The metacognitive component includes the knowledge and regulation needed for understanding and controlling one’s cognition. The cognitive component includes the knowledge and skills needed for scientific problem solving, inquiry, and critical thinking. The motivational component includes the beliefs and attitudes that influence the use and development of one’s cognition and metacognition (Schraw, Crippen, & Hartley, 2006). These three components of self-regulation interact to contribute to successful self-regulation in science. Recently, a flurry of research has described how key epistemic cognition (i.e., thinking about the nature of knowledge and knowing) is to the regulation of learning in science (Greene, Azevedo, & Torney-Purta, 2008; Lombardi, Nussbaum, & Sinatra, 2016). In addition, there has been an expansion of research on the need for emotion regulation when learning science (Sinatra, Broughton, & Lombardi, 2014). In the sections that follow, we draw on various perspectives to describe these five components (i.e., metacognition, cognition, motivation, epistemic cognition, and emotions) of self-regulation.

Metacognition

The metacognitive component of self-regulation involves the awareness and control of conceptual knowledge and problem solving skills needed for scientific proficiency. Self-regulation should not be equated with metacognition because self-regulation is a broader term that encompasses other components of learning and problem solving,

such as motivation (Greene & Azevedo, 2007; Wolters, 2003). The terms are sometimes used interchangeably in the literature, blurring important distinctions (Alexander, Dinsmore, Parkinson, & Winters, 2011). Metacognition has traditionally been conceived as having two components: knowledge of cognition and regulation of cognition. Knowledge of cognition is the extent to which learners understand their conceptual knowledge and skills, whereas regulation of cognition refers to management of knowledge and skills (Hacker, Dunlosky, & Graesser, 2009).

More successful problem solvers demonstrate high levels of metacognitive knowledge in that they can describe the strategies they use, when, why, and how to use them, and they can change strategies to be more effective. In contrast, less successful problem solvers are often unable to explain their strategy choice and use, and often persist even after a strategy has proven unsuccessful (Efklides, 2001). More successful problem solvers are also more likely to regulate their knowledge and problem solving. For example, they do more planning before beginning a problem. They are also more likely to monitor their strategy use during problem solving, and are more likely to evaluate their performance upon completion of a problem (Efklides, 2001). In addition, successful problem solvers are more motivated to self-regulate their knowledge and problem solving (Hoffman & Spataru, 2008).

Cognition

The cognitive component of self-regulation includes the conceptual knowledge and problem solving skills needed for success on scientific tasks. Conceptual knowledge is critical for success in science. In physics, for example, conceptual knowledge has been shown to have a positive impact on strategy use and problem solving accuracy (Taasobshirazi & Carr, 2009). In addition, a sufficient knowledge base is needed for successful participation in argumentation, scientific inquiry, problem solving, critical thinking, and reasoning (Anderman, Sinatra, & Gray, 2012; Asterhan & Schwarz, 2016; Schraw et al., 2006).

In addition to conceptual knowledge, problem-solving skills and strategies are pertinent for success in science. Performance in high school and college level physics and chemistry courses is typically assessed by asking students to manipulate equations to solve for an unknown quantity (Chi, 2006). Analogical, deductive, inductive, and abductive reasoning are examples of general strategies used in solving scientific problems (Sternberg & Williams, 2009). When solving well-defined, quantitative problems in scientific domains such as physics or chemistry, specific strategies such as working forward and working backwards are also commonly used (Taasobshirazi & Carr, 2009). Conceptual knowledge as well as the use of effective problem solving strategies provide a basis from which students can regulate their learning.

Motivation

The motivational component of self-regulation includes regulation of the motivation needed to maintain the engagement and deliberate practice necessary for scientific thinking and reasoning. Attaining scientific proficiency in a domain like biology, chemistry, or physics requires a considerable amount of practice (Ericsson, 2006). During deliberate practice, students set a goal, act on that goal, assess the outcome, and adapt their behavior to achieve the goal, processes which require significant regulation of motivation (Ericsson, 2006; Zimmerman & Campillo, 2003). This is particularly important when practice becomes tiring, frustrating, or boring (Ericsson, Krampe, & Tesch-Römer, 1993).

Although the bulk of the self-regulation research focuses on the metacognitive component, some of this research does focus on motivation (Wolters, 2003). As Zimmerman (1995) explained: “Educational psychologists need to expand their views of self-regulation beyond the metacognitive trait, ability, or stage formulations and begin treating it as a complex interactive process involving social, motivational, and behavioral components” (p. 217). Since Zimmerman’s call, research on the role of motivation in self-regulatory learning has burgeoned (for an overview, see Schunk, Meece, & Pintrich, 2012). The role of motivation in self-regulatory learning in science, in particular, was reviewed by Glynn and Koballa (2006) and recent work on motivation and engagement in science learning has expanded as well (for a review, see Sinatra, Heddy, & Lombardi, 2015). These reviews emphasize

the importance of regulating one's motivation in order to keep engaged and focused when learning science. This is important when students experience obstacles in their motivation, learning, or performance.

Epistemic Cognition

A key aspect of cognition relevant to self-regulation is reflected in the emerging field of epistemic cognition (Greene, Sandoval, & Braten, 2016) or "how people acquire, understand, justify, change, and use knowledge in formal and informal contexts" (Greene et al., 2016, p. 1). Effective knowledge evaluation requires a high degree of self-regulation of the cognitive and metacognitive skills and strategies just described. The justification of knowledge, in particular, depends on the regulation of strategies for evaluating sources and evidence in an intentional and thoughtful manner. "I saw it on Facebook" does not provide the degree of informed justification needed to effectively decide whether to vaccinate a child, seek stem cell therapy for Parkinson's Disease, or even consume kale, which is a genetically modified food (Newland, 2014).

Science as a domain sets particular demands on the self-regulation of epistemic cognition (Greene et al., 2015). Climate change, for example, is complex topic that involves emergent and interactive systems, such as the greenhouse effect, which are not well understood (Ranney & Clark, 2016). Climate models, like all scientific models, have a degree of uncertainty to them which, to the lay public, may seem too tentative to accept (Treagust, Chittleborough, & Mamiala, 2002). Individuals are left to coordinate evidence about scientific models versus evidence for skeptic models, which involves the self-regulation of such processes as warranting and sourcing information as well as evaluating source integrity (Lombardi, Sinatra, & Nussbaum, 2013). This entails consideration of who has epistemic authority (e.g., scientists or politicians) on the matter. In addition to the self-regulation of evidence evaluation, learning about controversial topics also requires the regulation of emotions. When evaluating strong messages from epistemic authorities such as scientists and politicians, people must consider whom to trust (Lombardi, Seyranian, & Sinatra, 2014). Regulating people's comfort with ambiguity is also key to objectively evaluating evidence that is not now, and may never be, as conclusive as they might want it to be before making marked changes in their lifestyles or economic strategies (Lombardi & Sinatra, 2013).

Emotions

Recently, research on emotions in science learning in general, and conceptual change learning in particular, has burgeoned (Sinatra et al., 2014). In their review, Sinatra et al. (2014) noted that the full range of human emotions from joy and excitement, to surprise and confusion, to anxiety and frustration are all born out in the science classroom. Research on academic emotions has shown that emotions impact learning (Pekrun & Stephens, 2012) for better and for worse. Students can hold strong emotions, as Broughton, Sinatra, and Nussbaum (2011) demonstrated in their study of elementary school students' negative reactions to learning that Pluto had been demoted to dwarf planetary status. This study illustrated that positive emotions are more likely to support attitudinal and conceptual change when learning about controversial science topics. Taasobshirazi, Heddy, Bailey, and Farley (2016) found that positive emotions such as enjoyment when studying physics were linked to higher motivation, course grades, engagement, and conceptual change. These studies are promising news for positive emotions; however, some research suggests a reduction in negative emotions may be even more important for science learning (Heddy et al., 2017; Heddy & Sinatra, 2013).

Villavicencio and Bernardo (2013) studied the impact of emotions on college students' self-regulation and achievement. They found that enjoyment and pride were positive predictors of course grades and that emotions moderated the relationship between self-regulation and grades. For students who had higher levels of the positive emotions, self-regulation was positively associated with course grades. However, for students who had lower levels of the positive emotions, self-regulation was either not related or negatively related to grades.

Emotions research in science learning suggests that regulating one's emotions is just as important as regulating one's cognition, metacognition, and motivation. In fact, given the new focus on emotions in the educational

psychology literature, current definitions of self-regulation are now including emotion regulation as one of the key components of self-regulated learning (e.g., Efklides, Schwartz, & Brown, 2018/this volume; Usher & Schunk, 2018/this volume).

Self-Regulated Theories of Conceptual Change in Science

In the previous sections, we highlighted the components and role of self-regulation in science learning. We also stressed that self-regulation is needed for overcoming scientific misconceptions and attaining conceptual change (Lombardi & Sinatra, 2013). In the next section, we describe self-regulated conceptual change and the Cognitive Reconstruction of Knowledge Model (CRKM). Then we follow with a discussion of intentional conceptual change, which takes a more explicit self-regulatory perspective on conceptual change.

Cognitive Reconstruction of Knowledge Model

The CRKM, developed by Dole and Sinatra (1998), is an interactive model whereby learner and content characteristics interact to determine a degree of engagement. This degree of engagement in turn, impacts the likelihood of conceptual change. At its core, the CRKM is inherently self-regulatory in its structure and processes. A detailed explanation of the CRKM is presented in an earlier edition of this handbook (Sinatra & Taasoobshirazi, 2011). Below, we provide a summary of the CRKM and then describe the role of self-regulation in the model.

The CRKM describes how characteristics of a learner's background knowledge, motivation, and characteristics of the content interact to produce a degree of engagement with the new concepts and a likelihood of conceptual change. Dole and Sinatra (1998) posited that the strength, coherence, and personal relevance of the content, as well as the learners' dissatisfaction with and commitment to their existing conception, interact with their dispositions towards the information, motivation for learning, and the social context of the learning environment. They further proposed that these interactions impact engagement, which in turn predicts the likelihood of conceptual change.

Self-regulation of the components we reviewed (i.e., cognition, metacognition, epistemic cognition, motivation, and emotion) plays a significant role in impacting each facet of the conceptual change process described in the CRKM. For example, if learners feel dissatisfied due to a discrepancy between their knowledge and the new concept being taught, and if the new concept seems more plausible, they should be motivated to resolve that state of disequilibrium. Self-regulatory processes would have to be invoked for the degree of engagement necessary to consider the new theory and weigh it against the existing theory (for an extended discussion of how this scenario plays out, see Lombardi et al., 2016). This weighing of arguments and issues requires cognitive, metacognitive, epistemic, motivational, and emotional regulation. We view the CRKM as a model that is inherently self-regulatory, although the mechanisms warrant further investigation. Now we turn to the notion of intentional conceptual change, which is a perspective that bridges CRKM toward a self-regulated view of conceptual change.

Intentional Conceptual Change

As the warming trend started by Pintrich, Marx, and Boyle (1993) "heated up," it became apparent that conceptual change is not only affective and motivational in nature; it can also be learner controlled or self-regulated (Sinatra, 2005). Sinatra and Pintrich (2003) distinguished conceptual change that emerges with little effort from learner-controlled conceptual change that is explicitly self-regulated. Research on the architecture of human cognition suggests that systems of thought are organized to allow for both quick, heuristic (i.e., System I) processing and more reflective, metacognitive, and self-regulated (i.e., System II) processing (Kahneman, 2011). Intentionality describes those processes that are initiated by the learner and deliberately enacted (Bereiter & Scardamalia, 1989).

In regards to conceptual change, learners do not necessarily plan to modify their knowledge in a specific way. Indeed, the knowledge construction process can even occur without the learner's awareness. An example of non-

intentional conceptual change is the construction of synthetic models (Vosniadou & Brewer, 1992). When young learners come to instruction with a flat Earth concept and hear that the Earth is round, they may conclude it is round like a pancake. It is unlikely that the construction of a synthetic model, blending the flat Earth and spherical view, is a deliberative process of knowledge reconstruction towards a particular conception.

In contrast, intentional processing is under the learner's conscious control (Bereiter & Scardamalia, 1989). It is by definition a volitional (Corno, 1993) self-regulatory process. Drawing on this view of intentional learning, Sinatra and Pintrich (2003) defined intentional conceptual change as "the goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge" (p. 6). However, despite the fact that intentional conceptual change is more likely to be the exception than the norm, it may be critically important for self-regulated science learning. The intent to change and the self-regulation of the change process are critical in science because students come to the science learning situation with deeply held knowledge and beliefs that many times conflict with scientific understanding. Self-regulated and intentional conceptual change may provide the leverage needed to overcome strongly held misconceptions. In the next section, we review research evidence in three important science domains where students' misconceptions have proven particularly vexing to overcome: climate change, biological evolution, and physics.

Research Evidence

Many topics in science need self-regulated, intentional conceptual change for successful learning. Three of these topics we have chosen to highlight are climate change, evolution, and physics. For each of these topics, misconceptions, biases, and everyday life experiences often conflict with scientific facts. Thus, self-regulated conceptual change is necessary to overcome these biases and misconceptions, and promote scientific reasoning. We also discuss instruments used to measure conceptual change in science.

Self-Regulation and Learning About Climate Change

Questions about the role that humans play in climate change have been at the forefront of media and political discourse. Misconceptions and misinformation about climate change in print, online, and television media sources, however, cause challenges when teaching or communicating about the issues (Stoknes, 2015). For example, students have the tendency to argue that short-term weather changes are evidence to support or refute long-term climate change trends (Lombardi & Sinatra, 2012), or they argue that climate change is caused by dust or increased solar radiation (Lombardi et al., 2013), when research shows that human activities leading to greater concentrations of greenhouse gases are the main culprit in rising global temperatures. Students confronted with conflicting information about the role humans play in climate change must resolve these discrepancies, while managing their emotions (Muis et al., 2015).

For conceptual change to occur when teaching individuals about climate change, components of the CRKM, including an individual's background knowledge (e.g., misconceptions and commitment to prior knowledge) and the message that is presented (e.g., whether it is plausible, comprehensible, and compelling), are particularly important. For example, messages to promote conceptual change in a subject area such as climate change should be plausible. Lombardi et al. (2016) described how when students are prompted through instruction to reappraise their judgment of a model's plausibility they are more likely to experience conceptual change. Such reappraisal processes must, to be effective, involve the intentional coordination of multiple sources of information and management of emotions—tasks that require self-regulation. Motivated, self-regulated conceptual change is necessary for evaluating sources, weighing evidence, and overcoming misconceptions on topics such as climate change.

Self-Regulation and Learning About Evolution

Evolution is another domain in which students often encounter information that may conflict with their prior knowledge and beliefs. The challenges of teaching and learning about biological evolution (i.e., misconceptions, disinterest, negative affect) have been extensively documented (Rosengren, Evans, Brem, & Sinatra, 2012). Effective instructional approaches are those that require a degree of self-regulated learning. For example, Teaching for Transformative Experience in Science (TTES) is an instruction model that aims to promote engagement with science content outside the classroom (Heddy & Pugh, 2015) that has been used successfully to teach evolution (Heddy & Sinatra, 2013). TTES is designed in a manner that effectively confronts the challenges of learning about evolution by promoting the active use of concepts learned in class in settings outside of the classroom. Active use occurs when students apply what they have learned about evolution to real-life situations (e.g., thinking about the concept of extinction when seeing a polar bear at the zoo). Next, students are encouraged to consider how that expands their view of the phenomenon. For example, they could realize that climate change can contribute to the extinction of polar bears. Finally, students are prompted to consider the value of what they have learned given what they experienced outside the classroom, such as valuing the concept of extinction for its utility in understanding the polar bears' plight. These three components of TTES require a considerable degree of self-regulation for learners to find the concept on their own outside of class, expand their conception beyond what was learned in class, and then to find their own value in it.

A second example of an effective approach to evolution instruction can be seen in the use of a dialogical argumentation strategy (Asterhan & Schwarz, 2007; 2016). In dialogical argumentation, students "are exposed to a multiplicity of ideas and encouraged to explore the validity of each other's ideas" (Asterhan & Schwarz, 2007, p. 626). Thus, this is a potentially effective self-regulated conceptual change approach. In a study with Israeli college students, participants worked in dyads and were either encouraged to work collaboratively or to use an argumentation strategy to solve two evolution problems. Those who engaged in argumentation were encouraged to critically examine each other's ideas and to "consider objections to their theories and assumptions, attempt to understand alternative positions, and formulate objections and counter objections" (Asterhan & Schwarz, 2007, p. 626). Those in the argumentation conditions outperformed those who were asked to collaborate, based on measures of conceptual understanding, presumably because they had greater opportunity to contrast their own point of view against the scientific ideas. The argumentation strategy likely encouraged students to become aware of and reflect on their own beliefs, requiring both metacognitive and self-regulatory processes. This provided the opportunity for students to engage in self-regulatory intentional reconstruction of knowledge.

Self-Regulation and Learning About Physics

Because of the fundamentally important concepts taught in physics and the many misconceptions about these concepts, physics is a domain where intentional, self-regulated learning is particularly important. Most of the research on self-regulation in physics focuses on the metacognitive component of self-regulation (Schraw et al., 2006). This research examines students' metacognitive skills during the problem solving process (Taasobshirazi & Farley, 2013) and has shown that metacognitively advanced students have greater problem solving success (Rozenchwajg, 2003). This metacognitive activity is particularly important when solving problems that involve the conceptual understanding of principles or laws rather than the rote application of facts (Shin, Jonassen, & McGee, 2003).

Successful problem solving also depends on accurate conceptual knowledge. When solving problems, students need to apply their knowledge in order to successfully solve problems (Snyder, 2000). Misconceptions in that knowledge can interfere with successful problem solving. In the area of mechanical physics, for instance, there are misconceptions that come up when students are solving problems involving Newton's Second Law. Some students mistakenly believe that the motion of an object implies an accompanying force (Reiner, Slotta, Chi, & Resnick, 2000). Students who hold this misconception have difficulty solving problems associated with this law

because incorrect forces are included in their calculations. In order to restructure their knowledge, self-regulated, intentional conceptual change is critical.

Instruments for Measuring Self-Regulation in Science

There are several instruments that measure self-regulated learning in general (e.g., Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, García, & McKeachie, 1993) and metacognition in particular such as the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994). Recently, Taasobshirazi and Farley (2013) developed the Physics Metacognition Inventory (PMI). The PMI is one of the first instruments to measure metacognition during science problem solving. The 26-item inventory uses a five-point Likert scale format to measure six components of metacognition including: knowledge of cognition, planning, monitoring, evaluation, information management, and debugging.

Taasobshirazi, Bailey, and Farley (2015) revised the PMI and assessed its psycho-metric properties with results supporting the validity of the instrument. Although the instrument was validated in the domain of physics, the PMI can be used to assess students' metacognition for problem solving in other sciences, such as chemistry, where problem solving also plays a significant role in learning and achievement. In such a case, the word chemistry can be substituted for the word physics in the inventory.

We argue that more efforts need to be made to understand and assess how students self-regulate their motivation and emotions when learning science. Only one inventory has explored students' self-regulation of motivation (Wolters, 1999). Research in science education and in conceptual change now recognizes the importance of non-cognitive factors on students' success in science; however, too little research has focused on the role of self-regulating non-cognitive factors on science achievement.

Future Research Directions

Dole and Sinatra's (1998) CRKM provided a theoretical framework for studying how the engagement of a learner with a message impacts conceptual change. The model includes many variables that have been empirically tested through a growing body of research over the last 18 years. What is needed is more research on the self-regulation of conceptual change. Perhaps, through the use of instruments like the PMI, researchers could examine how the self-regulation of metacognition impacts science problem solving across various grade levels and time points. For example, structural equation models can be used to test how the different components of metacognition (e.g., monitoring, evaluation) impact problem solving, which can provide specific information about the relative contributions of the various metacognitive components on problem solving success.

Also, we have seen a clear shift away from relying exclusively on self-report measures towards capturing self-regulation strategies from online trace behaviors and other learning analytics. This move has been called for repeatedly now in the field (for a discussion of this trend, see Graesser, 2015; Sinatra, 2016), and progress has been made (Gobert, Baker, & Wixon, 2015; Roll & Winne, 2015). We encourage more work in this area, particularly in linking learning analytics to conceptual change outcomes. With these advances, progress could be made in tracking the potential drivers of intentional conceptual change.

Finally, in our original contribution to this handbook, we called for motives, emotions, and self-regulation to be more thoroughly incorporated into conceptual change models (Sinatra & Taasobshirazi, 2011). While additional work is still needed to fully accomplish that goal, the plausibility judgment and conceptual change model of Lombardi et al. (2016) is definitely a step in that direction. This model explicates how emotions and motivations impact learners' critical evaluations of scientific models leading to shifts in their plausibility appraisals and, ultimately, conceptual change.

Lombardi and Sinatra (in press) recently provided an overview of their work on evaluating the potential truthfulness of scientific explanations compared to plausible but non-scientific explanations. They noted that “individuals typically have poor understanding about the distinctions between evidence and explanations, and epistemic judgments outside the purview of plausibility may be required to facilitate epistemic conceptual change” (Lombardi & Sinatra, in press, p. 9). Building on the work of Chinn, Rinehart, and Buckland (2014), they recommended the use of instructional scaffolds, such as the model evidence link diagram, to promote epistemic judgments of evidence. They also cautioned that students may judge evidence differently than they judge plausibility, which stresses the importance of promoting the self-regulatory strategies for evaluation of sources of scientific information.

Implications for Educational Practice

Numerous studies and literature reviews have been published on how to promote self-regulated learners and many examples can be found within the pages of this volume. We have five suggestions we have found particularly helpful for promoting self-regulated learners in science. First, we recommend using the PMI to assess and monitor students’ self-regulated learning in science. Students’ individual results on the metacognitive components of the PMI can be used to address weaknesses, such as by providing instructional interventions to improve students’ metacognition.

Second, we recommend constructing learning environments where students’ existing knowledge is challenged and they are forced to consider alternative theories (Lombardi et al., 2013). This is a conceptual change teaching approach that promotes self-regulation of the components we reviewed (i.e., cognition, metacognition, motivation, epistemic cognition, and emotion).

Third, we recommend providing students with the self-regulatory skills and strategies needed to critically evaluate scientific information. Now more than ever, with the proliferation of misleading headlines or worse, fake news, students need the tools to critically evaluate scientific findings for authenticity and veracity. Resources such as *Reading Like a Historian* (Wineburg, Martin, & Monte-Sano, 2013), which provides students with opportunities to critically evaluate historical events, need to be developed for ferreting out unsubstantiated scientific claims.

Fourth, we recommend more explicit instruction designed to promote epistemic conceptual change (Sinatra & Chinn, 2012). These are instructional approaches or learning environments that explicitly challenge students to question and confront their own views of knowledge. In such circumstances, students can be asked to justify what they know, and critically reflect not only on what they know but how they know it (for instructional ideas, see Greene et al., 2016).

And finally, we recommend more incorporation of emotion regulation into the self-regulation of science learning. We began this chapter noting how many topics in science and technology today are controversial in the minds of the public and students and may activate strong, negative emotions. Emotion regulation is needed if students are going to be able to engage productively with these topics and with others who may have different perspectives.

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11 Using Technology-Rich Environments to Foster Self-Regulated Learning in Social Studies

Eric G. Poitras and Susanne P. Lajoie

Introduction

The self-regulation of learning in history is an emerging area of research in the field of social studies education. The goal of self-regulated learning (SRL) research is to identify the cognitive, metacognitive, affective, and motivational processes that underlie learners' efforts to reconstruct the past along with the instructional strategies that can be used to enhance learning and task performance. The challenge facing educators and students in history classrooms is to engage in analytical skills to reason and gain better understanding of the past, drawing inferences on the basis of available and reliable evidence as opposed to memorizing lists of facts and dates (Donovan, Bransford, & Pellegrino, 1999). The seminal works by Wineburg (1991, 1994) highlighted the nature of novice-expert differences in historical reasoning and documented the complex interplay of cognitive skills involved in evaluating the credibility of historical sources, corroborating information from multiple accounts, and making inferences based on the available evidence and one's own prior knowledge. Considering the dynamic nature of historical thinking, and how learning unfolds throughout the course of studying multiple and often conflicting or unreliable sources of information, the importance of regulatory processes becomes apparent. From an educational perspective, we consider it essential to situate SRL development and instruction in the context of these disciplinary-based practices.

In a review of the terms metacognition, self-regulation, and SRL within contemporary research, Dinsmore, Alexander, and Loughlin (2008) alluded to theoretical frameworks that inform the study of these constructs. Although the definition and measurement of each construct is often inconsistent across studies, researchers typically distinguish between information-processing models (Winne, 2001, 2005; Winne & Hadwin, 1998, 2008, 2010; Winne & Perry, 2000) and social-cognitive models (Pintrich, 2004; Schunk, 2005; Zimmerman, 2001) of self-regulation in academic studying and other forms of learning. SRL emphasizes the dynamic nature of skills, attitudes, motivations, and contextual factors involved in these settings, and attempts to explain individual differences in learning outcomes as well as how to improve learning and performance. For a more detailed discussion of these theoretical frameworks, we refer the reader to Winne (2018/this volume) as well as Usher and Schunk (2018/this volume). This chapter compares the different ways in which SRL has been defined by educational researchers in the area of social studies. In particular, the relationship between self-regulatory processes and historical reasoning is examined under the information-processing view of SRL. To date, there are few studies that have investigated the domain-specificity of SRL (Alexander, Dinsmore, Parkinson, & Winters, 2011). While some research has been carried out on students' ability to regulate their learning as well as the role of technology in facilitating SRL in the social studies, there is still very little scientific understanding of how these factors mediate students' understanding of the past.

In this chapter, we discuss technology-rich learning environments (TREs) designed to support or scaffold students to gain a deeper understanding of the past that would otherwise be beyond their reach. We critically examine recent empirical evidence on the design of scaffolds in TREs such as hypermedia-based environments and intelligent tutoring systems to promote SRL. In doing so, scaffolds embedded in TREs are progressively faded as students become more competent in regulating certain aspects of their own learning (Lajoie, 2005; Lajoie & Azevedo, 2006). The past two decades has seen rapid developments in scaffolds embedded in TREs designed as metacognitive tools to promote SRL (Azevedo & Aleven, 2013; Moreno & Mayer, 2007; Quintana, Zhang, & Krajcik, 2005), and reviews such as that conducted by Reiser (2004) differentiate between structuring and problematizing certain aspects of learning and task performance. On the one hand, learning tasks can be structured to help students by reducing or sequencing the number of choices to make, providing guidance and cues, and facilitating performance through external representations. On the other hand, tasks can also be made more problematic to challenge students to construct their knowledge by addressing issues or gaps, thereby providing

them with opportunities for meaningful learning to occur. The theoretical assumptions that guide the design of metacognitive tools are described in the next section.

Relevant Theoretical Ideas

Alexander et al. (2011) reviewed the SRL literature to identify the domains under investigation and whether the choice of domain or task was purposefully defined or manipulated to address a particular research question. Very little research addressed the question of whether SRL may be affected by task or domain differences. The majority of the 77 empirical studies included in the review did not identify any particular academic domain or task and its relevance to specific SRL processes. The most popular disciplines reported in empirical studies on SRL included the areas of science, psychology, and teaching and instruction. An implication of this finding is the possibility that the nature of the task performed in a specific domain such as the social studies, along with the learners' prior knowledge of disciplinary-based practices, is often overlooked in the research literature.

Only in the past five years have studies of SRL directly addressed how disciplinary-based practices in the social studies affect learners' ability to regulate certain aspects of their own learning. Researchers studying SRL in the social studies have focused on a few particular processes, such as learners' understanding and level of interest towards a task, as well as how they plan their learning, use strategies, and monitor their progress. The first systematic study of SRL in the social studies was conducted by Greene, Bolick, and Robertson (2010). Learners' use of SRL processes were assessed in addition to the resulting knowledge of study tactics or strategies used in history as well as gains in declarative knowledge. Historical thinking skills were assessed as the students' ability to evaluate multiple sources, arrange events in the order of their occurrence, and come to an understanding of how a historical narrative might include multiple perspectives of the same event. The deployment of historical thinking skills was later examined throughout learning and task performance as a form of cognitive operation defined in accordance to information-processing models of SRL (Greene, Bolick, Jackson, Caprino, Oswald, & McVea, 2015; Poitras & Lajoie, 2013). From this perspective, historical thinking is not just a learning product but a process and a topic of cognition whereby we study how students allocate cognitive resources towards monitoring and controlling its products and appraising the amount of efforts required to achieve certain standards. For instance, students might investigate the causes of an historical event by asking appropriate questions, formulating an explanation, and evaluating the trustworthiness of sources while gathering, corroborating, and making sense of conflicting accounts. Another significant aspect of these domain-specific strategies is their interrelationships with students' understanding of the task and their efforts to set goals, monitor their progress, and adapt their approach in response to changing task conditions. In the following section, we describe the phases of SRL as outlined in the three-phase model of cognitive and metacognitive activities in historical inquiry (CMHI; Poitras & Lajoie, 2013), a model that characterizes disciplinary-based practices in history.

Defining the Task

Learners consider a learning task based on the resources that are available to them and any relevant constraints that will impact their performance (Winne, 2018/this volume). These considerations may be internal or external to the learner. Internal considerations refer to learners' knowledge of the historical time period or historiographical practices, as well as their motivation to pursue learning in this area. External factors may refer to the amount of time available to pursue the task, access to more knowledgeable peers or other sources of information, the nature and content of each informational source, and whether or not learners were in control of their learning goals. Historical evidence is often incomplete, unclear, or even contradictory, and the practice of history necessitates learners to continually re-define these task conditions as new evidence emerges, which leads them to re-evaluate their understanding of an event (VanSledright & L  mon, 2006).

A student learning about the sinking of the RMS Titanic, for instance, might begin by reading a firsthand account of the circumstances surrounding the events of the night of April 14, 1912. Although an iceberg reportedly sank the Titanic, the historical account raises several questions, among which are the reasons why the tragedy occurred.

An inquiry into the causes of the event and one's own emerging understanding is constrained by the factors mentioned above, and most importantly access to primary and secondary sources to support or refute plausible explanations. These explanations may include, but are not limited to, the high concentration of icebergs due to climate, thermal inversion refracting light and camouflaging the iceberg, the ship's high travel speed, failure to deliver an ice warning message to the bridge, and the use of wrought iron rivets instead of steel rivets. The writing of an historical narrative is often the end result of the inquiry process, although narratives themselves vary substantially in terms of their audience, structure, and criteria for assessing quality (Voss & Wiley, 2006). Learners' understanding of the task and the available resources are critical aspects of their efforts to regulate their learning, as they may seek assistance and indicate that some documents are not clear or are unusable.

Planning

Learners begin to write an historical narrative by stating goals and refining them into sub-goals. During the course of learning, learners may revisit or change their goals when they realize there is insufficient time to meet them or that they need more support to attain their goals. Planning is a complex process where learners progressively define the desired end result of the task, determine what level of achievement is suitable, identify the relevant knowledge that must be gained, and reflect on what steps must be taken to solve a problem (Winne, 2018/this volume).

As an example, learners may encounter an important event that occurred in an historical account. However, the account fails to mention any information pertaining to the causes of that event. Learners would likely begin their inquiry into the causes of an event by formulating a tentative explanation, which consists of an argument in favor of a specific cause (e.g., Frederick Fleet, a crewman and lookout, failed to spot the iceberg that sunk the Titanic because he forgot his binoculars). As the learners make progress and use strategies to analyze historical documents, their understanding of the event becomes progressively more coherent. They might consider the role of multiple causes and weigh alternative factors in their explanation of an event (e.g., Frederick Fleet, a crewman and lookout, failed to spot the iceberg due to an optical illusion caused by light refraction) or respond to counter-arguments (e.g., binoculars are not effective in the dark) by refuting or acknowledging such factors on the basis of evidence gathered from historical accounts. These different goal-setting and planning activities (i.e., formulating an explanation, weighing alternative causes, and anticipating counter-arguments) are distinguishable in patterns of strategy use and the resulting products or changes made to a narrative.

Using Learning Strategies

Learners engage in task performance utilizing cognitive operations to make sense of information and transform it in a way that is conducive to their stated objectives. For instance, the information-processing model of SRL assumes several "primitive" operations that include searching, monitoring, assembling, rehearsing, and translating, fittingly labeled as SMART operations (Winne, 2001, 2018/this volume). These primitive operations underlie more complex strategies involved in the transformation of information in a manner conducive to enhancing learning, such as generating inferences or elaborating information based on prior knowledge (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Greene & Azevedo, 2009). In the CMHI model of SRL, learners rely on a range of domain-specific strategies deployed in a cyclical manner during learning while performing inquiries into the causes of historical events.

For instance, an argument in favor of a particular cause necessitates that learners gather evidence such as a direct quote taken from a document. In the case of the Titanic's sinking, historical records may not be easily obtainable or complete, for instance weather records of that time period, survivors' testimonies, as well as ships' logs. Consider the following firsthand account provided by Dr. Washington Dodge, an eyewitness of the sinking of the Titanic on April 15, 1912:

The ocean as calm as the waters of a smooth flowing river we rowed off to overtake a boat having a lantern aboard, we being unable to find one in our boat—Having rowed about ¼ mile we found ourselves in close proximity to five boats—We observed the closing incidents the gradual submergence of the ship forward—[...] From this time until shortly after 4 in a sea gradually growing rougher a temperature extremely cold we rowed about—Observing in the darkness what first appeared to be a ship full rigged, but to our disappointment proved to be an ice berg about ½ mile distant.

Learners may evaluate a document such as this firsthand account as being a credible source of information by taking into consideration the author's reasons, perspectives, and opportunity for writing the account. For instance, the carelessness of Dr. Dodge's own handwriting may be suggestive of his state of mind, writing a firsthand account of the sinking within days after the disaster. The evidence itself may be corroborated by other accounts, which requires the learners to coordinate multiple sources of information. A critical factor in reconciling these different historical accounts is learners' ability to situate the documents in the time and place of their creation and imagine themselves in the context of the event as it unfolds to understand the values and perspectives of historical figures. This set of historical thinking skills enables learners without any prior knowledge of an event to carefully reconstruct its circumstances and build arguments as to the plausible causes that led to its occurrence.

Making Adaptations

Adaptations to historical understanding occur when learners evaluate their progress and determine that changes are needed to improve upon certain aspects of learning or task performance. These evaluations are complex and may be the result of (1) judgements about the adequacy of the sources they read in trying to meet their goals, (2) the effectiveness of specific strategies, (3) their emotional responses to certain aspects of the task, (4) their awareness of relevant prior knowledge, and (5) emerging understanding of the topic. These learning experiences leads to re-organizing the retrieval and retention processes that characterize learners' procedural knowledge, thereby modifying future efforts to perform similar tasks. In particular, adaptations include experiences where learners' explanations are evaluated against standards of causality. In these evaluations, causality serves as a standard by evaluating whether antecedent events are logically followed by their consequents. In doing so, causal standards constrain learning through the need to organize and interpret information obtained from historical sources as a coherent chain of causes and effects.

For instance, learners' understanding of the causes of the Titanic's sinking may settle on a primary factor (i.e., the lookout's failure to quickly spot the iceberg), whereas learners are unaware of the relevant conditions that enabled this event to take place (i.e., atmospheric conditions, high concentration of icebergs) or instead believe in the importance of irrelevant details (i.e., the lack of binoculars). Furthermore, the order of causation is another factor to consider while reflecting on one's own understanding. For example, is the time delay in reporting the iceberg a necessary condition for the sinking of the Titanic? What if First Officer Murdoch had not ordered a port-around maneuver? Would the Titanic still have collided with the iceberg with the bow veering port? What if steel rather than iron rivets were used? Would the hull have been capable of sustaining the damage? The time delay to report the iceberg may be a necessary condition for the event to occur, but there are also a number of sufficient conditions which are closer to, or immediately responsible for, the outcome.

An interesting facet of adaptation is that as an explanation increases in its level of coherence, the nature of the argument shifts from the achievement of lower-order goals (i.e., confirm the most likely cause of an event) to higher-order goals (i.e., weigh alternatives or anticipate counter-arguments). The learners' inquiries into the causes of the event are performed until coherence in understanding the event is reinstated to a sufficient degree given learners' motivations, task constraints, and available resources. Learners' gains in understanding, as a result of the learning task, subsequently impact future inquiries into the topic. For instance, learners may be able to search their memory for relevant information, re-read notes, and infer the motives and beliefs of familiar historical figures. However, learners might also recall how difficult the task was to complete because of the lack of resources, and decide that they should instead pursue their inquiries into other related subjects or consult a

different library. As such, the CMHI model of SRL characterizes the phases and cyclical nature of learners' ability to regulate certain aspects of their own learning while making inquiries into the causes of events in accordance with disciplinary-based practices in social studies. Having defined what is meant by the domain-specificity of SRL, now we move on to discuss recent empirical findings bearing on these notions and the role of TREs in facilitating SRL.

Research Evidence

TREs designed as metacognitive tools aim to model, track, and support learners' self-regulatory processes. In doing so, TREs may scaffold cognitive (e.g., goal-setting, learning strategies), metacognitive (e.g., feeling of knowing, judgement of learning, evaluation of understanding), motivational/affective (e.g., interest, confusion), and behavioral activities (e.g., define task demands, engage in help-seeking behaviors) that mediate learning and task performance (Azevedo, 2005, 2008). There are several reasons why learners may fail to regulate certain aspects of their own learning, e.g., the learning environment lacks structure (Mayer, 2004), or the learners lack the pre-requisite metacognitive knowledge (Veenman, Van Hout-Wolters, & Afflerbach, 2006), or the learners do not understand how to deploy self-regulatory processes during learning (Azevedo & Feyzi-Behnagh, 2011). Over the past decade, there has been an increasing amount of literature on the adaptive capabilities of TREs designed as metacognitive tools. Adaptive TREs provide scaffolds on the basis of the changing needs of each learner, fading assistance as individuals become proficient (Azevedo & Alevan, 2013). The following sections review recent empirical evidence on the role of TREs designed as metacognitive tools to foster SRL in the area of social studies, including hypermedia-based environments and intelligent tutoring systems.

Self-Regulated Learning in Hypermedia-Based Environments

Hypermedia learning environments enable learners to navigate through multiple sources of instructional content (i.e., text, animations, videos, sounds, and images) in a non-linear manner. The content is made accessible through hyperlinks that are embedded within each document, facilitating learners' efforts to access and manipulate relevant information (Jonassen, 1996). The most obvious finding to emerge from research on hypermedia is that multiple representations of complex topics may be helpful for learners, allowing them to access, transform, store, and revisit information in a convenient manner (Jacobson & Archodidou, 2000). However, the manner in which these representations are designed and delivered to learners is often problematic. Learners have limited attentional resources that can be allocated to assimilating and retaining information, and poorly designed representations often induce cognitive load (Baddeley, 2001; Mayer & Moreno, 2003). Furthermore, learners' prior knowledge of the topic or task may not be sufficient to allow them to effectively navigate through the content, resulting in cognitive disorientation due to the large amounts of potentially irrelevant or tangential subject matter (Azevedo & Feyzi-Behnagh, 2011; Lajoie, 2014; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000).

In a seminal study on SRL in history, Greene et al. (2010) asked high-school students to perform a think-aloud protocol (TAP; Greene, Deekens, Copeland, & Yu, 2018/this volume) while learning from primary and secondary sources (i.e., five text documents and four images) obtained from a larger collection about the Regulator Movement. The event in question occurred in the 1760s, and involved an uprising of residents in present-day North Carolina who claimed that British colonial officials were engaging in corrupt and oppressive practices. Multiple-choice/true-false tasks and open-ended essays were used to assess prior and gained knowledge of the Regulator Movement that could be attributed to self-regulatory processes. The results confirmed that students demonstrated modest gains in both declarative knowledge and the use of historical thinking skills while writing an essay about the Regulator Movement.

The most striking result to emerge from the think-aloud protocol data is that students often failed to engage in planning activities, preferring instead to rely on learning strategies and then monitoring their progress. However, a statistically significant relationship was found between planning activities and learning outcomes. Students who planned their efforts by setting goals and refining them into sub-goals obtained higher scores in declarative

knowledge about the historical topic at the end of the learning session. In other words, these students were better able to recall correctly factual information regarding the event under examination because they set goals during learning. A small but statistically non-significant effect was also observed with regards to learners' conceptual understanding and use of historical thinking skills while writing an essay.

Extensive research has shown that the ability to make inferences and elaborate on information by activating prior knowledge is necessary to improve learning about science topics (see Greene & Azevedo, 2007). However, students were observed to rely most often on ineffective strategies while learning about history (i.e., taking notes, as well as searching and summarizing information or selecting new informational sources). They often mentioned experiencing difficulties while performing the task (e.g., self-questioning as well as negative judgements of learning and evaluation of the usefulness of content).

These results are significant in at least two major respects. It may be the case that students would benefit from scaffolds that target goal-setting activities, supporting them to state and reinstate goals on a frequent basis during learning and task performance. Furthermore, students may require extensive training on the use of learning strategies, in particular, elaborative processes that enable students to control their own learning. However, the study conducted by Greene et al. (2010) made no attempt to substantiate claims in regards to the impact of domain-related differences in SRL processes towards learning outcomes and whether the benefits of elaborative processing may be restricted to science-related topics. The evidence reviewed here seems to suggest an approach to SRL training that may be transferable to multiple domains, including both history and science topics.

Greene et al. (2015) conducted a subsequent study where college rather than high-school students were randomly assigned to learn either about the Blue Ridge Parkway (i.e., history topic) or the phase change process as substances move from solids, liquids, and then gaseous states (i.e., science topic). The think-aloud protocol data were examined for the use of fine-grained SRL processes that were found to be predictive of learning gains in each discipline (Greene, Dellinger, Tüysüzoğlu, & Costa, 2013). The method involved the aggregation of effective and ineffective SRL processes into coarse-grained descriptions that characterized the broad phases of SRL (i.e., planning, using strategies, and monitoring) to more accurately model their outcomes towards learning.

College students were observed to engage often in strategy use rather than making efforts to monitor or plan certain aspects of their own learning, in a similar manner to the high-school students who learned about the Regulator Movement (Greene et al., 2010; Greene et al., 2015). However, college students did plan their efforts and set subgoals more often than high-school students while learning history, which may have contributed to the increase observed in declarative knowledge gains about the Blue Ridge Parkway. These results supported our previous conclusion that students should be supported in their planning skills while learning from hypermedia.

The comparison of effective SRL processes observed while students learn either the history or science topics provides important insights into the design of adaptive hypermedia learning environments. Regardless of the domain of study, students who are able to search their memory for relevant knowledge, reinstate information from memory, elaborate on what was read with prior knowledge, memorize text, as well as monitor the time left to task completion were found to gain more declarative knowledge about the topic than those who enacted other processes. In learning about history rather than the science topic, the ability to guess the content available in a source, monitor the effectiveness of strategies, and engage in self-questioning were positive predictors of scores obtained on post-test declarative knowledge measures. Finally, learning strategies that are exclusive to the history domain, referred to as historical thinking skills (i.e., comparing sources to determine the accuracy of their content and inferring historical figures' perspectives, thinking, and emotions), are amongst the most underutilized strategies reported by students, but are nonetheless predictive of gains in declarative knowledge.

Taken together, these studies support the notion that adaptive hypermedia-based environments should scaffold SRL processes in accordance with disciplinary-based practices. Researchers have noted the importance of demographic characteristics (i.e., high school vs. college level) as well as the domain (i.e., history vs. science) as predictors of students' self-regulatory processes. In particular, less-experienced students in history require

scaffolds that support them in setting goals and using effective strategies to make sense of information while navigating through hypermedia. The design of scaffolds should also be sensitive to the domain under examination. Learning strategies that are specific to an area may be underutilized by less experienced students due to their lack of domain knowledge. While many SRL processes are transferable across domains, the effectiveness of specific learning strategies may also vary depending on whether students are learning about history or science topics. The problem of fostering SRL processes in accordance with disciplinary-based practices in students with low prior domain knowledge has been examined further in the context of intelligent tutoring environments.

Self-Regulated Learning With Intelligent Tutoring Systems

Intelligent tutoring systems may be defined as any type of technology that adapts itself to the specific needs of different learners (Anderson, Boyle, Corbett, & Lewis, 1990; Greer & McCalla, 1994; Self, 1999). The adaptive capabilities of such systems are predicated upon comprehensive models and assessments of skills, emotions, and other factors that mediate learning and performance (Desmarais & Baker, 2012; Pavlik, Brawner, Olney, & Mitrovic, 2013). Shute and Zapata-Rivera (2012) listed the main features of intelligent tutoring systems as follows: (1) the capability to capture information about learners using multiple sources of data; (2) the real-time analysis of the data to make inferences about learners' progress; (3) the selection of the most suitable instructional content or strategy to support learners; (4) the delivery of instruction through the system interface. In doing so, the tutoring system may choose to sequence the order of tasks to be performed by learners or might intervene during task performance through hints, prompts, and feedback (VanLehn, 2006).

The MetaHistoReasoning tool was designed to support students in monitoring and controlling their own learning while performing inquiries into the causes of historical events (Poitras, 2015). Students learn about the circumstances in which a particular event occurred, such as the council meeting where the order to deport the Acadians was given by Governor Charles Lawrence at Halifax, in July 1755. However, the narrative excludes any information pertaining to the potential causes or contributing factors that led the governor to make his decision. Learners with low prior knowledge of the domain often fail to notice that gap in their understanding of the event and formulate tentative explanations (see Poitras, Lajoie, & Hong, 2012). The ensuing investigation into the causes of the event requires students to set goals, monitor their progress, and use disciplinary-based strategies to formulate their own explanations based on information obtained from primary and secondary sources. The MetaHistoReasoning tool was conceived as a modular system, wherein the first module completed by the students is designed to support skill acquisition (i.e., Training Module), while the subsequent one enables them to practice and refine these skills (i.e., Inquiry Module).

Poitras and Lajoie (2014) asked undergraduate students to learn with the MetaHistoReasoning tool and they examined trace logs of user interactions as well as pre-test measures of domain knowledge and post-test measures of topic knowledge and historical thinking skills. In regards to the pre-test survey, students were unfamiliar with historical practices in general, and did not know a lot about the topic under investigation (i.e., the Acadian Deportation). The examination of the topic knowledge assessments showed students were moderately capable of recognizing statements and inferences drawn from the source documents. The analysis of the least and most elaborate essays written by the students also suggested a broad range of abilities in applying historical thinking skills. On the one hand, the written essays argued in favor of the claim that the deportation was caused by the refusal of the Acadians to swear to the oath of allegiance on the basis of evidence gathered from the historical documents. On the other hand, the most elaborate essay also challenged the neutrality of the Acadians in the conflict with the British government, referring to specific quotations taken from primary sources and questioning the reliability of Governor Charles Lawrence as a witness due to his need to obtain the approval of the board members tasked with the administration of the colony. These findings suggested students were able to apply historical thinking skills such as sourcing and gathering evidence to support either single or multiple causes while formulating an explanation.

The examination of the trace log data of user interactions with the Training Module identified student behaviors that predicted the acquisition of skills deployed while regulating certain aspects of their inquiries into the causes of the event. In the Training Module, students recognized skills shown in examples by choosing amongst eight multiple-choice options. A logistic regression model of the correctness of their responses achieved 76.2% accuracy using a ten-fold stratified cross-validation procedure. The model suggested that historical thinking skills such as gathering, corroborating, and contextualizing evidence as well as using substantive concepts were the most difficult for students to correctly recognize from the examples. Students who spent more time studying and made more attempts to categorize an example were more likely to incorrectly recognize the relevant skills. Furthermore, the amount of prior exposure to examples of a particular skill was found to predict the correctness of example categorizations.

In the Inquiry Module, students were expected to practice and refine these historical thinking skills while regulating their own learning about the causes of the Acadian Deportation. A series of decision rules were applied to the trace log data of learner behaviors to detect students' goal-setting activities and strategy use while performing inquiries into the causes of historical events. The results showed that students performed on average only two lines of inquiries, where an explanation was formulated and revised based on information found by students while analyzing historical sources. The examination of the goals set by students while performing their inquiries suggested that they most often confirmed the most probable cause for the event under investigation, rather than weighing alternative causes or refuting counter-arguments. Furthermore, the strategies used by students to build their arguments also indicated several areas for future improvement, most notably the need to elaborate or describe in full detail the information used as evidence, as well as the need to explain their reasoning or the warrant that linked the evidence to their claim. Furthermore, students should have included additional efforts to build their evidentiary base, which often included repeated mentions of the same factual statement, or facts that were noted as being contradicted by other accounts.

These findings suggest that intelligent tutoring systems that adaptively scaffold SRL processes should consider student motivation as well as task conditions when assisting students to use learning strategies in the pursuit of goals. Students pursued only a limited amount of inquiries into the topic and preferred to settle on the most likely explanation for the event under investigation, whether due to lack of time, the amount of evidence available, or low interest in the topic. Such processes prevented students from building a solid evidentiary base; therefore prompts may be needed to support students in describing further the pieces of evidence and warrants of their arguments. The challenge is to design scaffolds that can efficiently support students in acquiring, practicing, and refining the use of these learning strategies, while at the same time allowing them to set meaningful goals to learn about different topics of interest. The following sections of this chapter elaborate further on these notions by making recommendations for future research and suggesting educational implications.

Future Research Directions

These findings have significant implications for understanding and supporting SRL processes with TREs in social studies education. The scope of this chapter was limited to empirical research that relied on process measures to capture the deployment of SRL processes during learning and task performance. In particular, think-aloud protocols were used to assess learners' verbalizations of their own thought processes, which provides the basis for researchers to infer the onset of cognitive, metacognitive, behavioral, and affective states that characterize SRL (Greene et al., 2018/this volume). Trace logs data of learner behaviors were also used as observable indicators of SRL processes, because they may be informative of how SRL processes unfold during the course of learning (Bernacki, 2018/this volume). A more systematic approach to these data would identify how events detected through each of these methods are similar or different, and whether the data provide common grounds for supporting theoretical claims. How think-aloud protocol data obtained by Greene et al. (2010, 2015) translate to observable indicators that can be analyzed by computers, and whether these same indicators are validated through alternative approaches, are important issues to explore to establish the validity, reliability, and practicality of assessment methods. These issues notwithstanding, additional research using controlled hypermedia

manipulations (i.e., history and science subject matter), as well as analysis of finer-grained constructs using process measures are needed to better understand the role of disciplinary-based practices within SRL frameworks.

One of the most important assumptions underlying the design of scaffolds in TREs is whether SRL processes can be externally supported by human or artificial tutors, as well as tools and representations, in a scalable manner. We use the term scalable to refer to any scaffolds embedded in TREs that support SRL processes while taking into account topic, domain, and/or environmental considerations and are faded once the learners become more competent. Learners are hypothesized to progressively internalize SRL processes, leading them to become more autonomous and proficient in their own future learning. Scalable scaffolding solutions enable TREs to adapt the delivery of instructional content, prompts, and materials depending on the topics studied by learners, the domain under investigation, or other scaffolds made available in the learning environment. As researchers differentiate between SRL processes that are generalizable across domains and others that are situated in specific disciplines such as the social studies, we call on the broader community to establish common standards for scaffold design guidelines that take into consideration the role of these mediating factors.

Research into the domain-specificity of SRL is still in its infancy, but it raises important questions about the feasibility of designing scalable scaffolding solutions in TREs, and the challenges involved in replicating research to evaluate their effectiveness in fostering SRL. For example, a textbox designed to support learners in making inferences may be made available under specific experimental conditions (i.e., pre-defined groups of students with access to different hypermedia pages), while logging the written content for further analysis. A research and training platform that facilitates access to these datasets, interface plug-ins, databases of hypermedia content, and standardized log records stands to increase the feasibility of group-randomized experiments of domain-related differences in SRL (Greene et al., 2015), as well as the scalability of models and scaffolds embedded in the system interface (Poitras & Lajoie, 2014). The issue relates to the broader impacts of how these findings translate to improved tool designs that foster the most effective SRL processes in specific tasks and domains, and how to make them widely available to the academic and educational community in a timely manner given the current state of the research literature.

Implications for Educational Practice

The findings obtained in recent empirical studies on SRL have several practical considerations for social studies education. Students have opportunities to practice how to regulate certain aspects of their own learning when it is necessary to perform a task such as solving a problem or answering a question. Teachers may ask groups of students to investigate questions and report their findings to the rest of the class. The open-ended nature of these tasks demand that students cooperate in terms of setting common goals, using strategies, and monitoring their progress while making sense of information obtained from an online collection of documents on the relevant topic. By problematizing the subject matter and challenging students, they have the opportunity to engage in meaningful problem-solving that results in SRL development.

As noted by Greene et al. (2015), an emphasis must be placed on supporting students to set goals and monitor their progress through external representations of such activities. This also provides opportunities for students to engage in disciplinary-based practices while regulating their own learning. In order to support students in acquiring such skills, teachers can explicitly model or verbalize these thought processes by explaining how proficient learners approach a similar task, and the strategies that are helpful in making sense of the past. The teacher can also monitor the performance of each group by offering hints, answering questions, and making recommendations while students are searching for relevant information.

As was made evident in the empirical literature, software tools may serve as meta-cognitive tools by creating external representations that structure thought processes in a manner that promotes learning and task performance (Poitras & Lajoie, 2014). The same line of reasoning applies to the classroom environment, and ensuring that students have access to a variety of means to express and record their thinking as it evolves throughout the course

of task performance is crucial to promoting self-assessment and reflective practices. For instance, one of the students in each group may rely on note-taking software or use sticky notes to evaluate what is known about the topic and what is unknown. Another student may keep track of the remaining time and list all the web pages that were visited by the group in order to set the search priorities and persist in finding relevant information. Periodically, teachers may inform each group to review the progress they have made so far, in order for students to re-adjust their efforts and correct mistakes. In this view, students encounter situations that are authentic and meaningful, enabling them to express their own understanding and interests while monitoring their progress using external visualizations. The assumption is that with repeated exposure to such tasks, students internalize effective strategies that are articulated by the teacher, allowing them to be successful and autonomous learners in similar circumstances (Usher & Schunk, 2018/this volume).

In conclusion, researchers can rely on TREs to serve as both research and training platforms to model and foster SRL in accordance with disciplinary-based practices. In the social studies, learners monitor and control their emerging understanding of historical events while reading firsthand and secondhand accounts (Poitras & Lajoie, 2013). Furthermore, the evidence suggests that the SRL processes that mediate successful learning may differ across disciplines, such as social studies and sciences. These findings raise intriguing questions regarding the nature of SRL skills and the extent of their transferability across domains, tasks, and the role of prior knowledge regarding disciplinary-based practices. Research infrastructures can facilitate work in this area, raising the possibility of personalized learning solutions that implement scalable models and scaffolds to foster SRL within and across academic disciplines.

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12 Self-Regulated Learning in Music Practice and Performance

Gary E. McPherson, Peter Miksza, and Paul Evans

Introduction

This chapter discusses self-regulated learning (SRL) in the context of music. SRL holds significant potential for increasing the efficiency of musical skill acquisition across all aspects of music performance instruction. We begin with a review of selected research that has studied skill acquisition when learning to play a musical instrument. Although the literature related to this topic is growing steadily, much of the scholarship is scattered and atheoretical. Moreover, researchers in music tend to concentrate on behavior and cognition as separate and somewhat unrelated theoretical topics to the exclusion of affect. We discuss these limitations and present a summary of literature that brings research-based evidence pertaining to behavior, cognition, and affect together into a coherent SRL framework. Current and future research priorities are then detailed as a means of outlining ways of maximizing music practice, teacher-student interactions, and efficient approaches to learning complex musical skills. Our final section summarizes the discussion and provides implications for how SRL might be adopted more widely in the music education domain.¹

Relevant Theoretical Ideas Underlying Musical Self-Regulated Learning

There are multiple reasons why SRL is relevant to studying music performance. Musicians spend hours practicing their instrument or voice by themselves and rehearsing with others, and unlike many other areas of academic learning, they typically do this because they have made a choice to study music, rather than being required to learn as part of a school curriculum (McPherson, Davidson, & Faulkner, 2012; McPherson & Zimmerman, 2002, 2011).

It is self-evident that being able to monitor and control one's learning is fundamental to the acquisition of the highest level of music performance skill. Yet despite this view, the area of instrumental and vocal performance is one of the most conservative domains of learning. It is dominated by teacher-centered pedagogy and a strong master-apprentice model in which a highly experienced music performer imparts his or her knowledge to a passive, receptive learner (Bennett, 2008). Indeed, there are many music performance teachers who are skeptical of the value of research and who view the processes of acquiring artistic expertise as too disparate or esoteric to study. Consequently, music teaching and learning processes are often characterized by a hierarchical and asymmetric pattern of interaction that can leave little room for students and teachers to discuss and reflect on the process, and few opportunities for input from the students (Creech & Gaunt, 2013; Young, Burwell, & Pickup, 2003). Such pedagogy compromises motivation and stifles practice quality, yet in many music environments, particularly at the tertiary levels, such approaches have remained largely unchanged and unchallenged for centuries.

A major distinction in music is that musicians do much of their personal skill development practicing in isolation, as compared to other areas such as sport, dance, and theater, where a coach or director provides informative feedback and well-defined tasks during frequent rehearsals or training sessions. In one-to-one studio sessions, teachers tend to focus on music techniques and interpretation of repertoire, rather than informative feedback regarding the student's hierarchy of goals, the strategies they are using, and how to monitor their progress towards goals. As a result, students do not explicitly learn how to practice. Accordingly, the practice quality of typical

music performance students is often poor because of their use of ineffective and unsystematic strategies. It is for this reason that we believe that SRL provides the best theoretical and applicable framework for understanding the context-specific set of processes that learners draw upon as they promote their own learning.

Yet another challenge in the music literature is the dominance of behavioral approaches to studying expert performance as a means of understanding the psychological mechanisms underpinning high-level performance and using this knowledge to inform the training of less advanced learners. To date, much of the literature on music practice has focused on either tracking the behaviors of musicians while practicing (Gruson, 1988, Gabrielsson, 1999; Miksza, 2006a; 2011b, Palmer, 2013) and the quantity of deliberate practice they engage in while practicing (Ericsson, Krampe, & Tesch-Römer 1993).

Initial theoretical efforts to apply the SRL framework examined the extent to which young music learners displayed the capacity to engage in the kinds of SRL processes that unsupervised home practice demands (McPherson & Zimmerman, 2002, 2011; McPherson & Renwick 2011). The first author framed much of these initial approaches to research in this area around Zimmerman’s (2000) six socialization processes that collectively explain a developmental pathway that beginning musicians experience as they progress during the early years of their learning. As can be seen in [Table 12.1](#), these six dimensions—motive, method, time, behavior, physical environment, and social processes—emphasized the kinds of support that young learners need from others before they can be internally regulated themselves.

Like the measurement of any artistic competence, assessing musical development and achievement is complex. Our early thinking about learners’ progress during the initial years of their instrumental lessons therefore focused on questions such as: What type of performance skills did the learners acquire and what differences distinguished successful versus unsuccessful learners? What were the learners thinking when they were performing music? What metacognitive strategies did they adopt to monitor their own performance and practice? We were also interested to understand how often the beginners needed to be supervised or encouraged to practice, and as they matured, the degree to which they became less dependent on others to regulate their practice.

[Table 12.1](#) Dimensions of musical self-regulation. Reprinted with permission from McPherson & Zimmerman (2002,2011)

Scientific questions	Psychological dimensions	Socialization processes		Self-regulation processes
Why?	Motive	Vicarious or direct reinforcement by others	→	Self-set goals, self-reinforcement, and self-efficacy
How?	Method	Task strategies are modeled or guided socially	→	Self-initiated covert images and verbal strategies
When?	Time	Time use is socially planned and managed	→	Time use is self-planned and managed
What?	Behavior	Performance is socially monitored and evaluated	→	Performance is self-monitored and evaluated
Where?	Physical environment	Environments are structured by others	→	Environments are structured by self
With whom?	Socialization	Help is provided by others	→	Help is sought personally

Research Evidence in Music

The theoretical ideas outlined above focused on the attributes music learners need to acquire in order to plan, monitor, direct, and regulate their own learning when practicing their instrument or voice by themselves. Research emanating from these approaches has helped to better understand how contemporary music teaching might be updated and redefined through the adoption of SRL. In this section, we review a range of our findings on SRL processes in instrumental music learning.

Research on Beginning Instrumentalists in Childhood and Adolescence

The first author’s empirical work on music-related SRL processes began with studying beginning instrumentalists in a range of different school music programs. This work traced children who began their instrumental learning around the ages of 8 and 9 and continued for another fourteen years until all had left high school and many had

completed university. Along the way, many of the children had ceased learning music but as they reflected back on their experience the impact of this learning provided valuable insights into their thoughts and feelings about having been a part of an elective instrumental program, and the value it played in their overall educational development.

From Other- to Self-Regulated Music Learner

As shown in [Table 12.1](#), a key aspect of the research examined how the children's musical development followed a simple linear trajectory of moving from other- to self-regulation as indicated by the initial support the children received from their teachers and parents. Our early estimates of the importance of other-regulation focused on the children's home practice, yet as we examined the data, we found some puzzling results. For example, we expected that children who continued learning would be those who were the most consistent and regular with their practice, which we defined at that time as the most self-regulated learners. However, what we found was that children who continued into the second year did not typically practice at the same time every day (McPherson & Davidson, 2002)—a habit that is often anecdotally positively associated with a more conscientious approach to instrumental practice. Our closer examination of the data showed that those children who practiced at the same time of the day were often doing so because they were receiving high levels of reminders and external encouragement or even coercion from their teachers or parents, as compared to initiating the practice by themselves as a result of their own internalized self-regulation.

This finding was supported by further evidence showing that the children whose parents used rewards to incentivize practice gave up earlier than their peers whose parents did not use such rewards (Faulkner, Davidson, & McPherson, 2010). Consistent with other studies on instrumental learning (Davidson, Howe, Moore, & Sloboda, 1996), differing kinds of parental support, such as gentle reminders, supportive comments, and informal checking of whether the child practiced his or her instrument each day, were seen as positively supporting the child's sense of autonomy. These could be compared to the more extrinsic motivators such as rewards or controlling and demanding interactions that apparently diminished the child's interest in learning an instrument (McPherson & Davidson, 2002; McPherson, 2009).

As we tracked children through their first year of learning, we observed changes in parents' support for music practice. Whereas many parents will continue to remind their children to complete their homework over many years, the support our learners received from their parents tended to decrease toward the end of the children's first year of learning (McPherson & Davidson, 2002; McPherson, 2009). Unfortunately, this is the very time the children needed ongoing encouragement to continue across the difficult period of adjusting to their instrument and gaining sufficient skill to continue into their second year of learning. We found also that some of their parents began to form judgments about their child's ability to cope with practice, as well as their own capacity to devote energy into regulating the child's practice through continual reminders and encouragement. Many parents therefore tended to withdraw their reminders, often because they felt that their child did not have a flair for learning music, was not investing the effort and commitment required, or because the parents were unwilling to invest their own personal time and effort into regulating their child's daily schedule. In other words, some of the parents had given up on their children much sooner than the children had given up on themselves (McPherson & Davidson, 2002; McPherson, 2009).

Task Strategies and Practice Behaviors

One initial attempt to understand SRL processes in music practice focused on the observable behaviors of beginning and intermediate level children from the early months of learning until three years later (McPherson & Renwick, 2001). The videos from this study of children practicing their instrument at home were analyzed according to practice content, the nature of performance errors and off-task behaviors, and interactions of family members. These early data collection techniques were important because they clearly documented low levels of self-regulatory behavior as evidenced in the children's lack of effective practice behaviors. Most of the students'

practice time was spent playing through pieces once or twice, with most errors being ignored or corrected by repeating one or two notes. Importantly, the self-regulatory processes used by the children varied widely thus providing important clues on why some music learners develop their performance skills quickly while others struggled.

As part of this longitudinal study, McPherson (2005) administered music performance tests at the end of each school year, across the first three years of their learning, to assess the beginning learner's abilities to perform rehearsed music, sight-read, play from memory, play by ear, and improvise. Ongoing interviews were also undertaken with the children's mothers in order to calculate how much practice they had accumulated on their instrument. During the process of assessing the music performance skills, the children were asked a series of questions that helped to identify the quality of task-related strategies they adopted to perform in each of the five ways.

The results of this study showed that understanding children's musical progress involves much more than simply examining the relationship between the amount of practice they have accumulated and their achievement on their instrument (McPherson, 2005; McPherson, Davidson, & Evans, 2016). Watching the children develop across the three years and analyzing their responses provided ample evidence that better players possessed more sophisticated mental strategies for playing their instrument very early in their development and that these players were the ones who went on to achieve at the highest level. Importantly, these were the most self-regulated players who knew when and how to apply their strategies (especially when asked to complete the more challenging musical tasks), possessed the general understanding that their performance was tied to the quality of their effort (particularly effort expended in employing appropriate strategies to complete individual tasks), and were able to coordinate these actions to control their own playing.

Motivation and SRL in Music Learning

Yet another aspect of research on this group of learners sought to understand why some students are more self-regulated than others. In one case study, the practice sessions of a 12-year-old clarinetist revealed stark differences between the intensity of her practice of repertoire assigned by her teacher as compared to a piece that she asked her teacher to learn (Renwick & McPherson, 2002; McPherson & Renwick, 2011). While practicing the piece assigned by her teacher, this student spent on average one second per note, almost exclusively using her 'default' play-through approach without stopping to work on errors. In contrast, while practicing a piece she had chosen herself, her time per note increased eleven-fold, and she was observed adopting more self-regulated, strategic behaviors, such as silently replicating the physical movements needed to play through passages, thinking carefully about upcoming measures before attempting to play them, deliberately slowing the music to grasp the actions necessary to play it, repeating sections, and stitching together short sections into longer, coherent sections. In this case, the student's more sophisticated practice of repertoire she chose was based on her desire to improve her playing and her determination to fully master the piece she wanted to learn. This result is consistent with findings showing that providing choice about what to work on and which method to use will increase intrinsic motivation and task involvement (Evans, 2015; McPherson, Davidson, & Evans, 2016).

The motivational climate seems to be an important antecedent for SRL and ongoing engagement with music. Students from homes where music was valued and seen as meaningful were more likely to value their music education and set higher musical expectations for themselves (McPherson & Davidson, 2002). In our longitudinal study, we studied the impact of school cultures that valued active, quality music programs, and found that over a ten-year period, students in these schools persisted with their music learning much longer before giving up (Evans & McPherson, 2015).

In parallel with this longitudinal study, work with other groups of music learners has sought to understand the importance of self-efficacy beliefs in demanding music performance situations. Music learners who were preparing for externally graded music performance examinations were surveyed before they undertook their performance examination. Structural equation modeling of two different populations showed that self-efficacy

was a strong predictor of the student's performance result in the examination, even more so than the amount of formal practice students devoted to preparing for their examination (McCormick & McPherson, 2003; McPherson & McCormick, 2006).

Research With Intermediate and Advanced Musicians

The research by McPherson and Evans within the Australian environment with children and adolescents has run in parallel to research in the United States by Miksza (2011a) focusing on more advanced students in high school and college. Miksza and colleagues have conducted observational studies of advanced (Miksza, 2006a, 2011b) and intermediate musicians practicing (Miksza, 2007; Miksza, Prichard, & Sorbo, 2012), as well as questionnaire-based studies investigating intermediate (Miksza, 2006b, 2011c) and advanced musicians' motivational dispositions and self-regulatory practice habits (Ersozlu & Miksza, 2015; Miksza & Tan, 2015). The work with intermediate musicians corroborates that of McPherson and colleagues in that beginning instrumentalists often reported or were often observed practicing with a lack of planning, direction, and self-monitoring. In contrast, the research dealing with more advanced musicians helped to identify the types of practice strategies (e.g., slowing, chaining, whole-part-whole playing) and motivation orientations (e.g., mastery and approach success) that seem to be most consistently associated with performance achievement and other indicators of self-regulation.

Miksza (2015) tested the effect of self-regulation instruction among advanced, collegiate instrumentalists. Participants were randomly assigned to a group that included video-based instruction in either (a) the application of practice strategies (slowing, repetition, whole-part-whole, chaining), or (b) self-regulation principles (concentration, goal-selection, planning, self-evaluation, rest/reflective activity) in addition to the aforementioned strategies. Pre- and post-test measures of performance achievement, self-efficacy, and practice behaviors were taken. The musicians' who received the self-regulation instruction showed greater gains in performance than those who did not. No significant differences were found between the groups' practice behaviors or self-efficacy reports. However, there was a fairly clear trend in the data suggesting that those who received the self-regulation instruction tended to feel more efficacious at the end of the study.

Most recently, Miksza, Blackwell, Roseth, and Cole (2016) examined the effectiveness of a pedagogical approach for enhancing advanced, collegiate music students' SRL tendencies by using a multiple-baseline experimental design with an intervention staggered across three participants. The intervention emphasized learning processes emblematic of the forethought, performance, and self-reflection phases described in Zimmerman's (2000) SRL process (Usher & Schunk, 2018/this volume). The intervention consisted of instruction in adaptive behavioral strategies and positive reframing of attitudinal beliefs. The behavioral strategies emphasized elements of practice highlighted in Miksza's (2006a, 2007, 2011b) previous work such as goal setting, repetition techniques, matching strategies to particular objectives, mental imagery, and mindful attention to focused activity. Attitudinal topics included degree of intrinsic interest for and value of practicing, personal appraisals of one's efforts, implicit theories of ability, response patterns when confronted with failure, attributions for success, and achievement goal orientations. The results of this study indicate that the intervention seemed to help the students develop a more sophisticated understanding of how to set goals, plan for practicing, and execute strategies in a deliberate manner. Overall, the participants were very forthcoming about how the personalized intervention increased their awareness of just how much care can be applied to developing a self-regulated practice approach. Given the research design employed, these findings cannot be generalized and must be considered tentative. Conducting research with more rigorous, true-experimental designs would help to assess whether interventions of these sort could lead to robust effects.

Autonomy Supportive Learning Environments

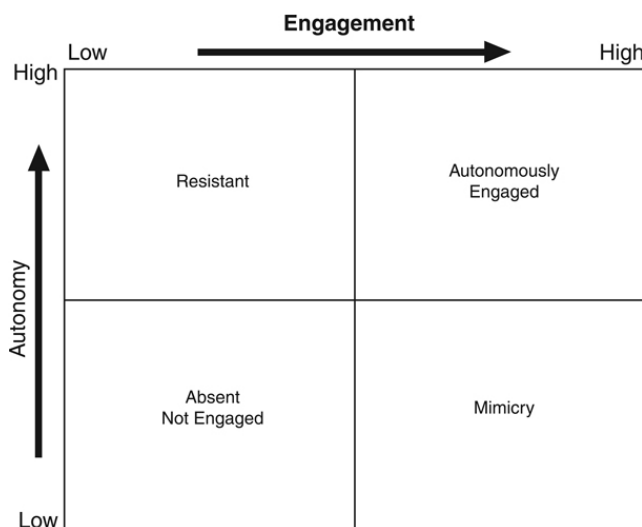
Autonomy has been examined as an important motivational antecedent to the use of SRL strategies in music (Evans, 2015). Autonomy is central in a young music learner's musical development where the social context plays an important role in development and where teacher's autonomy support is associated with positive

outcomes in learners. Studies with certified Suzuki-trained teachers (Küpers, van Dijk, van Geert, & McPherson, 2015) have sought to explore what types of teacher-student interactions best foster autonomy supportive learning and might best lead to higher engagement by the beginning music learner. ‘Engagement’ in this context may be considered as a conceptualization of SRL, as it was operationalized in this study as behavioral involvement in the lesson, help-seeking through asking the teacher questions and verbally interacting with the teacher, and showing initiative and creativity in the lesson. Student states in string instrumental lessons were coded according to levels of autonomy and engagement. The relationship between autonomy and engagement was configured using a four-quadrant representation as shown in [Figure 12.1](#):

1. Autonomous engagement (high autonomy and displaying SRL). Used to describe instances during the lesson where the student would take on-task initiative by asking questions or making relevant on-task remarks.
2. Resistance (high autonomy and negatively engaged). Used to describe instances during the lesson when students were actively resisting the task, by saying, for example, ‘I don’t want to do this,’ or by making off-task remarks such as ‘I’m going to the playground later.’
3. Mimicry (low autonomy and positively engaged). Used to describe instances during the lessons when student would be ‘going with the flow,’ merely doing what was expected by the teacher and not displaying their own SRL.
4. Absence (low autonomy and negatively engaged). Used to describe instances during the lesson when the student was not engaged with the task, would not answer teacher questions, but also not be actively resisting what was being taught.

(see Küpers, van Dijk, van Geert, & McPherson, 2015, pp. 340–341)

Using the above framework resulted in the observation of large differences in the dyadic transactions between students higher in autonomy and those lower in autonomy. We also observed instances where autonomy support was ‘negotiated’ between teacher and student, where the autonomy support and autonomy expression levels of both the teacher and student were well coordinated, and moments where there were large discrepancies. We describe this relationship as co-regulation (see also Hadwin, Järvelä, & Miller, 2018/this volume). These results led to an exploration of the function of the dyadic synchrony in autonomy levels and the conclusion that maintaining momentum in the learning process depends in part on interactions where a teacher offers autonomy support at a higher level than the student’s current level of autonomy. A key point is that there is no single approach that will work for every learner, and that autonomy development and the techniques teachers use to provide autonomy support need to be tailored to each individual student. Further research will also need to understand more fully the moment-to-moment synchronicity in teacher-student interactions and how moderate amounts of asynchrony might actually challenge, stimulate, and propel a student to higher levels of engagement.



[Figure 12.1](#) Four quadrants of student states of autonomy

(Reprinted with permission from Küpers, van Dijk, van Geert, & McPherson, 2015, p. 341)

Future Research Directions

The streams of work reported above in Australia and the United States are now coming together as part of a program of research that connects SRL with self-determination theory (Ryan & Deci, 2000; Evans, 2015). The research agenda examines motivation and practice quality in musicians who are majoring as performers in undergraduate music degrees and is focused on the types of research issues described below.

Our conceptual approach attempts to explain the complex relationships between motivation (operationalized as self-determined motivation), practice quality (operationalized as SRL), and performance outcomes as they unfold over time. The innovative aspect of this approach is that we are using self-determination theory to study how musicians' psychological needs and feelings of competence, relatedness, and autonomy impact their overall levels of motivation to become competent in music in combination with SRL. The self-determination theory framework can help explain how particular aspects of the music-learning environment can be problematic for learners: competition, anxiety, poorly-defined personal goals, and the teacher-centered approach to instruction so typical of the music studio environment at these levels. Evans and Bonneville-Roussy (2016), for example, found that university music students with self-determined motivation reported better, more productive practice. Bonneville-Roussy and Bouffard (2014) also found that when practice quality (self-regulated practice) was taken into account, it predicted achievement much better than considering the amount of weekly practice alone. It seems feasible therefore that practice quality—operationalized as musical SRL—may be predicted by self-determined motivation.

Another advantage of the SRL framework is that it covers the cognitive, affective, and behavioral processes involved when musicians plan their practice, approach difficult or novel tasks, master new repertoire and techniques, and reflect on their progress. Previous research on music practice has tended to focus either on cognitive, behavioral, or affective aspects of practice, without accounting for all three dimensions together. For example, a typical research strategy is to observe and then record the accuracy of the practice or map out how musicians document and reflect on their individual practice using self-report questionnaires, interviews, and journals of practice over time. But the limitation of this is that it does not have the theoretical and conceptual framework that SRL offers to be able to understand why particular strategies may or may not be effective. One technique we are using to approach these issues is microanalysis (see further Cleary & Callan, 2018/this volume). We are in the process of applying SRL microanalysis to gain an understanding of the cognitive, affective, and behavioral processes involved when students practice their instrument or voice. Microanalysis is “a strategic, coordinated plan of administering context-specific questions targeting multiple cyclical phase sub processes as students engage in authentic activities” (Cleary, Callan, & Zimmerman, 2012, p. 4). As such, it is a powerful way to examine SRL because it targets the full range of SRL processes and avoids the limitations of retrospective self-report measures that regard SRL as a generic, rather than context-specific, set of processes.

Our approach to microanalysis involves asking questions immediately before musicians commence a practice session, and then replaying a video of the practice session which the musician has just completed and asking brief context-specific questions for them to explain what they were doing, thinking, or feeling. The videos are used to avoid intruding on the lesson and manipulating the particular SRL strategies used by the learners. The use of videos in this way reflects a kind of stimulated-recall methodology (Calderhead, 1981), where video or audio is used to allow participants to ‘relive’ certain aspects of their experiences. The method thus maximizes the benefit of ecological validity by not intruding in the learning process itself, but somewhat overcomes the limitations of retrospective recall by providing a rich stimulus for more accurate recall. Videos of the microanalysis are also analyzed and coded according to the fore-thought, performance, and reflection cycles that occur during the practice sessions. This work (McPherson, Osborne, Evans, & Miksza, submitted) aims to extend our previous

studies that have attempted to understand the self-regulatory processes of beginning and intermediate level musicians.

Self-Regulated Learning Interventions in Music

Yet another area of our collaboration will utilize intervention studies to examine whether explicit instruction in motivation and practice quality can deliver lasting changes across time. Specifically, we are interested in examining whether targeted instruction can have a lasting effect on student motivation and practice quality. Part of the motive for undertaking this type of research is to help music teaching evolve from the longstanding conservative master-apprentice tradition that pervades much one-to-one instrumental and vocal teaching. Our future work therefore seeks to determine ways of introducing concepts and better teaching practices to musicians who teach in university music schools.

Education-based research interventions show that teachers appear to be able to effectively learn how to adapt to a student-centered environment, and provide more autonomy-supportive environments for their students, even when they may otherwise be resistant to such ideas (Su & Reeve, 2010). Our own anecdotal experience with students undertaking university pedagogy courses shows that trainee instrumental and vocal teachers are quick to accept student-centered environments, even though the master teachers with whom they are taking music lessons appear to be far less willing to change their teaching strategies. The same may apply for the explicit teaching of SRL strategies.

Miksza, McPherson, Herceg, and Meider (in press) have written specifically on the benefits of applying SRL theory to beginning and intermediate levels of instrumental music pedagogy. This work represents a collaboration between researchers and current school music teachers and includes descriptions of two exemplar music lessons for systematically introducing and reinforcing SRL principles among developing musicians. In both cases, the teachers describe methods that encourage the students to become autonomous learners via clear sequencing, peer-based activities, reflective exercises, and care for developing efficacious and adaptive motivation dispositions.

Overall, our core research aim is to understand how motivation and practice quality facilitate the acquisition of expert music performance skills. Our current belief is that there is a cyclical relationship between the two and that in music learning influences will occur in both directions where self-determined motivation is likely to facilitate self-regulatory strategies being spontaneously implemented, and in turn, self-regulatory strategies will fulfill basic psychological needs and facilitate self-determined motivation. In a study of a mathematics classroom, for example, students who were taught only self-regulatory skills showed declines in achievement, but those who were taught self-regulatory skills plus motivational strategies improved their achievement (Blackwell, Trzesniewski, & Dweck, 2007). Building on from our previous research, the proposed project will be the first to investigate these possibilities in the domain of music.

Conclusions

Surveyed within this chapter are some recent theoretical developments in SRL as applied to learning a musical instrument or voice. In the earlier sections we discussed research by the authors that has applied SRL theory. Subsequent sections documented (a) our current research which attempts to encourage innovation through the adoption of SRL theory, and (b) our more recent and ongoing collaborative efforts to combine this with self-determination theory to better understand music practice quality and motivation.

Research that clarifies more precisely how students develop into self-regulated musicians deserves special attention from music scholars who wish to draw upon and integrate some of the major developments in education into their own research. Adapting and expanding current theories on this issue and drawing on and integrating information from other areas of educational psychology will enable music researchers to develop more sophisticated theories of musical development that can be used to underpin future teaching and learning in music.

Most areas of education are slow to adapt to changing views that are based on research evidence, and this is particularly prominent in music education. Only when evidence-based approaches are sufficiently developed and presented to musicians and music educators in ways they can easily understand will the profession be convinced of the benefits for adopting different techniques for engaging learners and encouraging them to take charge of their own music learning in a self-regulated fashion. As part of this transition, it will undoubtedly be challenging to move from teacher-dominated methods of instruction where the ‘master teacher’ is seen as the most important source of knowledge, and where skill acquisition through repeated, habitual practice is the norm, to more learner-oriented styles of teaching. However, the rewards of adopting SRL to guide, frame, and motivate music learning have now become obvious. And for us, ingredients that enable optimized learning, including an intellectual curiosity and emotional engagement with the music being learned, blossom most effectively when learners are able to take control of their learning in the ways described in this and other chapters within this volume.

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Note

[1](#) The first-person ‘we’ and ‘our’ throughout the chapter refer to any or all authors of the chapter and our colleagues as indicated in citations.

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13 Self-Regulation in Athletes

A Social Cognitive Perspective

Anastasia Kitsantas, Maria Kavussanu, Deborah B. Corbatto, and Pepijn K. C. van de Pol

Introduction

Acquiring expertise in sport requires high levels of self-regulation and self-motivation (Kitsantas & Kavussanu, 2011). Elite athletes and coaches often mention self-regulation as one of the most important factors for their success. For example, top college football coach Lou Holtz said “Without self-discipline, success is impossible, period.”¹ Similarly, researchers and practitioners have focused their attention on gaining a better understanding of athletes’ self-regulatory functioning in sport, exercise, and physical education contexts (Gaudreau, 2014). In this chapter, we describe key processes of athletes’ self-regulation from a social cognitive self-regulatory perspective (Usher & Schunk, 2018/this volume; Zimmerman, 1989). We use the term ‘self-regulation in sport’ to refer to self-initiated thoughts, feelings, and actions that athletes use to attain various goals (Zimmerman & Kitsantas, 2005). First, we review a social cognitive cyclical model of self-regulation that describes key self-regulatory processes and motivational beliefs. Second, we discuss empirical studies that have examined athletes’ key self-regulatory processes (e.g., goal-setting, goal orientation, self-monitoring, and self-evaluating) and coach influences such as motivational climate on athletes’ self-regulatory functioning. Third, we discuss implications for practice regarding how to enhance learning and performance in sport using social learning experiences. Finally, we provide directions for future research.

A Social Cognitive Perspective of Self-Regulation in Athletes

Zimmerman (2000) developed a social cognitive model of self-regulation that includes motivational beliefs and cognitive processes in three cyclically interrelated phases: forethought, performance, and self-reflection. The forethought phase precedes athletes’ engagement in a task and includes task analysis processes (e.g., goal setting and strategic planning) and motivational beliefs (e.g., self-efficacy, task value, goal orientation) that facilitate athletes’ preparation and motivation to engage in self-regulated learning. Elite athletes and coaches often comment on the importance of these forethought processes. For example, former top tennis player Chris Evert stated “You’ve got to take the initiative and play your game. In a decisive set, confidence is the difference,” whereas football coach Homer Rice commented on the importance of self-motivation in learning and performance: “You can motivate by fear, and you can motivate by reward. But both those methods are only temporary. The only lasting thing is self-motivation.”

In the performance phase, athletes are actively involved in learning a task, observing their performance, and using strategies to facilitate the attainment of their goals. During this phase, an athlete uses strategies such as imagery, help seeking, self-instruction, and self-observation techniques such as self-recording. “When you record your training, it crosses the line between being casual or serious about the sport,” says Roisin McGettigan, an Irish track-and-field athlete. She also stated: “I was able to track my progress, learn what worked and what didn’t. I could figure out why I was tired and see if I over- or under-estimated my training.” It is important to note that the effectiveness of these strategies depends on how well an athlete engages in self-observation.

The self-reflection phase involves processes that follow learning and/or performance efforts, for example self-judgment and self-reactions. Self-judgment refers to self-evaluation and attributions, while self-reactions are self-satisfaction/affect or adaptive inferences (e.g., athletes engage in goal adjustment based on outcomes) and defensive inferences (e.g., athletes engage in procrastination or task avoidance). It is in this phase that athletes judge their performance and assign causes to their outcomes based on prior self-monitored data. For instance, a baseball pitcher, who is struggling with his command (e.g., consistently missing the strike zone) may reflect on his performance and attribute his failure to the mechanics of his delivery (e.g., the wind up, the leg kick) instead

of internalizing the failures in terms of being ‘a bad pitcher’. Self-reflection phase processes, in turn, influence forethought phase processes. For example, if a volleyball player keeps failing to score on a serve, she may begin to doubt her serving capability and may feel the need to review her technique and engage in more practice episodes. This phase completes the self-regulatory cycle of learning and influences subsequent efforts to learn and perform (e.g., goal adjustment, strategy selection, etc.).

Self-regulated learning in sport can be summed up with a quote from Brittany Bowe, an American Olympic speed skater, who stated: “You have to be a student of the game to be successful, and it’s promising when you can say that with a world-record performance, I still have things to improve on!” Indeed, expert athletes create self-oriented feedback loops to monitor the effectiveness of strategies and to adapt their functioning to maintain and improve performance outcomes.

Research on Self-Regulated Learning and Performance in Sport

There is extensive research evidence that athletes use a broad array of self-regulatory processes (Kitsantas & Kavussanu, 2011; Kitsantas & Zimmerman, 2002). In this section, we review pertinent research on the effectiveness of key self-regulatory processes across the three cyclical phases of self-regulated learning and performance, described in the previous section.

Forethought Phase

Goal Setting

Goal setting refers to identifying intended actions or outcomes. A number of studies have demonstrated that setting specific rather than general goals, short-term rather than long-term goals, and self-generated rather than assigned goals is more beneficial for learning and performance in sport (e.g., Kolovelonis, Goudas, Dermitzaki, & Kitsantas, 2013; Kitsantas & Zimmerman, 1998). In addition, moderately difficult rather than easy goals are the most effective goals in increasing achievement and motivation (Locke & Latham, 1990). Finally, process goals, which require athletes to focus on the processes (steps) rather than the end result promote athlete attention to detail and produce better performance compared to outcome goals, which focus purely on the end result (Zimmerman & Kitsantas, 1996, 1997).

Premature focus on outcomes before a skill is fully mastered increases the cognitive complexity of a skill and has a negative impact on motivation (Zimmerman & Kitsantas, 1996, 1997). Effective learning and performance best occur when one initially concentrates on process goals, then switches to an outcome goal when the task becomes automatic. For example, in an experimental study, where students were assigned to three experimental conditions (outcome goal, process goal, and a shifting process-outcome goal condition), participants who shifted from process to outcome goals outperformed students who maintained their process goal after reaching automaticity. These findings suggest that athletes should use both process and outcome goals depending on their phase of learning (Kitsantas & Zimmerman, 1998; Zimmerman & Kitsantas, 1997).

Goal Orientation

The best motivation always comes from within.

—Michael Johnson (Gold Medal Sprinter)

Achievement goal orientation, a central construct in achievement goal theory (Ames, 1992; Dweck, 1996; Nicholls, 1989), has received a lot of research attention in relation to self-regulation in the athletic domain. Two major achievement goals operate in sport and involve variation in the definition of competence and the criteria one uses to evaluate success. The terms task, learning, and mastery have been used by Nicholls (1989), Dweck (1996), and Ames (1992), respectively, to refer to a goal in which an individual strives to develop competence

and evaluates success using self-referenced criteria (e.g., learning, task mastery). The terms ego, performance, and ability have been used by these theorists to refer to a goal, where one strives to demonstrate competence and evaluates success using other-referenced criteria (e.g., winning).

Several studies have examined goal orientation in relation to self-regulation processes in physical activity contexts. Theodosiou and Papaioannou (2006) found that task orientation was a positive predictor of self-monitoring and evaluation, whereas ego orientation was unrelated to self-monitoring, in physical education students. Elite young athletes characterized by a high task/high ego profile used imagery more often than those characterized by a low task/moderate ego and moderate task/low ego profile (Harwood, Cumming, & Hall, 2003); in a second sample of elite athletes, those in the high task/moderate ego group reported more frequent use of goal setting, self-talk, and imagery compared to the low task/high ego and moderate task/low ego groups (Harwood, Cumming, & Fletcher, 2004). Finally, in an experiment involving undergraduate student athletes (Gano-Overway, 2008), participants in the task-involving condition (i.e., focus on improving their reaction time), used collectively more self-regulation strategies (i.e., planning, monitoring, goal setting, task strategies, and self-evaluation) while performing a novel computer reaction-time task, compared to those in the ego-involving condition (i.e., focus on outperforming others). These results suggest that task orientation is the critical goal in influencing the use of self-regulatory processes in athletes, but a high ego goal may have complementary benefits.

More recently, researchers have examined whether achievement goals differ as a function of the context, namely training and competition. Organized training (i.e., training sessions under supervision of a coach) is central to athletes' sport lives, as this is the context where they spend a vast amount of time to develop their skills, particularly at the elite level. Organized competition is an integral part of sport, which by nature involves social comparison. Several studies have shown that ego orientation is higher in competition than in training, whereas task orientation is more stable across the two contexts (van de Pol & Kavussanu, 2011, 2012; van de Pol, Kavussanu, & Ring, 2012a).

This line of research has also investigated the effect of context on the relationship between goal orientations and self-regulation strategies. In the first study to examine this issue, van de Pol and Kavussanu (2011) found that task orientation was positively related to goal setting and self-talk in both training and competition and attentional control in competition; ego orientation was unrelated to these strategies in either context. Task orientation was also positively associated with effort and perceived improvement in training as well as with perceived performance in competition. Finally, an interaction effect emerged, whereby ego orientation was linked to effort in competition, when athletes had low or average levels of task orientation. These findings suggest that athletes, who tend to evaluate success using self-referenced criteria, are more likely to use self-regulation strategies not only when they practice but also when they compete. These athletes are also more likely to try hard in both contexts. However, when athletes' task orientation is low or average, ego orientation may be beneficial for effort in the competition context.

In a recent experiment, van de Pol, Kavussanu, and Ring (2012b) created training and competition conditions in the laboratory. Participants—tested in pairs—were told that the purpose of the (training) session was to learn and improve the skill of golf putting, were given instructions on how to put a golf ball, practiced six blocks of ten putts each, and then they performed ten putts in a zero-sum competition condition. 'Zero-sum competition' involves a competition in which athletes compete against each other on a 'winner-takes-all' basis, i.e., one person/team either wins or loses (Stanne, Johnson, & Johnson, 1999). Ego involvement increased and task involvement decreased as participants moved from training to competition. Although ego involvement positively predicted effort and enjoyment in both conditions, the effect of ego involvement on these variables was augmented when task involvement was also high. Participants who scored higher in ego involvement performed better in competition. Thus, once a task has been mastered a motivational focus on an ego goal in competition may benefit performance.

Another line of research investigating the role of achievement goals on emotions has shed more light on the role of task and ego goals on achievement-related outcomes. In one study (Dewar & Kavussanu, 2011), golfers who

reported being task involved were more likely to also experience happiness and excitement, and less likely to feel dejection during a round of golf. In addition, when they perceived that they had performed poorly, the greater their ego involvement, the less happy and more dejected they were. Thus, ego involvement could lead to negative emotions when one performs poorly. In a second study of team-sport athletes (Dewar & Kavussanu, 2012), ego involvement positively predicted hope when perceived performance was high and dejection when perceived performance was low. Task involvement was positively related to happiness, pride, and hope, and negatively related to dejection and shame. These results suggest that task involvement is a robust predictor of positive emotions, whereas the relationship between ego involvement and emotions depends on how athletes perceive they have performed.

The findings discussed in this section underline the significance of adopting a task goal when one learns and performs motor skills, as it appears to be the most adaptive goal facilitating a variety of self-regulation strategies and achievement-related outcomes. The overall findings pertaining to an ego achievement goal are somewhat more complex. A combination of high task and high ego seems to be the most beneficial goal profile to adopt in competition, particularly concerning effort and performance. However, ego orientation may predispose athletes to experience negative emotions when they do not perceive they performed well, which may influence their self-regulatory functioning.

Self-Efficacy

Self-efficacy refers to “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 3). There is extensive evidence that athletes’ self-efficacy influences their motivation to initiate and sustain self-regulatory functioning. This construct influences many self-regulatory processes such as goals, task strategies, and self-reactions. For example, athletes reporting high self-efficacy are more likely to set challenging goals and search for strategies that will help them accomplish these goals compared to those with low efficacy (Kitsantas & Zimmerman, 2002, 2006). Self-efficacy has also been linked to sport performance, with a moderate relationship reported in a meta-analysis of 45 studies (Moritz, Feltz, Fahrback, & Mack, 2000). More recently, Halper and Vancouver (2016) examined the effects of Division I college football players’ self-efficacy beliefs on their squat performance, measured at three points in time. Multi-level analysis showed that athletes’ self-efficacy was positively related to squat performance, both at between-person and within-person levels of analysis (while controlling for past performance). These findings provide evidence that athletes’ self-efficacy is positively associated with their performance in sport.

Performance Phase

Self-Monitoring

A key process in the performance phase of self-regulation is self-monitoring, which refers to observing and tracking one’s own performance. Self-recording, a form of self-monitoring, in sport can greatly assist self-monitoring because it can increase the proximity and accuracy of feedback (Zimmerman & Kitsantas, 1996, 1997). In a study of students initially learning to throw darts, participants who engaged in self-monitoring (e.g., kept records of their performance) were more successful in learning to throw darts and reported greater motivation than the groups who did not self-monitor (Zimmerman & Kitsantas, 1996).

There is evidence that highly self-regulated learners use self-recording more often than poorly self-regulated athletes. Kolovelonis, Goudas, and Dermitzaki (2011) examined the effects of self-recording, along with goal types (process, performance, outcome, and multiple goals) in 105 fifth and sixth graders using a dart-throwing task. Self-recording had a positive effect on students’ performance of a new skill. Using self-recording during practice allowed them to compare their own performance with their goals; however, self-recording had no effect on their satisfaction with learning the new skill. Overall, these findings suggest that when teaching a sport skill, self-recording should be used as an aid to improve learning.

Adaptive help seeking involves approaching experts, such as coaches, to request assistance with one's learning. It involves seeking specific assistance to correct flaws in one's performance and is limited in duration. Help seeking is an important part of the self-regulation process because the learner needs to determine whether help is necessary, decide whether to seek help, the type of help and from whom, and solicit, obtain, and process whether the help received will enable them to achieve their goal (Karabenick & Dembo, 2011). A supportive social environment may allow learners to seek help, knowing that a strategy can lead to success. Research related to athletes and help seeking is limited. However, evidence suggests (Durand-Bush & Salmela, 2002) that Olympic and world championship athletes report that help is critical and they seek help not only from their primary sport coach, but from other professionals such as strength and conditioning coaches, sport psychologists, athletic trainers, and nutritionists. Thus, help seeking is an important self-regulatory process and may have implications for athletic performance.

Self-Reflection Phase

Self-Evaluation

Self-evaluation refers to using standards to make self-judgments about one's performance. Athletes evaluate their performance based on standards from previous performances (e.g., comparing current with previous performance), mastery goals (use a sequence of steps that leads to the outcome), and performance of other competitors. Kitsantas and Zimmerman (2006) examined whether graphing performance in combination with self-evaluation influenced dart-throwing performance. They found that novice learners, who graphed their performance and evaluated their outcomes based on graduated or hierarchically set standards significantly improved their dart-throwing skills and experienced more positive motivational beliefs than students who did not graph and evaluate their outcomes on graduated standards.

Closely linked to self-evaluation are the attributions athletes make for their errors. Attributing errors to strategy deficiency sustains motivation when performance outcomes do not meet desired standards (Zimmerman & Kitsantas, 1997, 1999). Self-evaluative and attributional judgments lead to different types of self-reactions. Two forms of self-reactions have been explored: satisfaction and adaptive inferences, which direct athletes to sustain or change their self-regulatory processes, and defensive inferences, which may lead to apathy, procrastination, and task avoidance. Highly self-regulated athletes make adaptive inferences, such as re-examining the effectiveness of their strategies, whereas poorly self-regulated individuals report defensive inferences, which serve primarily to protect them from future dissatisfaction (Zimmerman, 2000; Kitsantas & Zimmerman, 1998).

Research on Coaching Influences on Self-Regulated Learning and Performance

Training in Key Self-Regulatory Processes

Coaches can play a key role in supporting and promoting athletes' self-regulatory functioning. From a cyclical perspective of self-regulation (Kitsantas & Zimmerman, 2002; Zimmerman & Kitsantas, 1996, 1997), athletes acquire skills in four sequential levels: observation, emulation, self-control, and self-regulation (Zimmerman & Kitsantas, 2005). At the observational level, the coach models and describes a specific strategy that will assist the athlete to improve athletic skills. Then, the coach asks the athlete to emulate the model's strategy and provides him or her with corrective feedback and praise. Once the strategy related to a specific sport skill is mastered, at the self-control level, the coach slowly withdraws support and asks the athlete to practice on his or her own in a controlled setting using the strategy and process-oriented standards. Finally, at the self-regulated level of skill acquisition, the athlete is asked to focus on outcomes and adjust his or her performance as needed. At this level, an athlete's functioning continues to depend on the coach.

This multi-level model of self-regulation has been tested in many studies (e.g., Kitsantas, Zimmerman, & Cleary, 2000; Zimmerman & Kitsantas 1996, 1997). In a recent study with fifth and sixth grade students, Kolovelonis

Goudas, Dermitzaki, and Kitsantas (2013) used this model as a method for teaching basketball dribbling. Findings showed that students improved their basketball dribbling when they progressed through the levels of the model providing support for the use of the four-level model in developing novice learners' sport skills. However, we do not know whether the findings can be replicated in elite athletes using a longer intervention.

Research comparing expert, novice, and non-expert athletes also provides evidence for how coaches can structure the learning environment to foster self-regulation. Cleary and Zimmerman (2001) found that expert basketball players displayed higher levels of self-efficacy, set more specific goals, used more process-oriented strategies, and attributed failure to strategy more so than did non-expert and novice athletes. Similar findings were revealed in a study of volleyball players (Kitsantas & Zimmerman, 2002). It may be that experts display higher levels of performance because they engage in more effective self-regulatory processes than non-experts and novices. Similarly, Walsh (2012) stressed that from a purely operational perspective, as athletes' skill level improves, the feedback and instruction should be pared down, allowing them to master the exercise using more self-regulatory strategies.

Researchers have also investigated coaches' abilities to assist their athletes in their self-regulatory processes. Collins and Durand-Bush (2014) implemented an intervention based on Zimmerman's social cognitive model of self-regulation (Zimmerman, 2000) with one coach and one elite international curling team. The coach delivered eight 90-minute intervention sessions to his team along the themes of awareness, control, and adaptation of behaviors and goals. Results indicated that the coach used multiple strategies to assist the athlete with preparation for competition (forethought phase), such as intrinsic/autonomous goal setting and strategic planning. During the performance phase, coaches had much less influence on the athletes' self-regulatory skills, but they could help the athletes track their progress and give feedback and attention-focusing encouragement. In the self-reflection phase, the coach helped the athletes digest their statistical data, suggested corrective strategies, and guided them in finding solutions for issues that arose during performance. This study provides support for the role a coach can play in assisting their athletes using self-regulatory strategies.

Smith, Ntoumanis, and Duda (2010) asked regularly training athletes at the beginning of their season to select a personal sport goal to work toward and to indicate whether the goal was self-generated, whether they had a strategy to achieve it, the extent to which their coach supported their goals (i.e., was autonomy supportive versus controlling). Participants were retested at the mid-point and the end of their season. Athletes' perceptions of their coaches' support for their autonomy and participation in training decisions were positively associated with autonomous goal motives, whereas athletes who perceived their coaches as controlling also adopted controlled goal motives. The findings of this study suggest that coaches should avoid the use of controlling behavior such as reprimanding athletes for performing below the coach's expectations, as this could negatively affect the athletes' motivation. By nurturing the motivation of an athlete (e.g., by allowing some choice about the training, giving rationale for practice tasks, and giving clear, non-critical feedback) the coach can provide an environment that may have a favorable influence on athletes' motivation and performance.

Researchers also argue that what matters the most is the ability to strategically retune a goal (e.g., Smith & Ntoumanis, 2014). Smith and Ntoumanis (2014) examined the role of goal motives (i.e., autonomous or personal internal goals vs. controlled or external goals) in predicting self-regulatory responses to unattainable goals in athletes. Goal motives could forecast how easy it is for the athlete to disengage from the sport goal and reengage in an alternative goal. This is important for an athlete when a goal becomes unattainable, as failure can be psychologically damaging to the athlete and their performance if they are not able to disengage from this unattainable goal and reset a more realistic goal. Overall, the findings suggest that it is critically important to examine athletes' motives and behaviors when they have trouble meeting a goal. That is, coaches might facilitate awareness of the unachievable goal and help the athlete develop a strategy for disengaging from the goal and shifting to an alternative attainable goal.

Motor learning and performance typically occur in group settings. In these settings, the coach or physical education teacher plays a vital role in influencing participants' self-regulation and motivation. The main aspect of the coaching environment that has been examined in relation to self-regulatory processes and motivational beliefs is the motivational climate of the team. Motivational climate is a term coined by Ames (1992) to refer to the achievement goals that are salient in the achievement context and is created by significant others such as physical education teachers, coaches, and parents. These individuals structure the achievement context in a manner that conveys to participants the criteria for success through the evaluation procedures, the distribution of rewards, the type of feedback they provide, and other means. A mastery climate is evident when success is defined as individual progress, every person has an important role, and the focus is on skill improvement and development. A performance motivational climate is salient when success is defined in normative terms, the top athletes typically receive the most recognition from the coach, and the emphasis is on how one's ability compares to that of others (Ames, 1992).

Several studies have shown a clear link between mastery climate and the use of self-regulatory strategies and intrinsic interest in physical education. Theodosiou and Papaioannou (2006) found that mastery climate was positively related to self-monitoring and evaluation, while performance climate was unrelated to self-monitoring and was weakly related to evaluation. Ommundsen (2006) showed that mastery climate positively predicted meta-cognitive self-regulation, regulation of effort, and adaptive help seeking. The effects of mastery climate on help seeking were mediated fully by task orientation, while the effects on meta-cognitive strategies and effort regulation were partially mediated by this variable; this suggests that mastery climate may have positive effects on self-regulation in part because it enhances task orientation. Performance climate was a positive but weak predictor of meta-cognitive regulation. Finally, physical education students who perceived a mastery climate in their class were more likely to concentrate better in their physical education lesson (Papaioannou & Kouli, 1999).

Motivational climate has also been associated with adaptive motivational beliefs and affective reactions. Undergraduate university students enrolled in tennis classes who perceived a high mastery climate in their class reported significantly more intrinsic interest in the activity and exerted more effort compared to students who perceived a low mastery climate in their class (Kavussanu & Roberts, 1996). Interestingly, female—but not male—students who perceived a mastery climate in their class were more likely to report high self-efficacy. These females also had low perceptions of ability. Perhaps a mastery motivational climate is most beneficial for those individuals (i.e., females) who tend to doubt their physical abilities (Kavussanu & Roberts, 1996).

Motivational climate has also been investigated separately in the contexts of training and competition. Van de Pol, Kavussanu, and Ring (2012a) asked football players to complete questionnaires measuring perceived motivational climate, effort, enjoyment, and tension in these two contexts. Participants who perceived a mastery motivational climate in their team reported more effort in training, and more enjoyment in training compared to competition. It is worth noting that both effort and enjoyment were higher in competition than in training, which may explain these findings. That is, a mastery climate appears to be more beneficial during training, where athletes' enjoyment and effort are not as pronounced as they are in competition, making it even more important that coaches create a mastery climate in training. Performance climate was negatively associated with effort, and positively associated with tension, in both contexts.

A robust finding of the studies reviewed above is the positive link between mastery climate and self-regulation processes as well as motivational beliefs. This finding suggests that creating a teaching or coaching environment that focuses on individual learning and personal success could lead learners to set more effective goals, monitor and evaluate their performance, but also regulate their effort, seek help, and seek feedback to improve their skills. This climate may also lead to more satisfaction with performance and enjoyment of the activity and greater concentration. In contrast, performance climate does not have consistent effects on self-regulation.

Future Research Directions

In this chapter, we reviewed research emphasizing the importance of engaging athletes in self-regulated learning. We also discussed how self-regulatory functioning can vary from training to competition and the role of the coach in this process. In this section, we offer some directions for future research.

First, more research should be conducted on self-regulation in training and competition contexts. Goals represent an important aspect of self-regulation as they provide a clear picture of situation-specific strategies that individuals plan to use as well as the outcomes they seek to attain. Although recent research suggests that athletes may functionally adjust their goals in the context of training and competition (van de Pol, Kavussanu, & Ring, 2012b), it may be valuable to examine this issue from a self-regulation perspective, and in particular, how contextual motivational processes can be integrated into the cyclical model as proposed by Zimmerman (2000).

Second, the integration of technology is exploding in sport, particularly in the area of self-monitoring. Currently, athletes can monitor their physiological responses such as heart rate or maximum oxygen uptake through wearable apparel. They can measure their mental processes through applied biofeedback such as brain wave (quantitative EEG) measurement. And they can work on their motivation through apps on their phone. The integration of technology into the self-regulated learning platform is an area for future research.

Third, very few research studies have focused on coaches' self-regulatory functioning. Coaches can also employ self-regulation, and as they become aware of the impact self-regulated learning can have on performance, they can begin to apply this knowledge to their own coaching techniques and reflective processes. More research is needed in this area as the use of self-regulated learning processes in coaches may affect athletic performance. Finally, researchers could conduct qualitative studies to better understand self-regulatory processes that are specific to the context of sport, and based on these findings develop instruments to assess self-regulatory functioning in athletes.

Nurturing Athletes' Self-Regulation in Training and Competition: Implications for Practice

Rafael Nadal, after his first-round loss against Fernando Verdasco at the Australian Open 2016, stated: "Today I was not ready to compete the way that I was practicing, so not happy with that. That's it." Athletes continuously move between training and competition, and they may need to adapt their achievement goals to adapt to these contexts. A self-regulated athlete functionally adjusts his/her goals to these contextual affordances to obtain desirable outcomes such as skill improvement in training and performance in competition. Below, we present a practical example of how self-regulatory processes function when an elite tennis player moves from training to competition.

In training, the player may engage in the forethought phase; in this context, skill improvement is an objective typically desired and emphasized; for example coaches are likely to create a mastery motivational climate in training (van de Pol, Kavussanu, & Ring, 2012a). A self-regulated tennis player should be able to pick up these contextual cues (see Zimmerman, 2002) and may adopt a high task goal based on the self-motivational beliefs and knowledge so that this goal may assist him in obtaining desirable outcomes. Adopting this goal may facilitate a feeling of competence when players improve, and this should result in sustained motivation, which is essential to cope with the large number of training hours required for realizing one's full potential.

These forethought processes should influence how the player engages in the performance phase, when the training actually starts. Assuming that the tennis player strives for skill improvement in training, the drills and exercises are performed by using self-monitoring and control strategies (e.g., self-talk and attentional focus), which should facilitate this objective. Once the training is completed, the player may engage in self-reflection, thus evaluate his or her performance and assign causal attributions to the outcomes. For example, if the player has endorsed predominantly a task goal in the forethought phase, he or she may positively evaluate skill improvement by

attributing improvement to effort. This may lead to positive affect such as enjoyment and satisfaction in training (van de Pol & Kavussanu, 2011, 2012; van de Pol, Kavussanu, & Ring, 2012a).

When an important match is coming up the tennis player needs to shift his or her motivational focus to a 'competition mind state'. In this context winning is important, as the competitive outcome determines his ranking and potential prize money. Thus, in the forethought phase, the player may adopt a more 'balanced goal profile': a task goal, which may help him/her to reach an optimal personal performance standard, combined with an ego goal, which may provide him/her with just that extra effort to persist when faced with challenges during a tough match (see van de Pol, Kavussanu, & Ring, 2012b). When the match starts, the athlete engages in the performance phase where the task will be executed, and he/she may adjust his/her monitoring and control strategies to the desired goal(s). In this context, the player may focus less on technical (body movements) and more on tactical skills (ball placement), as this may benefit performance.

Finally, the match is finished and the athlete engages in the self-reflection phase where she or he evaluates his or her own performance and assigns causal attributions to it based on the adopted (high task/high ego) goal profiles in this match. The player evaluates whether he or she reached optimal personal performance standards (task goal) but also reflects on the outcome (win or loss) of the match (ego goal). For example, if the match was lost the player would attribute this loss to a controllable but unstable factor (e.g., 'I lost because I didn't put enough effort in today's match') which may help to protect their self-efficacy beliefs for the next match. In preparation of the next competition the athlete will use the knowledge from the last match and make adjustments needed for the next training episode.

When an athlete is less adept at self-regulated learning, it becomes important for the coach/teacher to intervene. The ability of the coach to create an appropriate performance environment, stressing appropriate forethought, performance, and self-reflective processes, is critical. When athletes (learn to) effectively use these self-motivational beliefs and strategies across the two contexts this may contribute to a fulfillment of the innate need for mastery and satisfaction from competing against other athletes, but it also helps them to become more self-regulated learners and performers. In the end, this may lead to higher achievement standards in both training and competition but also to a more enjoyable and enduring sport participation. Kimiko-Date Krumm comments after becoming, at age of 42, the oldest winner of a women's-singles match in Australian Open History, "I love tennis. I like practice. I like games. I like the tour. I enjoy it a lot" (Australian Open, 2013).

Coaches can also play an important role in nurturing athletes' self-regulation and maintaining their motivation. Coaches need to be aware of the importance of creating a mastery motivational climate, particularly in training, where general levels of effort and enjoyment are lower compared to competition (van de Pol & Kavussanu, 2012; van de Pol, Kavussanu, & Ring, 2012a, 2012b). By focusing on each individual athlete, emphasizing skill learning and development, and rewarding effort, coaches and physical education teachers can create an environment that is likely to maximize effort, enjoyment, and the use of self-regulation strategies in physical activity contexts. Coaches also need to de-emphasize a performance motivational climate, particularly in training, as it has been associated with higher tension in athletes in this context (van de Pol, Kavussanu, & Ring, 2012a).

Finally, in assisting athletes in setting autonomous goals and re-engaging in realistic goals when the prospect of achieving their goals are weak, coaches can help athletes perform at the highest levels.

Conclusion

In conclusion, in this chapter we reviewed research on self-regulation in sport and physical education, and examined the role of coaches and teachers in fostering athletes' self-regulatory functioning. Research findings in physical education and sport settings show that self-regulation is consistently associated with high levels of performance. Creating a mastery motivational climate that encourages skill development and supports athletes' independence is likely to enhance their self-regulation, motivation, and ultimately performance.

Note

1 All quotations are drawn from news sources and interviews.

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14 Self-Regulation

An Integral Part of Standards-Based Education

Marie C. White and Maria K. DiBenedetto

Standards have been developed across multiple disciplines and are established to ensure students are learning content critical for the discipline and that assessments are aligned with the content (Pennington, Obenchain, Papola, & Kmitta, 2012). Standards are the basis for all other educational constructs and laws associated with implementation of curriculum development, instruction, and assessment of student learning. In the field of education, standards involve a cumulative body of knowledge and set of competencies that are the basis for quality education. A standards-based education refers to a shared set of expectations of what students should learn and how they will demonstrate learning through assessments (Kendall, 2011). Its impact on education is significant because it guides curriculum, instructional design, and assessment instruments while providing opportunities for consistency of learning outcomes within and across international learning communities (Marzano, Yanoski, Hoegh, & Simms, 2013).

In the current state of educational reforms, standards have gained more attention as a policy rather than the criteria that make evaluations possible. Internationally, evaluations and assessments of students, teachers, schools, and education systems are based on a set of standards-based performances as defined by the government. Each country individually defines the knowledge and skills students are expected to have attained at different stages of their education. Implementers of the policy develop curriculum that covers the objectives identified in the standards and the assessments that indicate attainment of those standards. The results are only valid when the key elements of curriculum, assessment, and standards are well matched (OECD, 2013).

During the last few years, researchers have uncovered an association between self-regulated learning, standards, and standards-based education. Self-regulated learning (SRL) refers to the cyclical processes through which learners organize and direct their behavior, actions, and thoughts in order to attain specific goals (Zimmerman, 2000). In each phase of SRL, standards are the criteria for generating evaluations and monitoring goal progress (Winne & Hadwin, 2008; Zimmerman, 1998). Although research in self-regulation has focused on standards and standards-based education, much less is known about the actual nature of these associations. This chapter examines the role of self-regulation as an integral part of standards-based education in theory and application. Section one addresses the theoretical grounds linking SRL to standards-based education. Section two presents research evidence aligning SRL to standards in the classroom context. The importance of feedback, formative assessment, human agency, self-efficacy, motivation, and engagement in a standards-driven learning environment is examined in this section. The third section suggests future research directions in several areas that have not yet been investigated linking SRL to standards-based education. The fourth section describes implications for educational practice that could view standards through an SRL lens and provide teachers with a framework to translate standards into achievable goals.

Theoretical Foundations Linking Standards to Self-Regulated Learning

Often, the terms standards and goals are used interchangeably; however, they are not the same. Standards are generalized to describe the level at which a learner's accomplishments are considered to be competent in a particular area of study. They can be used to describe and communicate to the learner what counts as quality learning or as good practice, and they guide teacher's choices in lesson planning. In addition, standards can be used as measures or benchmarks and as tools for decision-making, indicating the distance between actual performance and the minimum level of performance required to be considered competent. Goals, in turn, are derived from standards and focus the learner on both the process and the outcome. In self-regulation, goals are specific, short-term, and set within a level of difficulty that is challenging but does not lower the learner's self-

efficacy (Schunk, 1989). Teachers and students use standards as a gauge to self-monitor and evaluate goal progress towards a specific target.

Learning standards are like targets, blueprints, or roadmaps for student learning and performance. They set the destination for what students need to know and be able to do, as well as the benchmarks they should reach along the way (Carmichael, Martino, Porter-Magee, & Wilson, 2010). Teaching and learning standards that include goals and objectives for self-regulation have been a guiding force behind successful learning outcomes and have contributed to the understanding of the application of social cognitive theory to learning and performance (Schunk, 1989). In this context, self-regulation is conceptualized as a cyclical process with three phases: forethought, performance, and self-reflection. The phases are cyclical because each process within each phase of self-regulation influences the next (see Usher & Schunk, 2018/this volume; Zimmerman, 2000).

Learning objectives that engage students in problem solving and critical thinking can be derived from a standards-based curriculum using SRL strategies to guide the learner to set process goals (Zimmerman & Kitsantas, 1997). Active self-regulated learners engage in processes that are critical for setting the learning stage in the fore-thought phase such as rating self-efficacy and goal setting. This phase involves the feelings, thoughts, and behaviors of students as they prepare to learn something. During the performance phase, students are trying out different strategies and monitoring their progress as they work on the learning task. Essential processes for guiding and controlling behavior in this phase include metacognitive monitoring and attention focusing. The self-reflection phase is pivotal for guiding future cycles as students evaluate and attribute feedback on performance to effort and strategy use after the work is completed (see Usher & Schunk, 2018/this volume).

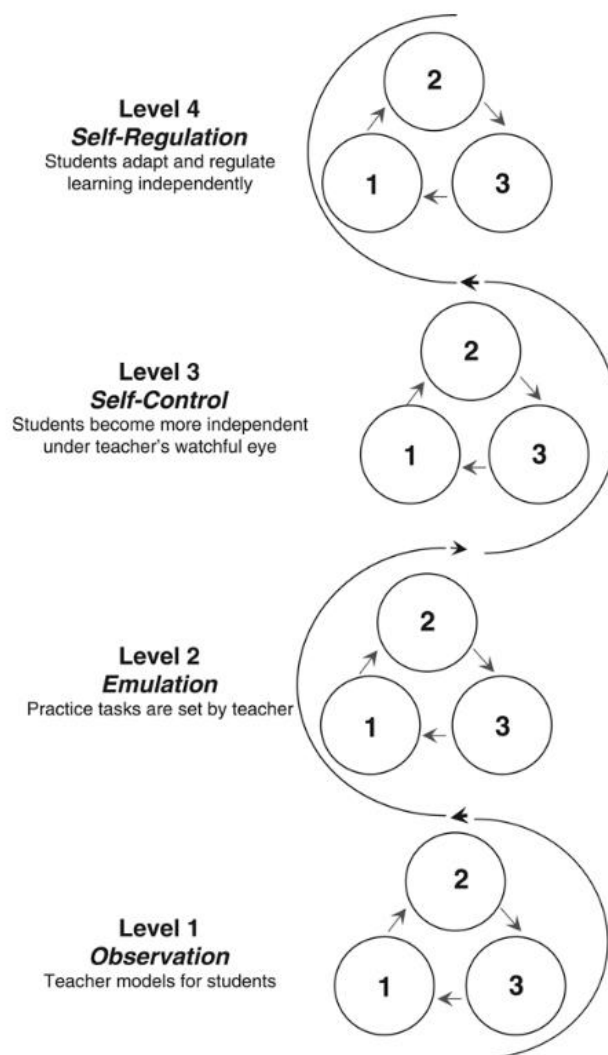
Self-regulation is dynamic because learners continually evaluate and adapt their performance against a standard or a modeled behavior through three cyclical phases (Schunk & Zimmerman, 1998). Self-regulation also requires a level of competency before learners can begin to use self-regulatory strategies outside of the presence of a model or teacher. Standards can serve as a guide to promote the development of self-regulation, through the strategic use of self-monitoring, formative assessment, self-evaluation, feedback, goal setting, learning objectives, and self-reflection (Bembenutty, White, & Vélez, 2015).

Developing self-regulatory competency begins at the observation level. Teachers model a standard of performance, which they convey to students as they demonstrate feelings of competency and the strategies for task success. Teachers model how to evaluate their self-efficacy beliefs for a specific task and how to choose strategies for self-set goals that are in line with outcome expectations for standards-based performance. This type of modeling provides behavioral indicators for students at all grade levels on how to engage in and how to practice self-regulation (White & DiBenedetto, 2015). The emulation level affords teachers the opportunity to reinforce outcome expectations while they provide learners with continuous feedback and modeling. As students begin to experience a sense of mastery, the teacher remains engaged with learners making sure their efforts increase rather than diminish self-efficacy. For instance, closely monitoring students as they practice an algebraic problem can help prevent students from feeling frustrated if unable to solve the problem correctly. As learners begin to experience self-efficacy for the given task, they transition into the third level of self-control. The learner has now retained a mental image of the standard and feels capable of making progress towards achieving the outcome expectations set at the beginning of the task. The teacher's role shifts at this level. Here the student engages in the task with minimal support from the teacher. The teacher provides assistance when requested by the student who is beginning to take more control of the pacing of the learning. When self-regulation is achieved, at the fourth level, the learner is able to systematically adapt performance to novel situations. The learner has high levels of self-efficacy and is motivated to set challenging goals in line with even higher learning outcomes (Zimmerman, Schunk, & DiBenedetto, 2015).

Some students will need to remain at observation, emulation, and self-control levels longer than others and reset goals based on feedback and self-evaluation. With this in mind, White and DiBenedetto (2015) proposed an integrated model of SRL that requires teachers to identify indicators of both levels and phases of self-regulation for individual students when engaged in specific learning tasks. The integrated model situates phases (i.e.,

forethought, performance, and self-reflection) into levels of self-regulation (i.e., observation, emulation, self-control, and self-regulation) providing a framework for SRL in the twenty-first-century classroom that includes increased cognitive modeling (Bembenutty, Cleary, & Kitsantas, 2013; Pape, Bell, & Yetkin-Özdemir, 2013). In this model, teachers enhance the learning environment by carefully pacing students according to their status at each level while guiding them individually through the three phases of SRL, providing feedback and criteria-based formative assessment (see [Figure 14.1](#) with forethought indicated by 1, performance by 2, and self-reflection by 3).

In the integrated model of SRL, at level one students observe the teacher model the forethought, performance, and self-reflection phases of the SRL cycle. During the forethought phase, students observe how to set proximal goals aligned with standards-based performance for a specific task. Criteria for goal attainment are examined and explained as the teacher engages the students in planning strategies and self-efficacy assessments. At the conclusion of the forethought phase the teacher shifts to the second phase, performance, modeling an actual enactment of the task. Students are reminded to pay close attention to how SRL strategies assist in attaining the goals set during the forethought phase. As the teacher demonstrates self-monitoring, progress is determined by checking performance against the criteria established for successful learning outcomes. In the final phase of the cycle, self-reflection, the teacher models self-evaluation by assessing the completed task with the criteria for goal attainment.



[Figure 14.1](#) Integrated model of self-regulated learning

Once the SRL cycle is completed students who become proficient at the observation level enter the next level of competency attainment, emulation. Students who have not yet fully benefitted from observational learning repeat the cycles until the first level of SRL competency is reached. They may have to cope with experiences of failure and the teacher can slow the pace down to provide additional learning opportunities that will foster mastery experiences to build self-efficacy. By monitoring, supporting, and providing feedback through the SRL cycles and levels of competency, teachers can determine which students need more time and adapt instruction to the needs of the students (Schunk & Zimmerman, 1998). The integrated model increases the focus on comparing one's performance to self-set goals by encouraging individual tracking of performance with metacognitive monitoring of progress towards the learning goals. The established criteria of standards at the onset of a task is critical to directing students' attention to specific behaviors through self-monitoring and self-evaluation.

Kitsantas and Dabbagh (2011) observed that the cycle of SRL promotes individual empowerment partially because it reinforces the beliefs the individual holds in his or her ability to effectively control aspects of a learning experience towards a desired outcome. Effective learners require SRL strategies in order to influence what they want to learn and how they want to learn it in the context of a standards-based learning environment. Bandura's (1997) emphasis on students becoming self-directed learners requires educators to facilitate flexibility, provide an understanding of the academic tasks, and give opportunities for learners to increase their capability to self-regulate towards goal attainment.

Standards-based education provides an opportunity for teachers to design instruction that can deepen cognitive processing and increase self-efficacy (Clark, 2012). Self-efficacious individuals believe in their capability to perform designated tasks (Bandura, 1997; see Chen & Bembenuddy, 2018/this volume). A significant amount of research has been conducted on the role of self-efficacy in teaching and learning environments and its link to academic achievement (see Usher & Schunk, 2018/this volume). With increased self-efficacy beliefs, students have an opportunity to demonstrate learning that is consistent with what was taught, but on their own. Self-efficacy is dynamic, meaning that it is continually susceptible to change (Schunk & DiBenedetto, 2015a, 2015b). Linking SRL with the current academic standards provides educators and researchers with opportunities to create learning environments that promote self-efficacy. Students' ability to exercise environmental control and manage social interactions depends on the level of self-belief in their capabilities. The ultimate goal of academic standards is to prepare learners to become more self-efficacious so that they can attempt challenging material and demonstrate competency across disciplines. In order to reach their academic goals, students must be able to adapt successfully to new and more complex learning tasks while maintaining self-control of behaviors, thoughts, and actions.

Research Evidence Linking Standards to Self-Regulated Learning

Standards-based education, in many ways, is best achieved when students can effectively self-regulate. Historically, models of self-regulation have included some type of feedback loop during learning (Carver & Scheier, 2011; Zimmerman, 1989, 2000). This loop refers to the cyclical processes by which students monitor the effectiveness of their learning methods or strategies and, in response to feedback, make adjustments in their behavior (Zimmerman, 2000). Comparison to a standard or expected outcome is the only way an evaluation can be made to determine if the preset goals are being met (Cleary & Zimmerman, 2012; Winne & Hadwin, 1998). When feedback indicates a discrepancy between the selected standard and actual behaviors, adjustments are made in an attempt to modify specific behaviors to meet the standard. In this framework, learning is a continual process of establishing goals and adjusting patterns of behavior to match those goals more closely by using feedback that can come from an external source, such as a teacher or an internal source through self-monitoring. Self-reactions to feedback require attending to and tracking specific aspects of performance through self-monitoring, self-recording, self-observation, and self-evaluation. However, a self-regulatory cycle is not completed unless the learner applies feedback during future learning efforts (see Cleary & Callan, 2018/this volume).

The intention of feedback at any level should be to empower students to become self-regulated learners. In academic settings, feedback is information about how the students' present states of learning and performance are related to goals and standards (Ivanic, Clark, & Rimmershaw, 2000; Nicol & Macfarlane-Dick, 2006). However, how students perceive and interpret feedback and how teachers intend feedback to be taken often leads to miscommunication due to unclear task specifications. Students cannot convert feedback statements into actions for improvement unless they have a working knowledge of the basic task requirements and the criteria by which their performance is judged. Teachers are often misinformed about their students' prior knowledge and make assumptions that lead to setting the standard too high and inhibiting the development of a skill (Sadler, 2010).

Labuhn, Zimmerman, and Hasselhorn (2010) explored the effects of self-evaluative standards and feedback on performance in mathematics problem solving and relevant subprocesses of SRL. Participants for the study were 90 fifth grade students randomly assigned to experimental and control groups. The experimental conditions were based on three types of self-evaluative standards (mastery learning, social comparison, and no externally set standards), and three types of feedback (individual, social comparison, and no feedback). Their results indicated that feedback positively influences self-regulatory processes in both social and individual contexts. Furthermore, students indicated the use of a standard to evaluate their performance. The researchers indicate that in the absence of externally set standards, self-set standards are employed, which might be less effective than externally set standards, and recommend clear communication of standards to students, and realistically achievable goals with a strong sensitivity to minor skill improvement.

Zimmerman (2013) stressed the influential role of feedback as the means by which self-regulated learners have their attention drawn to components of the social and physical environments, the results of their actions, and the thinking processes about a given task. Consistent and constructive feedback provides the learner with opportunities to adapt their performance during the completion of a difficult task rather than to persist towards an unsuccessful completion of the task.

To individually compare performance, the self-regulated teacher provides corrective feedback by focusing on standards that facilitate SRL and provide criteria for students. In addition, consistent referencing to the indicators of successful performance through modeling, reteaching, and leading students to correct answers can increase students' motivation to complete the task. In addition, feedback that leads to students' self-evaluation and correction increases self-efficacy (Pape, Bell, & Yetkin-Özdemir, 2013).

Black and William (1998) conducted a meta-analysis of 250 studies spanning all educational sectors and focusing on real teaching situations. Their findings indicate that effective formative feedback produces improved learning and achievement across all content areas, knowledge, skill types, and levels of education. In addition, other studies demonstrate that formative assessment feedback has a profound influence on how students engage with and enact the processes of learning (Gibbs, 2014; Hattie & Timperley, 2007). Formative feedback influences the cognitive, behavioral, and affective domains of student learning: it provides a point of engagement through which it is possible to stimulate transformation within students' learning, learning processes, behaviors, and motivation.

Sadler (1989) identified three conditions in which students would benefit from feedback in academic tasks. First, students need to know what good performance is and therefore possess a concept of the target goal or standard. Second, students need to know how current actions relate to a performance that indicates successful progress towards the expected outcome or standard. Third, students need to know how to make necessary adjustments to current performance to come closer to the expected outcome or standard. Significant to Sadler's argument is the comparison of student performance with a standard in order to obtain feedback from internal or external sources positioning formative assessment within a model of self-regulation.

Several researchers have supported formative assessment and feedback as important to models of SRL (Clark, 2012; Nicol & Macfarlane-Dick, 2006). Amongst other factors, the process requires specific targets, criteria, standards, and other external reference points in order for students to set goals and connect feedback to specific behaviors. In order for students to develop the self-regulation skills needed to prepare them for learning outside the classroom and throughout life, formative assessment cannot be exclusively the teacher's responsibility (Boud, 2000). From a social cognitive perspective of self-regulation, students' academic competence develops initially from social sources of academic skill, such as the teacher, and subsequently shifts to individual control (Schunk & Zimmerman, 1998). Therefore, the feedback loop in the SRL cycle generates formative assessments, and as students develop into self-regulated learners their ability to fully participate in meaningful dialogue with their teachers about personal goal progress will increase significantly. One requirement for feedback to be effective in facilitating SRL is keeping students well informed with statements that describe tasks to be attempted and the assessment criteria for achievement in a particular area of study. Statements in the form of goals derive from standards and guide the process necessary for starting the effective feedback flow that enables SRL (Rust, Price, & O'Donovan, 2003).

Butler and Winne (1995) proposed a model of self-regulation in which they stressed the importance of feedback as a catalyst in every activity, stimulating students' engagement in SRL. Additionally, Nicol and Macfarlane-Dick (2006) presented a self-regulation model that addresses how feedback actually promotes self-regulation from both external and internal sources. In their model, external feedback includes input from peers' or teachers' comments either verbally or in written progress reports. The purpose of internal feedback is to provide individuals with ongoing self-monitoring and self-evaluation that could increase an awareness of outcomes and progress towards goal attainment, resulting in the development of an internal self-regulatory process (Chung & Yuen, 2011).

To facilitate SRL teachers need to consider the impact of external feedback on the process of self-regulation, specifically encouraging the learner to consistently compare performance to standards and goals, not the progress of peers. Nicol and Macfarlane-Dick (2006) suggest that feedback should include clarifying to the learner what good performance is, facilitating self-assessment by the learner, encouraging teacher and peer dialogue, and encouraging positive motivation. Teachers' guidance could help students set goals, make good use of learning strategies and resources, and sustain motivation. In turn, learners are encouraged to be actively involved in monitoring and regulating their own performance in terms of set goals and the strategies used to reach their goals.

Research Evidence Linking Standards to Academic Goals

In today's academic settings, the teacher directs students' attention to selected standards from which goals will be set for a specific task. When standards are presented with realistic goals, motivation to engage in the task is high because students are able to make comparisons between the standard and their goal progress (Zimmerman, Schunk, & DiBenedetto, 2015). Adjustments can be made to the language of standards to increase self-efficacy by translating the standard into proximal and achievable goals that can be monitored and assessed by both teacher and student.

Goals provide standards against which people can compare their present performances (Bandura, 1986). When standards include performance indicators from which students can measure their progress students can better measure their self-efficacy for a given task. Consideration of how students approach and reach goals requires a sense of self-efficacy for learning (Schunk & Swarts, 1993). Schunk (1996) studied children's self-evaluation of their learning with 44 fourth graders who were average achievers in mathematics. Linking self-evaluations to learning goals, students were encouraged to learn to solve the problems and periodically evaluate their capabilities when compared to their requirements of the task. Findings indicated that having children periodically evaluate their capabilities makes it clear that they have made progress in learning, and this perception strengthens self-efficacy and keeps students working productively. Self-evaluation is especially important under performance goal

conditions. To the extent that learning goals or standards produce a long-term focus on skill improvement, periodic self-evaluation should highlight to students that they are making progress in skill acquisition.

Monitoring the effectiveness of students' learning methods and strategies in reaching their goals has been found to enhance the effects of goal setting, self-efficacy beliefs, and self-reactions. Reactions to this feedback included changes in skilled behavior and self-perceptions. Zimmerman and Kitsantas (1997) studied the effects of goal setting and self-monitoring during self-regulated practice on the acquisition of a complex motoric skill with 90 high school girls during dart-throwing exercises. They found that the girls who shifted goals developmentally from process to outcome goals surpassed classmates who adhered to only process goals and who, in turn, exceeded classmates who used only outcome goals in posttest dart-throwing skill, self-reactions, self-efficacy perceptions, and intrinsic interest in the game.

Winne (2001) emphasized the importance of precision when making comparisons generated from monitoring between the outcome and the actual standard. The more conditions added to the rules to classify when a standard is met, the more precisely learners will match actions with task requirements. Successful learning outcomes are products of learners acquiring the ability to reach goals more effectively (Winne, 1995). Winne and Hadwin (1998) theorized that learning occurs in four basic phases: task definition, goal setting and planning, studying tactics, and adaptations to meta-cognition (Greene & Azevedo, 2007). Within each phase, information processes construct standards-based information products that include the qualities of the predicted or actual goal or standard. Although Winne and Hadwin (1998) identified standards as an internal interpretation of task conditions from an external source such as the teacher, this model stresses the importance of having an external standard from beyond the teacher's gauge by which to measure growth and learning from a global perspective.

Research Evidence Linking Standards to Formative Assessment

Educators specifically generate formative assessments in order to improve or accelerate learning (Sadler, 1989). Standards have emphasized the need for formative assessment, a practice strongly advocated by self-regulation theorists. Clark (2012) suggests that through the use of formative assessment students are given feedback that can be compared with the information gained from self-monitoring and, as a result, become a catalyst for each iteration of the SRL cycle. Standards guide the teacher in selecting tasks and setting the criteria to begin the feedback cycle. Once the cycle is initiated, the teacher provides external feedback prompting the students to generate their own feedback through self-monitoring and self-evaluation of their goal progress. Consistent comparison to the standard guides the process until the task is complete to the satisfaction of both the student and the teacher. Both self-assessment and self-evaluation strategies along with the instructor's evaluations provide formative information for the learner to reflect on and apply to the next task. The strategic purpose of formative assessment is to promote an autonomous use of both cognitive and social strategies required for academic success in SRL (Clark, 2011). The process is considered to be bidirectional in that feedback provides learners with information on how to more accurately perform tasks while providing teachers with information that can guide instruction.

Teachers are the implementers of the standards, making decisions every day regarding classroom pedagogy while assessing individual students' prior knowledge, learning development, and learning differences. The implementation of standards is the foundation to ensuring that all students, regardless of where they live and attend school, will be prepared for success in postsecondary education and the workforce. Raising teachers' awareness of the impact their self-regulatory instructional practices have on their students is critical to creating learning environments where self-regulatory processes empower learners to achieve high levels of personal, academic, and professional outcomes (Butler, Schnellert, & Perry, 2017; Winne & Hadwin, 2008; Zimmerman, 2013). Instruction in SRL serves as a framework for metacognitive knowledge and skill acquisition that in turn builds students who are not only college and career ready but lifelong learners (White & DiBenedetto, 2015). There are standards, pedagogical approaches, curriculum choices, and student learning processes evident in learning environments that support self-regulation and are helping teachers and teacher educators transition

successfully into standards-based education. When viewed through an SRL lens, educational standards and goals serve as an invitation to teachers and learners to use higher-order thinking and employ the dimensions of SRL through metacognitive awareness in learning contexts.

Future Research Directions

Although the literature reflects a significant amount of research on self-regulation in many domains, how to successfully integrate SRL into a standards-driven learning environment requires further investigation. Future research linking SRL and standards with feedback and formative assessment can provide students, teachers, and teacher educators with information that will help learners become strategic, motivated, and independent in a standards-driven learning environment.

Research, specifically related to understanding how teachers can use standards as criteria to monitor student learning and achievement, could significantly influence the successful integration of SRL competency in classroom learning environments. Investigating the behaviors and practices that indicate how this is actually accomplished can provide scholars and researchers with a framework for developing SRL performance and competency within the context of classroom-based learning activities. White and DiBenedetto's (2015) integrated model could provide a framework for future investigation of indicators of SRL behaviors, thoughts, and actions that can be aligned with standards-based criteria for academic achievement. The model embeds cycles of SRL into levels of attaining SRL competency. With an emphasis on modeling, each SRL phase at the observation level is repeated until the learner's understanding of goal setting includes alignment with standards-based criteria for goal attainment. Future studies that examine the teachers' behaviors and students' responses at the emulation and self-control levels could provide educators with much needed information about how self-regulatory competency is attained over time.

Researchers need to work with those who are proposing standards for today's classrooms to recognize the connection between SRL theory and the intentional outcomes of the standards. This connection could influence the way the standards are introduced to classroom teachers, teacher candidates, and school leaders. Classroom observations of teachers trained in SRL and the process used to incorporate standards into lesson planning should be investigated prior to establishing methods for standards-driven learning.

The connection between formative assessments and SRL is relatively new and there is a need for more research-based evidence of its success with diverse populations of students whose learning experiences span global and cultural arenas. Research conducted in this area should include real-time investigations of current practices in classrooms from different parts of the globe, taking into account the present culture and past assessment practices. In addition, research that incorporates the functional role of the feedback loop in the SRL cycle, specifically linking it to formative assessment and self-evaluation, could provide insight into the attributes of its impact on learning gains when connected to standards-driven assessments.

Research into how human agency influences the development of teacher candidates as agents of change and specific strategies that would empower them to become proactive educators could increase the effectiveness in the training of highly qualified teachers. Often standards are viewed as cumbersome and unattainable; however, when broken down into proximal goals, the standards become guidelines for assessment, both formative and summative. Considerable attention could be paid to exploring how personal, environmental, and behavioral elements make up context and how teacher educators can incorporate SRL strategy applications into teacher candidates' clinical requirements. In addition, future research can explore the impact of formative and summative assessments collected by teacher candidates using SRL strategies on student learning.

Educational standards have become significant factors in measuring national and international educational achievement (Carmichael, Martino, Porter-Magee, & Wilson, 2010; Labaree, 2014). Valid and reliable methods measuring elements that define positive educational outcomes are gaining attention in classrooms and institutions

worldwide (OECD, 2013). It is important that the conceptualization of what standards represent be revisited by researchers as to their purpose and function in promoting learning and their role in curriculum development. Standards guide the formation of educational constructs, legal tenets, and policy decisions associated with curriculum development, instruction, and assessment of student learning. As international learning communities identify and apply the significance of SRL's contribution to standards-based teaching and learning they enable both teachers and students to share the responsibility of what can be done to improve the performance of all students.

Designing research that tests the proposed integrated model (White & DiBenedetto, 2015) could provide supporting evidence of the importance of the directive properties of standards in the SRL processes. Criteria-based evidence of learning could be derived from aligning standards with goals set at the observation level during the forethought phase and used for comparison throughout the interdependent phases and levels of SRL competency attainment. This type of research should also consider examining the integrated model to assess the connection between standards and the SRL culturally proactive pedagogy proposed by White and Bembenuddy (2016). In the self-regulated culturally proactive pedagogy model classroom teachers are considered to be cultural agents of change by first examining the lens through which metacognitive, cognitive, behavioral, and cultural similarities and differences among learners are assessed on a daily basis. This model is consistent with social influences of cultural awareness, achievement outcomes, and self-influences in reciprocal interaction with each other (Schunk, 1999). Analysis of informal social patterns at schools indicate an isolation of many immigrant students from their English-speaking peers (Daoud, 2003; Peguero, 2009). In this case, the actions of the teacher fall into the area of social influences through modeling, instruction, and feedback. The self-regulated culturally proactive pedagogy model provides mechanisms through which cultural limitations can be attenuated and eventually eliminated. The SRL culturally proactive pedagogy considers the concomitant contribution of learners and teachers as cultural agents of effective instruction. The interactive design of the model shifts the teachers' and students' roles that provide a framework for inviting learners to participate in self-evaluation and assessment processes.

Educational Implications

Significant progress has been made in assessing how students learn and the importance of self-regulation in classroom instructional practices. Students' active involvement in learning requires teachers support in setting meaningful goals, selecting appropriate tasks-specific strategies, monitoring motivational levels, and adapting performance based on feedback (Moos & Ringdal, 2012). Most teachers agree with the concept of supporting their students to become self-regulated learners; yet many of the teachers report feeling unsure about how that is done (Perry, Hutchinson, & Thauberger, 2008). SRL has yet to be linked in the literature to what standards are calling for in future educational learning environments. Yet the current evaluations of academic skills in the global arena, such as the Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), do reflect metacognitive development. The complexity of SRL has motivated educators and researchers to provide effective interventions in schools that benefit teachers and students directly. SRL has been viewed as a set of skills that can be taught explicitly or as developmental processes of self-regulation that emerge from experience and that begin with setting a goal directly in line with a standard.

Standards, when translated into proximal goals, can provide guidance, direction, clarity, and support to teachers. Schunk (1998) refers to goal setting as a criterion to monitor learning progress, indicating the need for standards that include performance criteria that can encourage self-monitoring and self-evaluation. As a result of comparing performance to standards or goals, self-regulated learners decide the best course of action to meet the criteria for successful goal attainment in light of the discrepancy in performance to the desired outcome. As already noted, standards for achievement have been set and reset, yet actual training in the metacognitive processes required to meet the standards has yet to be systematically and consistently part of the process. Often, standards are put in place without educating administrators and teachers on how best to implement them. The multiple layers of standards and the ways in which learning outcomes are measured are often confusing. Professional training should

be offered to teachers, parents, teacher candidates, and teacher educators on how focusing on the learning process rather than outcomes increases motivation and student engagement, and ultimately student performance and achievement.

Self-regulation of learning introduces clarity to standards-based education for teaching and assessment. The SRL processes recognize the significance of personal choice, the importance of individual goal setting, and how self-efficacy beliefs inform motivation. Educators could use standards to provide students with opportunities to learn to be independent, self-motivated, and active learners across multiple disciplines and contexts. Promoting SRL in a standards-driven learning environment can provide educators with the tools needed to teach content while promoting independence and problem-solving skills.

In order for assessments to be useful, they must be tied to reasonably well-documented learning progressions that demonstrate how students' increasing competencies can be supported and advanced. In addition, one use of SRL assessments should be to provide students with opportunities to monitor their own success and progress towards goal attainment. Formative assessment within the context of SRL can be a useful tool for educators to evaluate individual progress towards standards-based goals. The results can be an effective means towards helping students self-evaluate and reset goals that have not yet been attained. As demonstrated in the integrated model (White & DiBenedetto, 2015), developing SRL competency by embedding the cyclical phases into levels of SRL competency attainment provides the instructor with real-time data that serve as both formative and summative assessments. The phases provide the opportunity to improve in self-regulatory strategies such as self-monitoring and self-evaluation under the teacher's watchful eye at the observation, emulation, and self-control levels. The levels of competency are attained following a summative assessment of how well the student moves through the levels into becoming independent of the teacher's supervision.

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15 Teachers as Agents in Promoting Students' SRL and Performance

Applications for Teachers' Dual-Role Training Program

Bracha Kramarski

Self-regulation in learning is considered to be critical for 21st century success both academically and after schooling (Bembenutty, 2013; Pintrich, 2000; Zimmerman, 2008). Engagement of students in self-regulated learning (SRL) requires consideration of not only what students learn but also how they learn and if their gains attain their goals (Moos & Ringdal, 2012). Researchers have argued that teachers must act as agents to introduce and reinforce students' SRL experiences (e.g., Bembenutty, 2013; Kramarski & Revach, 2009). In the current chapter, I discuss the ensuing challenges for professional training in order for teachers to effectively support students' development and utilization of crucial SRL processes.

In essence, to cope with the complex dynamic challenge of helping students self-regulate their construction of knowledge and skills, teachers must undergo important dual processes. First, teachers need to learn to become more proactive self-regulated learners themselves, and then teachers need to learn how to help students achieve SRL (Bembenutty, 2013; Dembo, 2001; Kramarski & Michalsky, 2009a, 2010; Peeters, Backer, Reina, Kindekens, & Buffel, 2013). Teachers' ability to achieve their own SRL is called the learner's role, and their ability to help students achieve their personal SRL is called the teacher's role and may be termed self-regulating teaching (SRT; Kramarski & Kohen, 2015; Peeters et al., 2013). As seen in [Figure 15.1](#), teachers' dual SRL and SRT processes may interact with students' own SRL processes, thus creating reciprocal relations.

Substantial research has indicated that teachers experience difficulties applying self-regulation (SRL/SRT) spontaneously, especially novice teachers (e.g., Bembenutty, 2013; Butler, Novak Lauscher, Jarvis-Selinger, & Beckingham, 2004; Kauffman, Ge, Xie, & Chen, 2008; Kramarski & Michalsky, 2010; Peeters et al., 2013). Hence, training models were suggested to advance teachers' and students' reciprocal self-regulation processes (e.g., Bembenutty, 2013; White & Bembenutty, 2014). Yet, importantly, these models did not explicitly clarify differentiations between teachers' own SRL and SRT roles, as directed toward promoting students' regulation. Moreover, experimental interventions to assess these conceptualized dual effects are lacking. This empirical state-of-the-art implies the need for an evidence-based practical model that differentiates between teachers' dual SRL/SRT roles by investigating both teachers' dual gains and students' gains (Kramarski & Kohen, 2015).

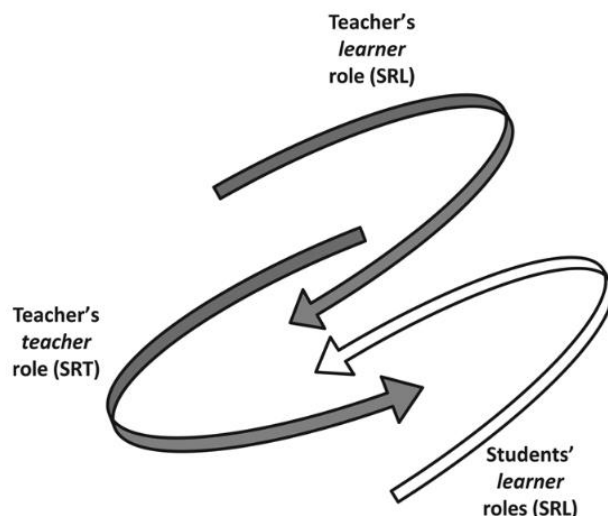


Figure 15.1 Reciprocal self-regulatory processes with interplay of teacher's dual SRL/SRT roles and students' personal SRL roles. SRL = self-regulated learning. SRT = self-regulating teaching

To fill this gap, in the current chapter I present an explicit practical model for professional training programs to help preservice and inservice teachers attain the necessary knowledge and skills for successfully implementing their own dual SRL/SRT roles, which, in turn, may empower students' SRL and their academic achievements. As such, the chapter addresses four major topics: (1) theoretical ideas underlying teachers' dual SRL/SRT roles in interplay with students' personal SRL, which led to the practical training model; (2) research evidence on teachers' and students' gains from applications of the dual-role training model in different disciplines and contexts; (3) future research directions on these dual roles as related to student outcomes; and (4) implications of this training model for educational practice.

Underlying Theoretical Ideas

This chapter's theoretical underpinnings are twofold, first involving teachers' dual SRL/SRT roles in interplay with students' personal SRL, and second concerning the theoretical notions underlying the practical dual-role training model.

Teachers' Dual SRL/SRT Roles in Interplay With Students' Personal SRL

Teachers' self-regulation as a learner (i.e., SRL) involves proactive, constructive processes where the teachers set goals and attempt to monitor and evaluate their own cognition, motivation, and behavior, while guided and constrained by their goals and by contextual features in the environment (Pintrich, 2000; Zimmerman, 2008). Self-regulation as a teacher (i.e., SRT) is similar, whereby teachers attend explicitly to helping students actively construct their personal SRL. In both of the teacher's roles, self-regulation is a proactive process that does not merely happen to teachers but rather happens by them (Zimmerman, 2008).

Overall, teachers' dual self-regulation processes build on both metacognitive and motivational strategies. Consistent with Zimmerman's self-regulation theory, these strategies for SRL and SRT follow a cyclical process that includes three phases (Usher & Schunk, 2018/this volume; Zimmerman, 2008). As seen in the left and central columns of [Table 15.1](#), in the forethought phase, teachers in the SRL role set goals for their own planning of specific activities, resources, and time allocations, while in the SRT role teachers guide students to be proactive in planning appropriate actions to complete a specific task. Next, in the performance phase, teachers in the SRL

role use their goals to monitor the process and move it along, while in the SRT role teachers guide students to use goals as checkpoints for progress along tasks. Finally, in the evaluation phase, teachers in the SRL role use information gained from the completed task to improve the next task's performance, while in the SRT role teachers guide students to examine what did and did not work. Metacognitive strategies are accompanied by motivational strategies and self-efficacy beliefs for investing efforts into the SRL/SRT roles along the cycle's three phases. As seen in [Table 15.1](#), the dual roles demand that teachers become self-aware, knowledgeable, and decisive (Kramarski & Michalsky, 2010; Randi, 2004; Schraw, 1998) while considering what, how, why, and by whom activities are directed, whether toward their own SRL or in SRT directed toward promoting students' SRL.

Likewise, as illustrated in [Table 15.1](#) (right column), in parallel to self-regulated teachers in their dual roles, self-regulated students effectively implement metacognitive and motivational strategies as they learn along the three-phase cyclical process, while attending to the what/how/why/by whom of their own actions and deliberations. Specifically, students' "learning is shaped by the academic environment through the personal agency of the teacher who introduces and reinforces learning experience" (White & Bembenuddy, 2014, p. 2). That is, in order for students' SRL to take place in the classroom environment, teachers must be reciprocally engaged with their students, becoming agents of self-regulatory change through their teaching (i.e., their SRT).

Moreover, at the same time as teachers' SRT is shaped by their own SRL experiences, it is also shaped by feedback from teaching experiences with students who are actively constructing their personal SRL (see [Figure 15.1](#)). These reciprocal experiences permit both teachers' and students' autonomy during goal-setting, self-monitoring, and self-evaluation of personal SRL cycles (Bembenuddy, 2013; Paris & Winograd, 2003; Schunk, 1999). Yet, such reciprocal experiences may also lead to proactive teachers' SRT and students' SRL, through interactions where each participant (i.e., teacher, student) brings different kinds of self-regulatory challenges and expertise to jointly negotiate co-regulation, which temporarily mediates regulatory work among the self and others (see Hadwin, Järvelä, & Miller, 2018/this volume).

Table 15.1 Phases of teacher's dual self-regulatory roles (as learner-SRL and teacher-SRT) and student's personal SRL role as reflected in their actions and considerations (what/how/why and by whom)

Self-regulatory phase	Teacher's dual roles as learner and teacher		Students' learner roles
	Learner role (SRL)	Teacher role (SRT)	
Phase 1: Forethought (Planning)	<i>Teacher's actions and considerations are directed to his/her own SRL.</i>	<i>Teachers actions and considerations are directed to promoting the students' SRL.</i>	<i>Students' actions and considerations are directed to their own SRL.</i>
	Sets goals, plans specific activities, resources, and time allocation by taking control over the topic (<i>what & when</i>)	Guides students to set goals and time allocation by taking control over the topic (<i>why</i>)	Proposes a plan to complete a specific task (<i>what & when</i>) by taking control over strategy choice (<i>why</i>)
	Draws from prior experiences to inform planning (<i>when & how</i>)	Helps students to draw from prior experiences (<i>when & how</i>)	Draws from prior experiences to plan a strategy choice (<i>when&how</i>)
	Selects strategies that best fit the lesson topic (<i>when & how</i>)	Guides students to select strategies that best fit the lesson topic (<i>when&how</i>)	Explains how one makes choices (<i>when & how</i>)
	Pays attention to increase and sustain motivation (<i>why</i>)	Stimulates attention to increase and sustain students' motivation (<i>why</i>)	Pays attention to take part in group discussions and feedback exchanges (<i>why</i>)
Phase 2: Performance (Monitoring)	Follows the plan, using goals to move process along (<i>when & how</i>)	Guides students to focus on the plan, using goals to move process along (<i>when & how</i>)	Follows the plan, using goals to move process along (<i>when & how</i>)
	Thinks about adjustments if plan is not working (<i>why</i>)	Guides students to reflect and evaluate progress, before/during completing the task (<i>why</i>)	Stops and evaluates progress. Thinks about adjustments if plan is not working (<i>why</i>)
	Praises oneself for correct answers (<i>why</i>)	Encourages students to praise themselves for correct answers (<i>why</i>)	Praise oneself for correct answers (<i>why</i>)
Phase 3: Self-reflection (Evaluation)	Assesses one's own comprehension and handles misunderstandings (<i>when & how</i>)	Guides students to self-assess comprehension and handle misunderstandings (<i>when & how</i>)	Assesses one's own comprehension and handles misunderstandings (<i>when & how</i>)
	Attributes successes and failures to choices made (<i>why</i>)	Stimulates students to attribute success and failure to choices made (<i>why</i>)	Self-evaluates success and failure to choices made in planning and performance (<i>why</i>)
	Pays attention to use information gained from the completed task to improve performance on the next task (<i>why</i>)	Guides learners to pay attention re: what worked and what did not work and what can be done to improve future tasks (<i>why</i>)	Uses information gained from the completed task to improve performance on the next task (<i>why</i>)

Specifically regarding teachers' unique SRT role, beyond its metacognitive and motivational strategies, SRT can also be conceptualized as an overall process of strategic instruction that can be measured along a continuum (van Beek, de Jong, Minnaer, & Wubbels, 2014). At the low end of the continuum for SRT-oriented strategic instruction is general self-regulation training that only focuses vaguely on its importance for learning and teaching. A bit further along the continuum is teachers' strong external regulation of students, where teachers directly transmit self-regulation knowledge to students (i.e., a low level of teachers' SRT-oriented instruction). A teacher's intermediate regulation of students remains connected with the teacher's presence, as in external regulation, but begins to include the teacher's moderate SRT attempts to activate students' understanding by asking questions and demonstrating examples. At the highest end of the continuum is strong internal regulation of learning by students (i.e., teachers' high level of SRT) that allows students to think, discuss, self-correct, and

reflect by themselves and to share knowledge in co-regulating interactions with other students and the teacher, which may lead to students' personal internalization of SRL. Thus, high levels of SRT-oriented strategic instruction by teachers place students at the center of autonomous learning, where the teacher's role is to proactively support students' SRL (Bolhuis, 2003; Schraw, 1998; van Beek et al., 2014). Considering the complexity of these interactive processes and teachers' difficulty in spontaneously applying proactive self-regulation, researchers have recommended developing practical self-regulation training models for teachers based on theoretical frameworks and environments that reciprocally empower teachers' SRL/SRT and their students' SRL (e.g., Randi, 2004).

Practical Multidimensional Teacher-Training Model in Dual SRL/SRT Roles to Promote Students' SRL

The practical training model presented in this chapter is an elaboration of the multidimensional cognitive and metacognitive training model advocated by Kramarski and Kohen (2015), which focused on teachers' self-regulation training in learning and teaching. This model derived from theoretical self-regulation frameworks and pedagogies that were previously implemented targeting school students' SRL (Kramarski & Mevarech, 2003; Mevarech & Kramarski, 1997, 2014). As seen in [Table 15.2](#), the dual-role teacher-training model involves three major dimensions: (a) exposure to the theoretical SRL/SRT framework, (b) training in instruction strategies, and (c) interactive learning environments supported by reflective prompts. This dual-role training program for preservice/in-service teacher education has been and is currently being carried out in blended courses, which incorporate interactive web-based environments such as online forums with in-class practical instruction. This practical training model is presented next, with its three major dimensions, followed by research-based evidence from its application.

Dimension A: Exposure to the Theoretical Framework

As illustrated in [Figure 15.1](#) and [Table 15.1](#) and as described above, the rationale underlying the theoretical framework for teachers' dual SRL/SRT roles upholds teachers as agents for promoting students' proactive SRL. As seen in [Table 15.2](#), in their practical training program, teacher trainees are exposed to these reciprocal processes characterizing teachers' SRL/SRT cycles and students' SRL cycles, along with strategic considerations (what/how/why/by whom) through the three phases and elements of planning, monitoring, and evaluating lessons (Zimmerman, 2008). During their training course, the theoretical material is taught to preservice/in-service teacher trainees in university classrooms or pedagogical centers by specially trained professional educators ("instructors") via the two types of teaching instruction described next in Dimension B and utilizing practice with the interactive learning environments described in Dimension C below.

Model Dimension	Training Components		
Exposure to conceptual framework	Phases in cycle	Regulatory elements	Considerations
	Forethought	Planning	Declarative (<i>What?</i>)
	Performance	Monitoring	Procedural (<i>How?</i>)
	Reflection	Evaluation	Conditional (<i>Why? By Whom?</i>)
	[Metacognition & motivation]		[along the three phases]
Training in instruction	Explicit strategies	Engagement activation strategies	
	Presenting & naming:	Knowledge construction:	
	Theories	Process-oriented	
	Concepts	Student-centered	
	Strategies for SRL/SRT roles	Teacher roles:	
	Reciprocal processes	Activator	
	Considerations: <i>What/How/Why/By Whom?</i>	Challenger	
	Modeling:	Regulator	
	Thinking aloud	Motivation	
	Explaining	Feedback	
	Questioning		
	Core activities	Reflective prompts	
Interactive learning environment	Blended web-based learning and in-class practice		IMPROVE self-questions:
			Comprehension
	Video-scenario analysis:		Connection
	Ready-made expert/novice SRT clips		Strategy
	Ready-made student SRL clips		Reflection
			[Pop-ups on online forums & flashcards in class]
	Lesson designing		Generic
	Peer discussion and feedback:		vs.
	In class		specific
	Online forum		
	Individual/dyad/group/class activities		

Note. Elaborated from Kohen and Kramarski (in press).

Dimension B: Training in Instruction

Within the dual-role practical training model, the teacher-training program instructors expose preservice/in-service teacher trainees as learners to the theoretical framework, starting with two general types of teaching instruction (see [Table 15.2](#)): explicit strategies and engagement activation strategies.

Explicit Strategies

Researchers have argued that teachers' SRL/SRT knowledge is mostly tacit and remains non-conscious until teachers are challenged to use that knowledge explicitly (Randi, 2004). It was found that despite findings that school students' exposure to explicit SRL strategies are associated with gains in their SRL and learning performance (Kistner et al., 2010), explicit SRL/SRT strategy instruction remains rare in teacher-training programs. In our practical training model, we execute two steps in order to make SRL/SRT processes explicit to teacher trainees: presenting/naming and modeling.

First, training instructors should present and name the theories of SRL/SRT cyclical phases, concepts, and strategies to raise teacher trainees' explicit awareness about these processes' utility for increasing teachers'/students' academic success. Instructors should present teacher trainees with explicit what, how, why, and by whom justifications for using these concepts/strategies to promote their own SRL/SRT or their students' SRL.

Second, instructors should model some recommended self-regulation strategies such as thinking out loud, explaining, and questioning. By thinking aloud to externalize their thought processes, instructors may serve as an "expert model" who enables teacher trainees to hear effective ways of using SRL or SRT (Veenman, Bernadette, Hout-Wolters, & Afflerbach, 2006). Explaining may include explication of instructors' mental processes while performing a task such as solving a problem or answering a question. By questioning, instructors can guide trainees' performance through the three SRL/SRT phases of the lesson or task solution, which can improve self-awareness and control over-thinking, thereby improving teachers' performance (Kramarski & Revach, 2009).

Engagement in learning requires a process-oriented teaching approach to knowledge self-construction that focuses on students' activation, which consistently supports the student at the center of learning (Bolhuis, 2003). Researchers suggested three prominent SRT approaches that promote students' SRL engagement, where teachers take on the engagement roles of activator, challenger, and regulator of students' learning (van Beek et al., 2014), highlighting their importance in the practical dual SRL/SRT training model. As an activator, training instructors stimulate the teacher trainees to use SRL while learning by means of questioning, probing modeling, and presenting arguments or explanations. As a challenger, instructors urge teacher trainees to try out new SRL strategies via challenging environments that: provide complex tasks, employ explicit SRT strategies, generate a climate that effectively stimulates interest, encourage not only self-regulation but also co-regulation that has been associated with motivation to learn (Butler et al., 2004), and praise learners (give feedback). As a regulator, instructors may activate teacher trainees' SRL to different degrees along a continuum ranging from external to internal regulation.

Dimension C: Interactive Learning Environments

Research on school classrooms has indicated that teachers' use of SRL/SRT strategies and, in turn, their students' use of SRL increase significantly when teachers are trained in interactive learning environments that encourage and support active engagement in analysis of videotaped or live teaching/learning scenarios, accompanied by reflective peer discussions and feedback exchanges (Kramarski & Kohen, 2015; Kramarski & Michalsky, 2009b, 2010). In particular, the emerging web-based learning environment (WBL_e) has been pinpointed as an effective teacher education milieu with high potential for supporting teachers' self-regulation in school classrooms (Jonassen, 2000; Kauffman et al., 2008; Kramarski & Michalsky, 2009a). As a nonlinear environment incorporating activities for individual trainees, dyads, small groups, and the whole class, the WBL_e provides new possibilities for challenging teachers to develop their dual SRL/SRT roles by granting access to diverse autonomous and collaborative activity modes and opportunities to move beyond theoretical knowledge into proactive learning and teaching practice (see Azevedo, Taub, & Mudrick, 2018/this volume; Moos, 2018/this volume). As seen in [Table 15.2](#), such environments contain two major components: core activities and reflective prompts.

Core Activities

The core of the dual-role training model is implemented in blended WBL_e and in-class practical experiences, where the teacher training focuses on teachers' dual SRL/SRT roles and students' SRL in the context of analyzing ready-made videotaped learning and teaching scenarios presented on the computer screen with reflective prompts. Trainees analyze ready-made video clips of three types, focusing on classroom events related to expert or novice school teachers' SRL or SRT and to students' SRL, similar to the event example types presented in the three columns of [Table 15.1](#). By analyzing videotaped teaching/learning scenarios, teacher trainees can identify the videotaped teacher's goals, SRL/SRT strategies, and instruction approaches, and their effects on students' learning, thereby reflecting the teacher trainees' role as learners (i.e., SRL).

In addition, trainees engage in designing lessons. By developing lesson designs, teacher trainees must proactively examine more complex SRL/SRT considerations (what/how/why/by whom) that require the trainees to set their own goals for the lesson, select contents, adapt materials/environments to students' needs, and place their students at the center of the learning process via autonomous learning, thereby reflecting the teacher trainees' role as teachers (i.e., SRT), who help students gain SRL-promoting knowledge. Importantly, trainees also summarize their main conclusions from video-analysis and from lesson designs in preparation for ensuing reflective peer discussions that are conducted in online forums or in the classroom, with the whole class or within small groups/dyads. Peer exchanges aim to increase teacher trainees' knowledge and self-awareness of the reciprocal interplay between the teacher's dual SRL/SRT roles and the students' personal SRL role.

In line with research showing teachers' poor spontaneous ability to differentiate between SRL acquired for promoting their own learning and SRT acquired for promoting students' SRL, as justified by what/how/why/by whom considerations along the self-regulation cycles (Zimmerman, 2008), the embedment of reflective prompts into the learning environment has been recommended (Kramarski & Revach, 2009; Peeters et al., 2013). Prompts are external stimuli like self-questioning or simple statements that evoke strategy use, with the objective of enhancing SRL and SRT. Prompts provide the balance between necessary external support and desired internal regulation (Koedinger & Aleven, 2007). By stimulating teachers to think ahead and to think back, prompts help teacher trainees to focus on their own or others' thoughts during interactions with materials like video clips and lesson plans, and during interactions with peers such as discussions about teaching and learning scenarios (Kauffman et al., 2008; Kramarski & Kohen, 2015). From an instructional point of view, there are two vital ways to externally provide support for reflective SRL and SRT processes: generic prompts and context-specific prompts.

Generic Prompts

Generic prompts such as Stop and think (Davis, 2003) or What is the problem? (Mevarech & Kramarski, 1997, 2014) stimulate an open-minded thinking approach (Salomon & Perkins, 1989) that can be used across various situations and contents to focus attention. Such prompts provide teachers with opportunities to autonomously and flexibly attend to the learner's and the teacher's self-regulation roles, which may enhance teachers' ability to transfer their own SRL and SRT to the new context of students' SRL.

An integral part of the multidimensional teacher-training model is implementation of four generic self-questioning prompts for teacher trainees, based on Mevarech and Kramarski's (1997) four IMPROVE prompts, which aim to support key aspects of teachers' self-regulation along the SRL/SRT phases (see [Table 15.3](#), left column). Comprehension questions help trainees understand the task's or problem's goals or main idea (e.g., What is the task's objective?). Connection questions help trainees understand the task's deeper level relational structures by focusing on prior knowledge and by articulating thoughts and explanations (e.g., What is the difference/similarity?, How do I justify my conclusion?). Strategy questions encourage trainees to plan and select appropriate strategies and to monitor and control their effectiveness (e.g., What is the strategy? Why?). Reflection questions play an important role in helping trainees evaluate their solution processes by encouraging consideration of various perspectives regarding their solutions and processes (e.g., Does the solution make sense?, Can I plan/solve the task in another way?). These four self-questioning prompts can also be adapted to fit a particular context, thereby becoming specific prompts as described next (see sample adaptation to WBL on [Table 15.3](#)).

Context-Specific Prompts

The specific prompting approach directs attention to reflective thinking in a given context (Davis, 2003) by using detailed statements or questions to promote the comprehension and implementation of self-regulation (e.g., What do you see as the primary problem? Explain why). Specific prompts help trainees focus on details in their own or others' thoughts, processes, and actions, thereby achieving explicit knowledge about setting goals, planning, monitoring, and evaluation (e.g., Zimmerman, 2008) while eliciting overt what/how/why/by whom considerations. Thus, specific prompts may help trainees build an internal SRL/SRT model that in turn can aid them to promote students' SRL.

Table 15.3 Study 2: Combined generic+specific prompts approach based on IMPROVE self-questions embedded in technological pedagogical content knowledge (TPCK) for preservice teachers' dual roles

IMPROVE self-questioning generic prompts	TPCK-oriented specific prompts			
	Identifying objectives in hypermedia	Selecting content in hypermedia	Designing didactic material in hypermedia	Adapting hypermedia learning environment to students
Comprehension: What is the task's goal?	Do I understand the <i>aim</i> of the task? Explain.	Do I understand the <i>content-matter</i> in the task? Explain.	Do I understand the <i>didactics</i> in the task? Explain.	Do I understand the <i>uniqueness</i> of the environment? How can it help students' learning? Explain.
Connection: What are the similarities between tasks?	Are the goals I identified <i>similar</i> to what I was exposed to in the course? Demonstrate.	Are the terms <i>connected</i> to the subject of the lesson? Explain how.	What <i>prior</i> knowledge is important?	Which theories are <i>connected</i> to the learning environments?
Strategy: What are the tools/strategies appropriate for solving the task, and why?	Which <i>tools</i> will help me to <i>analyze</i> the learning objectives? Demonstrate.	Which <i>tools</i> will help me <i>analyze</i> the content? Demonstrate.	Which <i>tools/strategies</i> will help me understand whether the material is appropriate? Demonstrate.	Which hypermedia <i>tools</i> will I use to design the environment? Why? Demonstrate.
Reflection: Does the solution make sense?	Are the contents of the unit <i>related</i> to the objectives? Demonstrate.	Have I missed material that is <i>important</i> to the study? Demonstrate.	Are the <i>links</i> I selected suitable to task? Explain.	Is the learning environment I <i>designed</i> adapted to students' needs? Explain.

Note. The learner role (SRL) or the teacher role (SRT) was prompted by an electronic pop-up question (first generic, then specific) following each online task.

Generic vs. Specific Prompts

Research evidence on both prompts has focused mainly on school students and less on teachers. Moreover, evidence has been inconsistent regarding these prompts' possible differential effects. In the science and mathematics domains, generic prompts were identified as effective tools for guiding students to use a set of problem-solving strategies for complex and transfer tasks (Ifenthaler, 2012; Kramarski, Weiss, & Sharon, 2013). In contrast, other research favored specific prompts over generic prompts (e.g., Aleven, Pinkwart, Ashley, & Lynch, 2006; Kauffman et al., 2008). Research investigating generic vs. specific prompts' effects on teachers' dual SRL/SRT is scarce, particularly work examining real-time learning/teaching experiences as manifested in transfer tasks oriented explicitly to SRT processes and students' SRL. In the current practical training model, the entire process is stimulated by self-questioning prompts (i.e., generic/specific) that appear as pop-ups on the web or as flashcards during class discussions.

Research Evidence Bearing on the Multidimensional Teacher-Training Program

Although an accumulating body of studies have examined various aspects of this multidimensional dual-role training model, including variations in the core interactive learning activities (e.g., Bolhuis, 2003; Butler et al., 2004; Kauffman et al., 2008; Kistner et al., 2010; van Beek et al., 2014) or in the dual-role theoretical framework (Dembo, 2001; Dignath-van Ewijk, Dickhäuser, & Büttner, 2013; Moos & Ringdal, 2012; Peeters et al., 2013; Perry, Hutchinson, & Thauberger, 2008; Randi, 2004), joint dual-role research is still in its early stages. In particular, there remains little research examining reciprocal processes between teachers' dual roles and student outcomes, or investigating effects of diverse generic and/or specific prompts during teacher training. Accounting for potential prompting benefits of both top-down by starting with the big picture and bottom-up by piecing together elements, I conducted a series of studies with colleagues to assess the effects of the practical dual-role training model (Table 15.2) on preservice and inservice teachers under varying conditions, using different prompting approaches based on the IMPROVE questions.

As presented next, three of these studies examined the training model's effects for preservice science teachers' SRL/SRT development and task performance related to technological pedagogical content knowledge (TPCK; Angeli & Valanides, 2009). TPCK refers to the concurrent development of technology knowledge and pedagogical content knowledge via technology-rich lessons (see sample prompts in Table 15.3). The fourth study investigated the holistic reciprocal model (Figure 15.1) for inservice mathematics teachers' SRL/SRT and mathematics achievements and for their students' SRL and mathematical achievements in an actual classroom.

Study 1. Effects of Generic Prompts, Directed Singly to Only One of the Three Self-Regulation Phases, on Preservice Teachers' SRL/SRT and TPCK Performance

Considering teachers' difficulties in SRL knowledge and SRT practice (Spruce & Bol, 2015), particularly regarding tasks' goal-setting (i.e., forethought phase) and evaluation (i.e., reflection phase), Kramarski and Michalsky (2009b) aimed to compare three generic metacognitive self-questioning prompts that each focused on

a single phase of the SRL/SRT cycle. In a 56-hour quasi-experiment to investigate which kind of WBL prompt would optimally develop preservice teachers' dual SRL/SRT roles and their performance on TPCK-oriented analysis of videotaped lessons and lesson-design tasks, 144 first-year preservice science teachers were randomly assigned to one of three self-regulation groups: planning, monitoring, or evaluation, according to the group's generic prompting phase (Zimmerman, 2008). Based on IMPROVE self-questions (Mevarech & Kramarski, 1997), the planning group received comprehension questions at the forethought phase, before performing TPCK-oriented lesson analysis/design; the monitoring group received strategy questions during performance; and the evaluation group received reflection questions at the end of the process.

Measures were administered at pretest and posttest. Participants completed two self-reports of metacognitive awareness along the three-phase cycle (Schraw & Dennison, 1994): (a) to measure SRL (e.g., At the end of the task I ask questions to make sure I know the material I have been studying); and (b) to measure SRT (e.g., I know if the lesson was good immediately when I finish teaching it). Also, TPCK-oriented video-analysis and lesson-design performance were assessed by measuring preservice teachers' TPCK of four main issues: identifying goals, selecting contents, designing didactic materials, and adapting learning environments to student needs (see examples on [Table 15.3](#)). Analysis showed a clear benefit for prompts given in the evaluation phase, after task performance. Such post-action prompting with reflection questions focusing on only one self-regulatory phase revealed a synergic effect on the entire dual SRL/SRT cycle (i.e., planning, monitoring, and evaluation), which in turn seemed linked to better analysis and design of lessons oriented to the four main TPCK issues (see [Table 15.3](#) examples). In contrast, strategy prompts given to the monitoring group during performance led to the lowest scores in both SRL/SRT and TPCK measures.

These findings supported theoretical suggestions that the reflection phase plays an important part in acquiring self-awareness and learning competencies (e.g., Zimmerman, 2008). Despite these interesting findings, we suggest caution in interpretation because these data were self-reported and collected only at the beginning and end of the course; therefore, conclusions cannot be drawn regarding possible SRL/SRT patterns along the course of the study. This shortcoming was addressed in the following three studies.

Study 2. Effects of a Combined Generic+Specific Prompts Approach on Preservice Teachers' SRL/SRT and TPCK Performance

This study (Kramarski & Michalsky, 2010) resembled Study 1 (i.e., 56-hour quasi-experiment on dual SRL/SRT roles and TPCK-oriented lesson analysis/design in hypermedia technology environment) but focused on the effects of a combined generic+specific prompts approach for 95 preservice science teachers randomly assigned to one of two groups. The experimental group received IMPROVE self-questions in a complementary format (see [Table 15.3](#)), first generic and then specific prompts, to promote pre-service teachers' SRL/SRT considerations (i.e., what/how/why/by whom) relating to the four main TPCK issues. The control group received a general introduction to TPCK issues and experienced the same TPCK-oriented hypermedia tasks but without the SRL/SRT framework and prompts.

Four measures were administered at pretest and posttest: performance measures of TPCK-oriented analysis and design skills as in Study 1 (Kramarski & Michalsky, 2009b) and two online self-reflection measures oriented to the three self-regulation phases (Schraw & Dennison, 1994): (a) self-reflections concerning lesson analysis, reflecting trainees' learner cycle (i.e., SRL) of acquiring knowledge and self-regulation; and (b) self-reflections concerning lesson designing, reflecting trainees' teacher cycle (i.e., SRT) of helping students gain knowledge and self-regulation. Quantitative analyses showed that the experimental group exposed to the generic+specific prompts significantly surpassed the control group in developing TPCK both for lesson analysis and design skills relating to the four main TPCK issues in the hypermedia environment. Furthermore, compared to the controls, the experimental group demonstrated higher levels of online self-reflections at all three phases about their learner role (i.e., SRL—analyzing lessons) but continued to demonstrate relative difficulties in reflecting on their teacher role (i.e., SRT—designing lessons) at all three phases.

Study 3. Effects of Generic Versus Different Specific Reflection Prompts Directed to the Three Phases on Preservice Teachers' SRL/SRT and TPCK Performance

Self-reflection abilities were selected for further investigation in light of preservice teachers' documented difficulties in conducting critical self-reflection (see Study 1; Kramarski & Michalsky, 2009b) and in conducting self-reflection on the lesson-design skills oriented to TPCK (see Study 2; Kramarski & Michalsky, 2010). Study 3 (Michalsky & Kramarski, 2015) resembled Study 2 (i.e., 56-hour quasi-experiment on dual SRL/SRT roles and TPCK-oriented lesson analysis/design in a technology environment) but focused also on self-reflection ability and compared generic prompts with different specific self-reflection prompts based on the IMPROVE questions for 199 preservice science teachers randomly assigned to one of four reflective prompting groups: generic reflections ("stop and think"), specific judgment reflections ("thinking back"), specific modification reflections ("thinking ahead"), and combined specific reflections (judgment+modification, "thinking back and ahead" explicitly directed to all three phases of the SRL/SRT cycle). Data were gathered online at pretest, posttest, and follow-up on: (a) designing an SRT-oriented lesson transfer task that was not practiced directly in the course, and (b) two self-reflection measures referencing the three SRL/SRT phases: judgment (i.e., Satisfied/dissatisfied with lesson design?) and modification (i.e., Intend to improve performance? Explain how).

Findings revealed that the combined specific prompting approach (i.e., judgment+modification) surpassed all other groups. Also, each of the single specific prompting approaches (i.e., judgment and modification separately) led to better performance than the generic approach. These findings emerged both for self-reflective judgments and modifications directed to SRL/SRT phases as well as for the transfer task, which asked trainees to design SRT-oriented lessons emphasizing technology's added value enhancing pedagogical and self-regulation issues. Interestingly, a short-term transfer effect on lesson design emerged immediately after training, as expected, but long-term lasting effects also emerged after preservice teachers continued studying in their natural environment for another full semester without experiencing any prompts or TPCK focus. These results call for reinterpreting the instructional-reflective framework of teacher education programs to include not only thinking-back but also thinking-ahead reflection throughout the SRL/SRT cycles, to help develop preservice teachers' capacity to integrate technology into their lesson designs.

Study 4. Reciprocal Effects of Generic Prompts on Inservice Teachers' SRL/SRT and Their Students' SRL in the Context of Mathematical Problem Solving

To further examine the SRL/SRT training model (see [Table 15.2](#)) as demonstrated in Studies 1–3, Kramarski and Shilo (2015) extended the focus in several ways: by investigating a holistic model of the reciprocal interplay between teachers' SRL/SRT and their students' SRL ([Figure 15.1](#)), exploring inservice rather than preservice teachers, studying a new context of teaching mathematical problem-solving, and using mixed-method assessments including authentic in-class measures.

In this five-week quasi-experiment, 32 inservice math teachers and their fifth-grade students (n = 813) were randomly assigned to an experimental or control group for 16-hour inservice training in mathematics problem-solving. The experimental group received the multidimensional teacher-training model (see [Table 15.2](#)) supported by generic IMPROVE questions to prompt teachers' dual SRL/SRT roles and students' SRL along the cyclical phases in teaching or learning activities. The control group received a strategic approach recommended by the official math curriculum, without self-regulatory guidance.

Mixed-method assessments at pretest and posttest were similar for teachers and students: (a) self-reports on "mathematical knowledge for teaching" for teachers and mathematical problem-solving achievements for students; (b) teachers' and students' SRL at the three phases (Schraw & Dennison, 1994); and (c) self-efficacy beliefs in regard to teachers' and students' teaching/learning. Videotapes of actual lesson events were coded for teachers' proactive SRT actions in supporting students' SRL, and think-aloud protocols were coded to assess 30 students' solution of a novel mathematical problem in focus groups.

The experimental group revealed significantly higher change on all measures compared to the control group. The untrained teachers' and students' self-perceived efficacy at teaching/learning even decreased at posttest. Qualitatively analyzed videotaped lessons showed that, compared to the controls, the teachers who were trained in the SRL/SRT model adopted more student-centered actions/beliefs by allocating time to thinking and opportunities for sharing knowledge and autonomous learning. Similarly, their students' think-alouds during the novel task manifested more strategic mathematical thinking. These outcomes can be attributed to the training program's explicit usage of the dual SRL/SRT model, with generic prompts that created a concrete "internal model" to help teachers and students think about what should be observed, said, or done, and to encourage asking why questions during learning-teaching events. This study offered support to claims that teachers' ability to cultivate students' SRL is tied to teachers' own SRL/SRT, which requires explicit training even for experienced inservice teachers (White & Bembenutty, 2014).

Future Research Directions

The multidimensional training model presented in this chapter makes an important contribution to the literature, exploring the interrelations between preservice/inservice teachers' differential self-regulatory roles as learners (i.e., SRL) and as teachers (i.e., SRT), which, in turn, have the power to affect their students' SRL in class, as theorized in [Figure 15.1](#). The research studies reviewed here are a starting point for testing this claim by implementing the theoretically grounded dual SRL/SRT training model supported by different types of generic and specific reflective IMPROVE prompts.

Future researchers would do well to expand empirical scrutiny of the multidimensional dual-role training model. In the studies presented here, the model was assessed for preservice teachers in university classrooms in the science domain (i.e., TPCK) and inservice teachers in authentic school classrooms in the mathematics domain (i.e., problem solving), focusing on metacognition in the self-regulation cycle oriented to planning, monitoring, and evaluation phases. Furthermore, transfer ability was tested only on an SRT-oriented lesson design (i.e., Studies 1–3). Future studies should extend study of the model to other academic domains and self-regulation aspects like motivation and affect (Efklides, Schwartz, & Brown, 2018/*this volume*).

Importantly, research is still in its infancy regarding the dual model's effects for the holistic reciprocal relations between teacher's SRL/SRT and students' SRL in authentic classrooms. In particular, substantial future research attention should focus on the relatively disregarded part of the reciprocal processes presented in [Figure 15.1](#), namely how the students' SRL behaviors may be leveraged to further improve the teacher's SRT. That is, researchers should investigate how effectively self-regulated teachers learn not only from their own SRL experiences but also from analyzing how their own SRT impacts students' SRL behaviors and achievements, in order for teachers to refine future attempts to promote students' SRL.

Moreover, transfer effects should be assessed further, using multiple real-time measures like think-aloud (Greene, Deekens, Copeland, & Yu, 2018/*this volume*) or other trace and temporal/sequential process data methodologies (Bernacki, 2018/*this volume*). Testing can occur immediately after training as well as after a follow-up period to study lasting effects in authentic real-class situations. Such assessments could reveal both self-regulation and co-regulation, at interplay in the holistic reciprocal SRL/SRT dual model and in domain-related performance. Comparing well-structured (e.g., math, science) vs. ill-structured domains (e.g., language literacy) has been pinpointed as relevant to prompts' effectiveness for SRL/SRT (Aleven et al., 2006). Thus, generic prompts that trigger "thinking about the problem" may be most effective in well-structured domains by allowing trainees more latitude to discover deficits in their own knowledge. In contrast, in an ill-defined domain, prompts of a specific nature may be more beneficial to elicit insightful interpretations in pedagogical issues.

This chapter underscored that teachers, and preservice teachers in particular, are always learners too, which requires them to consider their dual SRL and SRT roles simultaneously in order to effectively promote students' ability to self-regulate their own learning (Kramarski & Michalsky, 2009b, 2010; Kramarski & Shilo, 2015; Peeters et al., 2013; Perry et al., 2008). The multidimensional training model offers a blended, practical, web-based means, within class activities, to stimulate dual-role considerations in teachers at all stages of their career, through a user-friendly set of self-questioning prompts embedded in classroom scenario analysis and lesson design, aiming to arouse trainees' awareness about what, how, and why self-regulation happens and by whom: by teachers (i.e., SRL or SRT) or by students (i.e., SRL). The model offers workable guidelines for enhancing professional training by fostering the acquisition, activation, and application of teachers' SRL/SRT as agents to promote students' SRL (Table 15.2). This clear operational program may be widely applied in diverse professional settings, from the university classroom to mentoring sessions in the field, thereby inserting the concept of self-regulation as an integral part of teachers' critical reflective discourse, which may lead over time to the construction of mental models for dual SRL/SRT roles (Hattie & Timperley, 2007; Krauskopf, Zahn, & Hesse, 2012).

This research evidence adds to current understandings about the effects of generic and specific prompts for teachers, inasmuch as such prompts were previously investigated mostly for school students, with inconsistent findings about their effectiveness. The findings favoring specific over generic prompts corroborated prior research, which reported that teachers at the novice stage are often unable to spontaneously and systematically direct their attention to key elements of SRL/SRT instruction like goals or strategies (Star & Strickland, 2008), requiring direct instruction to support development of a systematic mental model (Krauskopf et al., 2012). These findings are important in light of previous outcomes (Spruce & Bol, 2015), which showed that teachers demonstrated gaps between their SRL knowledge and their SRT practice, in particular around goal-setting for a task and evaluation after a learning event. In sum, in light of the dual roles' overall importance to address 21st century global challenges, the current chapter presents a multidimensional evidence-based teacher-training model offering future directions for teachers' SRL/SRT to promote students' SRL.

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Section III

Technology and Self-Regulation of Learning and Performance

16 Emerging Classroom Technology

Using Self-Regulation Principles as a Guide for Effective Implementation

Daniel C. Moos

Introduction

Educational systems have a long tradition of integrating technological advances in the classroom to enhance the learning experiences for students. Current integration reflects a growing trend to design environments that enable students to learn with, as opposed to from, classroom technology. Hypertext, a common technology in the classroom, reflects this principle through design features that promote active participation in the learning process. For example, access to textual information through hyperlinked nodes offers immediate and nonlinear access to text-based information. Advances in the field have enabled classroom-based technology environments to move beyond text-based nodes. Students can now access vast amounts of information presented through multiple representations, often in the form of interactive videos and audio. Computer-based learning environments that integrate multiple representations with text are described as hypermedia.

At its inception, hypermedia was considered a unique tool for engaging students in a constructive learning process due to its inherent design features (Jonassen & Land, 2000). Unlike existing technologies and more traditional approaches to learning, hypermedia offers nonlinear access to vast amounts of information, provides students with the opportunity to self-pace instruction through hyperlinks, and potentially captures students' attention due to the use of multiple representations (Nielson, 2000). However, research from various fields revealed that classroom technologies optimize learning only if they are designed in a manner that is consistent with how students think and learn within these environments. For example, access to nonlinear information, a common design feature in today's classroom technology, requires students to actively monitor the relevancy of multiple sources of information in relation to developing schemas. Furthermore, multiple representations require the use of varied strategies to optimize learning (Jonassen & Reeves, 1996).

These processes have been characterized as self-regulated learning (SRL; Azevedo, 2008; Pintrich, 2000; Schunk & Zimmerman, 2013; Winne & Hadwin, 1998; Zimmerman, 2008). Research has demonstrated that SRL is a critical variable in learning with classroom technology, particularly hypermedia-based environments. This chapter first provides an overview of relevant theories that have been used to examine how students self-regulate learning with hypermedia-based classroom technology. This section is followed by an overview of empirical evidence that has examined what SRL processes are most predictive of learning in these environments. The chapter concludes with implications for using SRL principles to guide effective implementation of classroom technology.

Overview of Theories and Methodologies

Understanding how students are active agents in the learning process is of great interest to educational researchers, and the field of SRL offers a guiding framework for this research area. While this well-established field has produced divergent theoretical perspectives (Zimmerman, 2008), there is a general consensus concerning the underlying assumptions and the operational definition. SRL is conceptualized as processes related to the regulation and monitoring of cognition, behavior, and motivation (Azevedo, Feyzi-Behnagh, Duffy, Harley, & Trevors, 2012; Winne, 2005; Zimmerman, 2006). Four core assumptions provide the foundation for this broad conceptualization (Pintrich, 2000). First, learning is a byproduct of an active construction of knowledge guided by idiosyncratic goals and choice of strategies. Second, SRL models assume that students modify behavior to

meet idiosyncratic goals. Third, behavior modification results from monitoring and regulating processes related to cognition and motivation (Duffy & Azevedo, 2015). Lastly, regulatory behavior is a mediator between (a) an individual's performance, (b) contextual factors, and (c) personal characteristics.

Information Processing Theory

These core assumptions provide the foundation for different SRL theories (see Zimmerman & Schunk, 2001, for a review). While various theories have been used to explain active learning in a myriad of contexts, the Information Processing Theory (IPT; Winne, 2018/this volume; Winne & Perry, 2000) and the Social-Cognitive Theory of SRL (SCT; Schunk & Usher, 2012; Usher & Schunk, 2018/this volume; Zimmerman, 2008) have been the two frameworks most widely used to examine how students self-regulate their learning with classroom technology. IPT describes self-regulation across four phases: (1) understanding the task; (2) goal-setting and planning how to reach the goal(s); (3) enacting strategies; and (4) metacognitively adapting studying. During the first phase, the student constructs a perception of the task from two core sources: Cognitive Conditions and Task Conditions. Information about the task, such as learning goals, constitutes Task Conditions, while prior domain knowledge related to the learning task reflects Cognitive Conditions. These two sources of information affect how a student understands the task (Winne, 2001). The student develops an idiosyncratic perception of the task, which leads to the creation of learning goals during the second phase of self-regulation.

This second phase includes the creation of plans to meet these goals, which can be updated as students proceed through the learning task (Butler & Winne, 1995). Strategy use, which constitutes the third phase of SRL, facilitates the construction of information. The final phase includes monitoring activities and cognitive evaluations about discrepancies between goal(s) and current domain knowledge. Identifying potential discrepancies enables students to adapt their planning and/or strategies to more effectively meet the learning goal(s). This framework assumes a recursive relationship between the SRL phases. Information processed in one phase can become an input to subsequent information processing (see Winne, 2018/this volume).

Social Cognitive Theory

The SCT approach to explaining self-regulation during learning shares many of these same assumptions. Much like the IPT framework, this theoretical framework assumes that self-regulation consists of interactive phases. The first phase of SRL (i.e., forethought) entails an analysis of the learning task, which results in the creation of learning goals. This theory underscores the role of motivation orientations in the task analysis and subsequent creation of learning goals. Various motivation orientations are assumed to influence the cognitive and metacognitive processes that occur during the next phase of SRL, the performance phase. Much like the IPT framework, this theoretical framework emphasizes the role of metacognitive monitoring during performance. Internally generated feedback, which is produced through metacognitive monitoring activities, guide students' regulation and govern task execution. Self-reflection, the final phase of SRL, occurs when students evaluate and develop reasons for their performance. Self-reflections potentially affect subsequent motivational orientations, a relationship that underscores the dynamic and iterative nature of SRL processes (see Efklides, Schwartz, & Brown, 2018/this volume).

Summary of Research on SRL and Classroom Technologies

Methodology Overview

These theories provide a framework for measuring how students self-regulate learning with classroom technologies. The emergence of methodologies that produce trace data, for example, reflect the commonly held theoretical assumption that cognitive and meta-cognitive activities are dynamic processes that unfold within specific learning contexts. Early forms of methodology that reflected this theoretical assumption, such as error detection tasks, were designed to measure monitoring and control in specific contexts. Inducing errors enables the observation of when and whether the student detects the error, and what the student does once the error is

detected. SRL processes related to monitoring have been measured both by asking the students to mark the errors (e.g., by underlining) and through eye fixations. It is considered an observable indicator of SRL activity when students underline and/or fixate on a specific point within the environment. These indicators are labeled as traces (Winne, 2001).

More recent classroom technologies offer methods to unobtrusively collect trace data in the form of real-time information on studying actions when learning. Winne and colleagues, for example, developed a software program (gStudy) that includes multimedia learning kit packages. Guided by the IPT framework, gStudy is designed to: (a) support metacognitive monitoring; (b) reduce cognitive load so students can more efficiently use cognitive resources; and (c) prompt the use of new studying tactics. Information on learning is captured from traces recorded in the software program, and represents fine-grained and temporally identified tactics and strategies employed by the student during learning (Winne, 2005). For example, a quicknote tool allows students to annotate a segment of highlighted text through selecting an appropriate label (“don’t understand” or “important”). This action supports “thinking about their thinking” (i.e., metacognition) while simultaneously providing a precise time-stamped record of this self-regulatory process. Data on learning events are also captured through clicks on a menu or scrolls through content. These “view events” are recorded in the software and a log file analysis is performed on recorded XML files using LogAnalyzer (Hadwin, Oshige, Gress, & Winne, 2010). These frequency counts and time-event position graphs enable an analysis of the dynamic interactions between various self-regulatory processes during learning with classroom technology.

In addition to other cutting-edge technology advances that capture cognitive and metacognitive traces of student learning with technology (see Azevedo, Taub, & Mudrick, 2018/this volume), research in the SRL field has utilized the concurrent think-aloud. The field of cognitive psychology has a robust history of employing concurrent think-alouds, particularly within the field of reading comprehension (see Ericsson, 2006, for a review). This methodological approach requires participants to verbalize their thoughts and actions as they learn. Despite common misconceptions, asking individuals to verbalize thoughts will not disrupt the learning process if they are not asked to elaborate these thoughts (Ericsson & Simon, 1993). Concurrent think-alouds provide additional trace data of cognitive and metacognitive processes that may not otherwise be accessible through log file analyses (see Greene, Deekens, Copeland, & Yu, 2018/this volume). The use of these theoretically grounded methodologies has positioned researchers to address fundamental questions, including: What SRL processes are most predictive of learning with classroom technology? The following sections address this question within today’s classroom technology.

Research Within the Context of Today’s Classroom Technology

Classroom-based technology offers students by access to nonlinear information presented through multiple representations. Furthermore, today’s classroom models, such as the Flipped Classroom (FC), capitalize on technology to provide individualized instruction and more flexible learning environments. In the FC model, lectures and direct instruction are moved to homework assignments, often in the form of online hypermedia lectures. Videos assigned as homework offer students the opportunity to control the pacing and sequencing of homework, and thus the learning process becomes more individualized. Additionally, pacing issues found in more traditional classrooms are potentially minimized because students have the opportunity to self-pace content delivery. This fairly unique approach to teaching and learning is becoming immensely popular, as evidenced by both its recognition and use in classrooms (Johnson, Adams, Estrada, & Freeman, 2014). Despite the increasing prevalence of the FC model, however, teachers report mixed experiences with its effectiveness. These mixed experiences can be explained by the model’s origin and the potential self-regulatory challenges students may face when learning with videos assigned as homework.

Jonathan Bergmann and Aaron Sams, pioneers of the FC, developed this model in response to students frequently missing end-of-day classes for other school-related events. The teachers began recording lectures so students could view the delivery of content outside of the class. By moving content delivery to homework, the teachers

were able to shift class time to a more student-centered learning environment. Additional class time was used for collaborative activities, hands-on learning, and individual interactions between students and teachers. Bergmann and Sams (2012) reported an increase in student engagement and an improved experience in meeting individual needs during class. Struggling students could receive individual attention during class, while advanced students could continue to progress due to the flexible schedule enabled by the FC model.

While quantitative and qualitative data on the effectiveness of FC are still fairly limited, some teachers have reported higher student achievement, improved attitudes toward learning, and improved student motivation. Furthermore, teachers using this model are less likely to be faced with the daunting task of creating an appropriately paced lecture, which is often designed to meet the needs of middle-performing students. Higher-performing students can become disinterested, while lower-performing students may become frustrated in such lectures. Moving the content delivery to self-paced videos assigned as homework provides a more individualized educational experience. Consistent with the inherent design features of hypermedia environments, videos provide students with the opportunity to control the pacing and sequencing of information. Struggling students can pause and rewind the video as many times as necessary, whereas those who have developed sufficient mastery can spend less time viewing the content. Additionally, videos also offer the opportunity for information to be presented through multiple representations.

Nonlinear access to information individualizes the learning experiences, but these environments potentially introduce fairly unique challenges that can undermine learning if unmet. In particular, learning with hypermedia environments, such as videos designed for FCs, creates cognitive and metacognitive demands. When presented with multiple representations of information, students need to determine how much time to spend in different representations of information (Azevedo, 2014; Moos & Azevedo, 2008; Shapiro, 2008). Furthermore, the ability to control the sequencing and pacing of information requires students to monitor comprehension and use repair strategies when comprehension breaks down (Azevedo, 2009; Johnson, Azevedo, & D'Mello, 2011; Greene & Azevedo, 2009; Moos, 2014; Winne & Nesbit, 2009). To complicate matters, students need to accurately monitor emerging understanding in order to maximize learning with this type of technology. Research has routinely demonstrated that certain metacognitive activities, such as monitoring emerging understanding and relevancy of content, are most predictive of learning with this type of classroom technology.

The Role of Training, Scaffolds, and Prompts in Learning With Classroom Technology

Despite the importance of SRL processes when learning with classroom technology, many students fail to adequately self-regulate during learning. These failures have been explained by individual characteristics, such as lack of prior domain knowledge and low self-efficacy (Moos & Azevedo, 2008a, 2008b). Students with low self-efficacy lack the task-specific confidence to engage in effortful self-regulatory processes, whereas those with low prior domain knowledge do not have the requisite knowledge base to engage in metacognitive activities. In order to better support students in their self-regulation with classroom technology, researchers have examined various types of support, including SRL training, prompts, and scaffolds. Researchers have generally found positive benefits of short SRL training sessions that explicitly teach students empirically and theoretically based self-regulatory processes, how to use them, and why they are important. In a foundational study, Azevedo and Cromley (2004) demonstrated that a 30-minute training session significantly improved students' conceptual learning about a complex science topic with hypermedia. This training session was guided by a script based on Pintrich's conceptualization of the SRL phases and areas (Pintrich, 2000). This script reflected theoretically grounded SRL processes that have been empirically proven to enhance learning with classroom technology (e.g., prior knowledge activation, judgment of learning, content evaluation, and knowledge elaboration).

In addition to SRL training prior to learning with technology, researchers have also found that embedded prompts and scaffolds positively support active participation in learning (Bannert, 2009). Scaffolding was originally conceptualized as ongoing support that assists students with elements of a learning task that are beyond their current level by enabling them to focus on the elements that are within their range of competence (Wood, Bruner,

& Ross, 1976). This original conception of scaffolding highlighted the role of an expert (e.g., teacher or parent) in assisting the student. Effective scaffolding requires an expert to provide content knowledge and facilitate the use of necessary strategies. Providing questions that engage students in self-reflection, highlighting critical features of the learning task, and offering just enough support for the student to accomplish the goal are core components of effective scaffolding (Wood & Middleton, 1975).

This concept has evolved over the years, which has led to the identification of additional elements involved in scaffolding (Palincsar, 1998). First, a shared understanding of the learning task goal, often described as intersubjectivity (Rogoff, 1990), enhances the effectiveness of scaffolding. A shared understanding results in a combined ownership between the student and expert. In addition to a shared understanding with the student, the expert needs to engage in ongoing, dynamic assessment and support of the student. Scaffolding should reflect assistance that is appropriate for “this tutee, in this task at this point in task mastering” (Wood et al., 1976, p. 97). This individualized approach to providing assistance necessitates ongoing diagnosis and support during the learning task, which allows the expert to provide appropriate support and feedback. Lastly, effective scaffolding entails reducing assistance as student competence increases and the process for completing the particular task is internalized (Rogoff, 1990). Recent technological advancements have enabled hypermedia environments to embed adaptive scaffolding within the learning environment. In addition to an interface that offers several tools to support SRL, these environments provide pedagogical agents that are readily available and accessed on screen during the learning task (see Azevedo et al., 2018/this volume).

Researchers have also demonstrated how alternative forms of support can be easily added to existing classroom technology, such as videos designed for FCs. Embedded static prompts, for example, can direct students to perform activities at specific points during the learning task (Wirth, 2009). These prompts can be presented in various forms, including simple questions (“What is your first step in this learning task?”), incomplete sentences (“Your first step should be ...”), and explicit procedural instructions (“Your first step should be to write a list of questions you have on this topic”; Bannert, 2009). Empirical research provides direction on the types and timing of prompts that successfully support self-regulation during learning with hypermedia (Ifenthaler, 2012).

The SCT approach to self-regulation (Schunk & Mullen, 2012; Usher & Schunk, 2018/this volume; Zimmerman, 2008) offers an accessible framework for creating and embedding such prompts. This theory suggests that students need to engage in self-regulatory processes across three phases of learning (forethought/planning, performance/monitoring, and self-reflection), a theoretical assumption that has been empirically supported. Planning prompts, which should be provided at the start of learning task, are designed to activate relevant prior domain knowledge (“What do you already know about the topic for this learning task?”) and assist in planning for the learning task (“What strategies do you think will be effective while learning about the topic for this learning task?”). The monitoring prompts, which should be provided approximately halfway through the learning task and/or at probable points of conceptual change, are intended to assist students in monitoring their emerging understanding (“What information have you learned so far?” and “What questions (if any) do you have about the information presented?”). These prompts can also be designed to support monitoring of strategy use (“How effective have your strategies been in learning about this topic?”). Lastly, students should be prompted to engage in self-reflection with reflection prompts provided at the conclusion of the learning task (“Do you need to review any material in the video because of a gap in understanding?”).

The effectiveness of these prompts on SRL with classroom technology has been empirically demonstrated with older students. Moos and Bonde (2015), for example, demonstrated that embedding static prompts in classroom technology can successfully support self-regulation during learning. In this study, SRL prompts were embedded in a video designed for an undergraduate Educational Psychology FC on motivation theories. Participants were randomly assigned to learn with a video or a video + SRL prompts. Prior knowledge and learning outcomes were measured with an essay and use of self-regulatory processes was measured with a concurrent think-aloud. Results indicated that monitoring of understanding was significantly related to pausing and restarting the video during the learning task. Furthermore, students who received the static prompts during the video engaged in more SRL processes while learning with hypermedia, including monitoring understanding and activating prior domain

knowledge. Lastly, instructional efficiency data indicated that embedding SRL prompts in the video did not negatively affect participants' mental effort during the learning task. These results suggest that static prompts offer a practical advantage because teachers can easily create and embed prompts that align with the core assumptions of SRL theories. However, while static prompts offer a practical approach to supporting students' self-regulation with classroom technology, they cannot be adapted to meet the individual needs of students. Responses to planning, monitoring, and reflection prompts can be highly individualized due to a number of factors, an issue that needs to be more fully explored in future research.

Future Directions

While current research provides empirical evidence on what SRL processes predict learning with classroom technology and the type of prompts that support these processes, a number of questions need to be addressed with future research. First, the dynamic relationships among SRL phases needs to more fully explored in order to inform the use of prompts in classroom technology. Much of the research in this area is guided by theories that assume phases are interactive. As an example, the SCT approach assumes that task analysis and goal setting, which occur in the forethought phase, affect how students use cognitive strategies during the following phase of performance. Self-evaluations, which occur in the final phase of reflection, are grounded in perceptions of individual performance and assessment criteria. These self-evaluations can result in negative or positive emotions, which influence future task analyses and motivation orientations. This theoretical perspective underscores the dynamic and interactive nature of SRL processes, which raises a practical question regarding static prompts designed to support SRL. Is it necessary to provide prompts across all three phases of SRL? Theoretically, prompting students in the first phase (e.g., activate prior domain knowledge and set appropriate learning goals) affects engagement during the performance phase of self-regulation, even in the absence of a prompt designed for this phase. Future researchers would be well served to more fully explore how static prompts provided during single phases of SRL differentially affect learning with classroom technology.

A second important issue with future research concerns the potential of domain specificity of SRL processes, which has implications for designing static prompts within specific learning tasks. A growing body of research has explored this critical issue in the field. Poitras and Lajoie (2013), for example, proposed that students' comprehension of complex historical topics reflects metacognitive activities that are specific to learning within this domain. According to this proposed framework, uncertain, unknown, or unreported causes of historical events leads to a breakdown in comprehension. Disciplinary-based metacognitive and cognitive practices facilitate the repair of such comprehension breakdowns.

Greene et al. (2015) provided further empirical evidence supporting the assumption that some SRL processes are domain specific. In this study, college students were randomly assigned to a learning task that involved either a history or science digital library. Using evidence generated by a think-aloud protocol, the researchers examined the extent to which SRL processes differed by academic domain. While the use of some SRL processes was similar across domains (e.g., the importance of corroborating sources), differences emerged (e.g., the predictive validity of self-questioning). Similar findings regarding the potential for domain-specificity have been reported in other academic areas, as well. Hrbáčková, and Hladík (2011) assessed how college students self-regulated their learning in different academic courses. Findings suggested that students were relatively inconsistent in their metacognitive activities across these courses. Furthermore, motivation orientations were significantly higher for those courses viewed as more useful for future professions.

Other lines of research have supported these findings of domain-specificity, which suggests that SRL is not stable across learning tasks and domain. Moos and Miller (2015), for example, used self-report and think-aloud data from participants to examine the stability of SRL processes between learning tasks. Participants, all of whom were pre-service teachers, learned about a science topic (i.e., Circulatory System) and a topic related to their area of study (i.e., Constructivism). Results indicated that whereas some motivation orientations were stable between topics, task value and self-efficacy was significantly higher for teachers' area of study. Not surprisingly, this

higher level of motivation led to the increased use of strategies during the learning task. Taken together, these findings suggest the effectiveness of generic prompts may be limited when learning necessitates domain-specific SRL processes and/or individual characteristics require differentiated prompts.

Conclusion

Classroom technology has substantially evolved since the emergence of media for instructional purposes in the 20th century. Today's classrooms place students in the position of learning with technology, as evidenced by the ubiquitous presence of hypermedia-based environments. Students can now readily interact with vast amounts of information presented in a nonlinear format. While these features should engage students in a constructive learning process, research has revealed that the design of classroom technologies needs to be consistent with how students think and learn within these environments. Successfully navigating nonlinear information and developing comprehension requires students to actively self-regulate their learning. Many students do not sufficiently self-regulate their learning, which can create challenges and undermine learning within hypermedia-based classroom technologies. In response to these challenges, research has examined the impact of scaffolds and prompts designed to support student self-regulation while learning with classroom technology. Technological advances have led to the creation of adaptive scaffolding that can be embedded within classroom technology (Azevedo, Johnson, Chauncey, & Burkett, 2010). Less sophisticated approaches to supporting SRL, such as static prompts aligned with theory, also potentially offer a mechanism to support students' active participation while learning with classroom technology.

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17 Understanding and Reasoning about Real-Time Cognitive, Affective, and Metacognitive Processes to Foster Self-Regulation with Advanced Learning Technologies

Roger Azevedo, Michelle Taub, and Nicholas V. Mudrick

Self-regulated learning (SRL) involves learners' ability to monitor and regulate their cognitive, affective, metacognitive, and motivational¹ (CAMM²) processes and plays a critical role in learning about challenging domains (e.g., science, mathematics) while using advanced learning technologies (ALTs; e.g., intelligent tutoring systems, simulations, serious games, hypermedia, tangible computing, virtual reality). Additionally, emerging empirical evidence indicates that CAM processes play an important role in learning and problem solving as well as self-regulation with ALTs. However, capturing CAM processes during learning with ALTs poses several major conceptual, theoretical, methodological, and analytical challenges. For example, researchers currently measure CAM SRL processes using several online trace methodologies, such as concurrent think-alouds, eye tracking, log files, physiological sensors, and so forth. While these methods have the potential to advance current SRL frameworks, models, and theories, they still pose serious challenges (e.g., temporal alignment of data channels, lack of analytical techniques, and accuracy of inferences made from individual channels and across data channels) that currently plague the field.

Another major challenge is related to the use of real-time CAM trace data to make ALTs adaptive. More specifically, using these trace data can provide support for learners' CAM processes and domain learning in real time by allowing researchers to make inferences based on the temporally unfolding deployment of the learners' CAM processes. However, issues remain such as the lag time between capturing real-time deployment of CAM processes, inferences made by the ALTs to adapt to learners' needs, and the ALTs' ability to effectively monitor and regulate their own external regulation over time (e.g., a virtual agent self-regulates and modifies the timing, sequencing, and type of scaffolding of metacognitive judgments because it typically induces frustration in learners; Azevedo, Taub, Mudrick, Farnsworth, & Martin, 2016). In sum, the educational effectiveness of ALTs hinges on researchers' ability to collect real-time CAM trace data by converging a myriad of interdisciplinary methods (e.g., eye tracking) and analytical techniques (e.g., data mining, machine learning) to understand these processes, making accurate inferences regarding the underlying CAM processes, and modeling and embodying these processes to enhance learners' ability to effectively monitor and regulate their own CAM SRL processes and overall learning (Taub, Azevedo, Bouchet, & Khosravifar, 2014).

As such, our chapter focuses on understanding and reasoning about real-time CAM processes to foster self-regulation with ALTs. More specifically, our chapter will focus on the following: (1) a critical review of various ALTs that use SRL models and others that also focus on CAM processes but use different theoretical frameworks to analyze online trace data with ALTs (e.g., Winne and Hadwin's information-processing theory); (2) analysis and discussion of key issues related to investigating CAM SRL processes during learning with ALTs with online trace methodologies (e.g., the role of contextual factors, representation of CAM processes, temporal dynamics); (3) a critical review of the factors influencing the use of CAM processes during learning with ALTs; (4) strengths and weaknesses of several interdisciplinary online trace methodologies used in ALTs to detect, track, model, and foster SRL and domain learning; and (5) future directions that will significantly augment our understanding of the role of CAM SRL processes during learning with ALTs and enhance the instructional effectiveness of these systems based on their ability to detect, track, model, and foster learners' CAM SRL effectively. Lastly, we propose implications for using multichannel data to foster CAM SRL processes with ALTs, followed by implications for designing ALTs capable of detecting and fostering CAM processes.

A Review of ALTs' Detection of CAM SRL Processes

Emerging empirical evidence indicates that CAM SRL processes play a critical role in learning and problem solving in different domains (e.g., science, mathematics, computer literacy) with ALTs (Azevedo, 2015). One key component of ALTs is that they have been shown to play an important role in facilitating students' SRL by

scaffolding, fostering, and supporting CAM processes (Azevedo et al., 2013). Many of these ALTs are unique not only in design, but also in their theoretical frameworks and intervention methods. Research on CAM SRL processes and ALTs is varied, and a succinct synthesis of the empirical research on their capability to detect, track, model, and foster SRL and domain learning is needed (Azevedo & Alevan, 2013a, 2013b). Currently, several unique ALTs are being designed to function as both a research and learning tool and therefore facilitate the collection, detection, tracking, modeling, and fostering of self-regulation of CAM processes through various methods (e.g., interface designed to afford learners opportunities to engage in metacognitive monitoring and regulate their learning by using sophisticated strategies and affective reactions by providing a wealth of nonlinear multimedia materials and conversations with artificial pedagogical agents). As such, the purpose of this section is to synthesize the current literature on ALTs that target SRL processes as well as ALTs that foster specific CAM processes and to provide an overview of the strengths and shortcomings of these systems.

ALTs have been developed to foster students' SRL in response to research that has shown students do not typically deploy SRL strategies effectively or efficiently (Azevedo, Taub, & Mudrick, 2015; Moos, 2018/this volume; Poitras & Lajoie, 2018/this volume; Winne & Azevedo, 2014). Many types of ALTs can foster different CAM SRL processes such as intelligent tutoring systems, hypermedia- and multimedia-learning environments, game-based learning environments, and simulations, all of which task students with engaging in different types of SRL processes. For example, MetaTutor, nStudy, and SimSelf foster the use of metacognitive monitoring and cognitive learning strategies during learning, whereas Betty's Brain requires students to create causal concept maps to teach Betty (a computer agent) science material, and CRYSTAL ISLAND requires students to engage in SRL and scientific inquiry to solve a mystery. In addition, many ALTs involve interactions between students and pedagogical agents so the ALT can provide scaffolding to students to teach them how to use SRL strategies effectively. MathSpring, AutoTutor, Affective AutoTutor, Gaze Tutor, Guru, and iSTART are all intelligent tutoring systems that engage students in dialogue with the system to discuss their levels of affect and understanding of the material they are learning. As such, many different types of ALTs each have specific components to foster learning using CAM processes in different ways.

ALTs Theoretically Grounded in SRL Theories, Models, and Frameworks

For this chapter, we use the information-processing theory of SRL (Winne & Hadwin, 1998, 2008) as our leading theoretical framework. According to this model, SRL is viewed as an event that temporally unfolds over time, and occurs through a series of four cyclical stages, where information processing occurs via the use of cognitive and metacognitive strategies. We focus our attention on the second and third phases, setting goals and plans and use of learning strategies, because it is during these phases that students engage in planning, monitoring, and strategy use as they learn with ALTs (see Azevedo, Moos, Johnson, & Chauncey, 2010; Greene & Azevedo, 2009, 2010; Johnson, Azevedo, & D'Mello, 2011; Winne, 2018/this volume). Regarding ALTs with SRL as a guiding framework (e.g., Winne & Hadwin, 1998), there are similarities in how cognitive processes are detected and scaffolded, and differences in how they are modeled for learners and how adaptive they are to learner actions. More specifically, most of these ALTs (e.g., MetaTutor, nStudy) detect and track learners' cognitive processes based on user-interface interactions such as selecting among various multimedia content, collecting scientific evidence and making hypotheses about a particular biological agent, taking notes on vast amounts of content, building new knowledge representation from existing system-provided information, and so forth. The real-time behavioral enacting of these cognitive processes is captured through eye tracking, log files, and pre- to post-test learning gains. Additionally, apart from Betty's Brain, all of these systems require learners to take notes in some manner (i.e., through the note-taking feature of MetaTutor and nStudy vs. the concept matrices in CRYSTAL ISLAND; Azevedo et al., 2013; Lester, Mott, Robison, Rowe, & Shores, 2013). Another commonality among these ALTs is the use of different learning strategies such as coordinating informational sources (e.g., creating causal maps in Betty's Brain vs. tagging information in nStudy; Beaudoin & Winne, 2009; Biswas, Segedy, & Kinnebrew, 2013).

Despite their similarities, these systems differ in their ability to scaffold and model cognitive processes in real time as well as cognitive learning strategies. For example, neither CRYSTAL ISLAND nor nStudy provides explicit scaffolding, but rather both rely on their interface or environment to promote the enactment of learning strategies (Beaudoin & Winne, 2009; Rowe, Shores, Mott, & Lester, 2011). In contrast, both MetaTutor and Betty's Brain employ pedagogical agents to prompt and scaffold learners to enact specific learning strategies (e.g., summarizing in MetaTutor vs. crafting inquiries in Betty's Brain). Furthermore, these systems are predominantly adaptive with the exception of nStudy. For example, MetaTutor makes inferences based on real-time analyses of trace data, using time thresholds and user behaviors to trigger production rules that, when met, adaptively scaffold the learner's cognitive strategy use (e.g., time threshold on page triggers a page quiz) and metacognitive monitoring. Furthermore, MathSpring adaptively regulates its level of difficulty through criteria such as math-problem selection based on specific learner actions (i.e., number of attempts on a problem), the amount of time spent on a problem, and whether help is requested (Arroyo et al., 2014). Overall, ALTs' ability to detect, track, model, and foster cognitive processes has produced significant results in learning, problem solving, reasoning, and scientific reasoning (see Alevén, 2013; Azevedo & Alevén, 2013b; Azevedo et al., 2013; Biswas et al., 2013).

Most ALTs that are theoretically grounded in SRL ignore the critical role of affect, as few attempt to detect, track, and scaffold learners' emotions in real time while interacting with these systems (D'Mello & Graesser, 2015). The majority of current systems use self-report measures of emotions prior to, during, and following learners' interactions with specific components of ALTs, and therefore address learner emotions in a post-hoc fashion through analyses of self-report measures and post-hoc analyses of facial expressions of emotion data (Azevedo et al., 2016; Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015). However, MathSpring is one of the only ALTs situated within SRL that facilitates and scaffolds learners' affective processes in real time. For example, MathSpring monitors learners' affective states with physiological sensors, facial expressions of emotions, and self-reports, and it also scaffolds learners' affective processes with animated affective learning companions (Arroyo et al., 2014). These agents are designed as peer learners who offer support and guidance as learners encounter obstacles throughout their interactions with the system and have been found to increase help-seeking behavior (Woolf et al., 2010). While this method of addressing learner affect is one that has found some success, affect detection is notoriously difficult and has continued to be a problem for ALT researchers for some time. Further, even when affect can be detected, most systems fail to employ system interventions or models to assist learners in regulating their affect (e.g., AutoTutor, CRYSTAL ISLAND, MetaTutor). Along with affect, metacognitive processes have also proved difficult to detect, facilitate, and scaffold as learners interact with these ALTs.

There are similarities and differences in the methods used to facilitate SRL strategies and metacognitive monitoring within these different ALTs. More specifically, these systems (1) promote similar macro-metacognitive processes (i.e., planning, setting goals, and monitoring progress towards goals within nStudy, MetaTutor, SimSelf, and Math-Spring); (2) model efficient deployment of monitoring behaviors (e.g., a pedagogical agent in MetaTutor modeling how to appropriately set a subgoal vs. a pedagogical agent in SimSelf providing information on what metacognitive monitoring is; Azevedo, 2014; Taub, Mudrick, Azevedo, Markheliuk, & Powell, 2016); and (3) have specific components within their user interfaces that foster the self-initiation of specific micro-level metacognitive monitoring processes and SRL behaviors (i.e., self-initiating a feeling of knowing judgment by clicking the SRL palette of the MetaTutor interface vs. linking a self-made learning strategy with specific content in nStudy).

Although these systems model some of the same metacognitive processes, they still differ in the manner in which they scaffold SRL behaviors. For example, Betty's Brain is distinct from these other systems as it relies on the learning-by-teaching paradigm, which requires learners to use three important teaching principles that serve to support SRL (Biswas et al., 2013); as the learners prepare to teach, they must interact with the agent, monitor, and reflect upon what has taken place. On the other hand, MathSpring facilitates self-reflection through an open learner model (Arroyo et al., 2014). Another distinct difference among these systems is the level of granularity of the metacognitive processes examined (i.e., micro-level SRL behaviors in MetaTutor [feelings of knowing,

judgments of learning on a specific component of the human circulatory system] vs. macro-level metacognitive processes in nStudy [planning, monitoring throughout the overall web-based interaction]; Greene & Azevedo, 2009; Winne & Hadwin, 2013). Adaptively, many of these systems behave in much the same manner from a metacognitive standpoint as they do from a cognitive one. For example, Betty's Brain, nStudy, and SimSelf lack any form of adaptive scaffolding and rely on post-hoc assessments to detect and track learners' metacognitive behavior. This is a common theme within these ALTs, as detection is generally left to data derived from log files and self-report measures during post-hoc analyses.

ALTs Theoretically Grounded in Theories Other Than SRL

Our review of the literature has also uncovered another group of ALTs that has proved efficient in detecting, tracking, and modeling CAM without being grounded in theories of SRL. These systems generally use some version of two distinct theoretical frameworks: explanation-based constructivism with human tutoring models or the ACT-R theory of learning and performance. Explanation-based constructivist theories suggest learners must actively construct explanation-based meanings and knowledge through interaction, and progress is achieved through telling and doing (Aleven & Koedinger, 2002). In contrast, the ACT-R theory of learning and performance proposes that learning is achieved through the development of simple components that become complex in summation. Progress is achieved through the mastering of simple components that make up larger and more complex components (Anderson & Schunn, 2000). Although both of these frameworks lend themselves to supporting CAM processes within ALTs, they do so in different ways. Systems that use explanation-based constructivism (AutoTutor, Affective AutoTutor, Gaze Tutor, Guru, and iSTART) resemble human tutor-like interactions, and systems that use ACT-R (ASSISTments, PSLC Cognitive Tutor) attempt to build learner knowledge incrementally (Anderson & Lebiere, 1998; D'Mello & Graesser, 2012a, 2012b; D'Mello, Olney, Williams, & Hays, 2012; Jackson, Boonthum-Denecke, & McNamara, 2015; Mendicino, Razzaq, & Heffernan, 2009; Olney et al., 2012; Singh et al., 2011). These different ALTs produce varied methods of detecting, tracking, and scaffolding learner CAM processes. However, similarities can still be found between these two groups.

While these systems do not scaffold, detect, or foster explicit SRL processes, they still address CAM components related to SRL; however, they are different in terms of their real-time adaptivity. For example, AutoTutor, Affective AutoTutor, and Guru address learners' cognitive processes in real time with natural language processing to adaptively model appropriate cognitive strategies and adapt content to learners' individualized abilities. Furthermore, Affective AutoTutor detects students' current affective states by monitoring facial expressions and body posture, whereas Gaze Tutor uses learners' eye movements to monitor attentional patterns and assess levels of learner engagement (D'Mello et al., 2012). While these systems primarily focus on learners' cognitive and affective processes, Cognitive Tutor and ASSISTments adaptively monitor and foster learners' cognitive and metacognitive processes through production rules and example-tracing (Anderson, Corbett, Koedinger, & Pelletier, 1995; Mendicino et al., 2009). Although dissimilar in their guiding theoretical frameworks, these systems still promote the effective use of CAM processes related to efficient SRL.

In sum, this section highlights the similarities and differences in the methods that contemporary ALTs use to detect, track, model, and foster CAM SRL processes. ALTs that use SRL as a guiding framework emphasize cognitive and metacognitive processes at the expense of affect, whereas ALTs that are grounded in explanation constructivism predominantly focus on cognitive and affective processes. Furthermore, all of these ALTs are distinct in the means by which they promote and monitor CAM SRL processes. Specifically, even though these ALTs attempt to foster similar CAM SRL processes, they do so in different ways. Although many of the ALTs discussed here emphasize adaptivity and converging multichannel data (e.g., log files, facial expressions of emotions), it is clear that no system addresses the detecting, scaffolding, and fostering of all components of CAM SRL processes. In the next section, we focus on factors that influence the use of CAM processes during learning with ALTs.

Factors that Influence the Use of CAM Processes with ALTs

Context

One important factor to consider when investigating how students use CAM SRL processes during learning is the context in which they are learning. Learning can take place in a multitude of contexts that can differ based on the type of ALT being used (e.g., hypermedia-learning environment, game-based learning environment, intelligent tutoring system) or the topic the student is learning about (e.g., the circulatory system, microbiology, math, physics). No matter the distinction, contextual factors can impact CAM processes in many ways. Additionally, an ongoing issue regarding learning with ALTs is how learning can transfer to different domains over time. In the following section, we discuss the importance of context for near and far transfer of CAM processes.

The Impact of Context on Transfer

The context in which students are learning can impact their ability to transfer what they learn to different contexts. For example, if students successfully complete game-based learning using effective CAM processes, then these strategies can be applied to learning with a different environment, which would aid completion of the learning task with another ALT. The ability to transfer from one context to another would therefore depend on how well students use CAM processes in general. For example, if students can use the metacognitive monitoring strategy of judging their understanding of the material (i.e., judgment of learning) effectively with one ALT, they should be able to use this monitoring strategy with a different ALT (Heidig & Clarebout, 2011; VanLehn et al., 2007). However, in addition to considering how different contexts can impact transfer of learning using CAM processes, students' levels of knowledge and skills (e.g., declarative, procedural, and conditional) can also impact how well they can transfer the information they learn and the CAM processes they use. We discuss the impact of knowledge on the use of CAM processes in the next section.

Knowledge

When assessing how students learn with ALTs we often consider individual differences, such as students' knowledge. When examining differences in knowledge and its impact on using CAM processes, we can use multiple categories to distinguish them, such as knowledge type (content vs. SRL knowledge, or declarative vs. procedural or conditional knowledge), quality versus quantity of CAM processes, and prior versus acquired SRL knowledge. In this section, we discuss some of these influencing factors.

Knowledge of Using CAM Processes Effectively

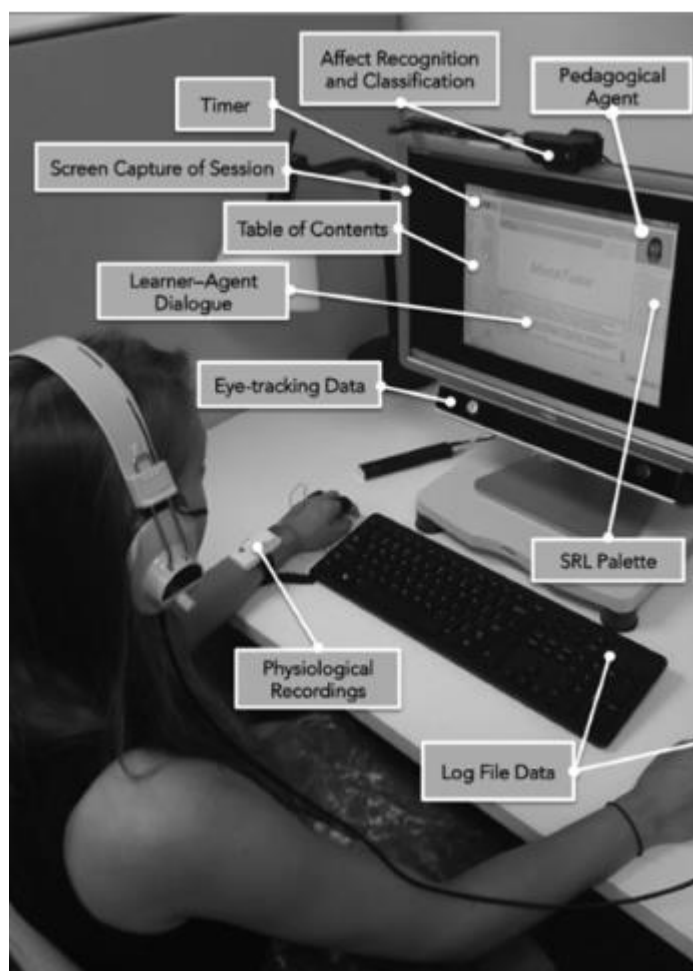
When we investigate how students use CAM processes, we often examine the frequency of use of these processes (e.g., frequency of judgments of learning), with the assumption that higher frequency means better use. However, this also involves an implicit assumption that might not be indicative of what is actually occurring. For example, if Student A takes a lot of notes during learning, as opposed to Student B who takes fewer notes, we might assume that Student A has better note-taking skills than Student B. However, if we further investigate the quality of these notes, we might determine that Student A took less-efficient notes (e.g., copied the text verbatim onto the notepad) than Student B, who took fewer notes but summarized the text into his or her own words. Thus, Student B used the cognitive learning strategy of taking notes more efficiently than Student A, despite the fact that Student A had a higher frequency of note-taking. This demonstrates the importance of differentiating between quality and quantity as well as how the quality of CAM processes can influence learning more than the quantity.

These issues related to knowledge are important in designing adaptive ALTs because any different types of individual differences can influence how a student uses CAM processes for learning. A major issue, however, in considering how to detect these different student characteristics lies in measuring these CAM processes with multiple data channels and being able to detect these processes based on the data. In the following section, we

address these issues by discussing the different types of data channels typically used as well as the issues pertaining to aligning these data channels to accurately detect CAM processes during learning.

Measurement and Detection of CAM Processes During Learning with ALTs

The previous section described temporally unfolding CAM processes with ALTs based on the use of both obtrusive and unobtrusive trace methodologies (Aleven, 2013; Azevedo, 2014, 2015; Azevedo et al., 2010; Bernacki, 2018/this volume; Bernacki, Nokes-Malach, & Aleven, 2013; Greene & Azevedo, 2010; Greene, Deekens, Copeland, & Yu, 2018/this volume; Molenaar & Järvelä, 2014). When students engage in CAM processes during learning, we can collect multichannel data to investigate how their use of these processes might improve or impede their learning (see [Figure 17.1](#)). Such data channels include: (1) log files, (2) videos of facial expressions, (3) eye tracking, and (4) physiological data. Log files can be used to capture student activity within an ALT, which can inform us of how they are using cognitive and metacognitive processes by frequency, duration, and quality of responses. Videos of facial expressions can be run through facial expression recognition software (e.g., Attention Tool) to identify the affective states (e.g., confusion) or action units being activated during the learning session. Eye-tracking data can generate students' gaze fixations, saccades, and regressions, informing us of where on the screen (i.e., areas of interest; AOIs) the student was looking (SMI Experiment Center) as potential indicators of CAM processes (Taub et al., 2016a, 2016b, in press). Physiological data (Empatica E4) can capture many behaviors, such as galvanic skin response, blood volume pulse, movement, body temperature, interbeat interval, and heart rate.



[Figure 17.1](#) Illustration of instrumented participant during learning with an ALT

We can detect all of these data during learning, which can be indicative of engaging in cognitive or metacognitive processes or a change (e.g., a spike in physiological arousal or a sudden facial movement) of affective states (e.g., confusion or frustration). Therefore, different data channels can capture different types of CAM process data, making it ideal to align and merge these data to identify how they can produce behavioral signatures of CAM processes during learning. To create these behavioral signatures, we must consider and address constraints pertaining to measuring affect and aligning data channels, which are discussed next.

Measuring Affect

Many SRL researchers have investigated how to measure the use of cognitive, meta-cognitive, and motivational SRL processes during learning (see Bernacki, 2018/*this volume*; Reimann & Bannert, 2018/*this volume*); however, little attention has been focused on methodological considerations when measuring students' emotions. When measuring students' affective states during learning, a series of approaches can be taken to detect and analyze these data. First, the term affect is an umbrella term that can encompass both emotions and mood, where emotions are short-term behaviors and mood is longer lasting (Scherer, 2009). Typically, as students learn we want to measure their emotional reactions to particular events that occur frequently. Therefore, we are interested in measuring their changing emotions as opposed to their mood when they begin learning.

Second, many categories of emotions could be of interest, such as discrete or non-discrete emotions, basic emotions, learning-centered emotions, and compound emotions. If we were to assume that emotions are discrete, this would imply that students can only experience one emotion at a time and not multiple emotions simultaneously. Research in this area might therefore select the highest evidence score of an emotion and assume that to be the emotion the student is expressing at that time. It can be difficult to single out one discrete emotion during learning with ALTs, as the multiple elements in the environment and learning context can evoke many emotions simultaneously. Thus, in contrast to examining discrete emotions, if emotions are nondiscrete (i.e., co-occurring) students can feel multiple emotions simultaneously during learning, which is more likely the case. For example, when assessing students' evidence scores of enjoyment and confusion, it is possible to detect scores indicating the presence of both emotions, suggesting the students can be enjoying themselves but might also be confused about the material they are reading.

Students can also express different categories of emotions during learning. Basic emotions such as enjoyment, anger, fear, disgust, sadness, and surprise (Ekman, 1973) pertain to emotions typically felt during daily activities. In addition to nondiscrete emotions, they can also be compositions of different aspects of a range of emotions, called compound emotions, which combine these basic emotions (Du, Tao, & Martinez, 2014). For example, a student can be surprised, but this can be further differentiated into happily surprised, sadly surprised, fearfully surprised, or angrily surprised. Thus, compound emotions combine different dimensions of basic emotions to elicit 21 categories of emotions instead of the six basic emotions (Du, Tao, & Martinez, 2014).

While students can exhibit basic emotions during learning with ALTs, researchers have also investigated the following learning-centered emotions that are specifically demonstrated during learning: confusion, frustration, boredom, and engagement (D'Mello & Graesser, 2012a, 2012b). These emotions are typically expressed during learning, as they are common influences on or responses to learning-related activities. Thus, investigating these types of emotions is more specific to learning, and learning with ALTs, than basic emotions (e.g., anger, joy). As illustrated above, many different types of affective states can be studied during student learning with ALTs. Once researchers have specified which aspects of affect they wish to study, they must then decide how they will detect these emotions methodologically.

Therefore, a final consideration in measuring emotions focuses on what exactly is being measured and analyzed. For example, when running video data through facial expression recognition software (e.g., FACET, FaceReader, Affdex), the software can yield evidence scores for both emotions and facial action units (i.e., possible movements of facial muscles on the learner's face, such as brow lowering and lip tightening). Evidence scores (i.e., "output

estimates of facial expression presence” or “facial expression recognition output”) of emotions can be limited in that people express emotions in different ways, and the software might not detect an instance of frustration if it is not elicited in a particular manner (i.e., based on how the software was developed to detect frustration). Thus, it can be beneficial to examine students’ action unit evidence scores, which demonstrate the areas on the face that are changing and at what evidence level. From these data, we can infer the students’ emotions using the action units that are associated with emotions (e.g., brow lowering as an indicator of confusion). In addition, this can allow for differences in expressing emotions as we can combine the evidence scores from different action units, similar to the work previously done on compound emotions (Du et al., 2014); however, we can expand on the emotions by including action units indicative of learning-centered emotions as well. This is important because it stresses not only that emotions can be expressed differently by different people, but also that there are different types of the same emotion, such as effective confusion and ineffective confusion. Therefore, detecting action units can be useful for assessing students’ emotions during learning with ALTs. It is evident that many challenges need to be addressed when assessing affective states, all of which need to be considered prior to conducting analyses regarding students’ use of CAM processes. In addition, if we are using multichannel data, other issues need to be considered prior to aligning the data; we address these issues in the following section.

Aligning Multichannel Data to Create Behavioral Signatures of CAM Processes

When collecting multichannel data using different types of data, a number of challenges need to be overcome prior to analyzing the aligned data. Different data channels collect data at different frequencies; for example, the SMI eye tracker measures eye movements at a rate of 120 or 250 data samples per second, facial expression recognition can be performed at every frame of video (typically 30 frames per second), and the Empatica E4 bracelet collects electrodermal activity data at a rate of four samples per second. Thus, to combine these data across a specific time period, the varied sampling rates must be reconciled. Once the data are combined, we can apply them to create behavioral signatures of different CAM processes used during learning.

Although it might seem the most beneficial to include all data channels when creating behavioral signatures, there are issues to consider in selecting data channels as well. When sampling multiple data channels, it is possible to gather enough data (and contextual information) from one data channel that might indicate a student is engaging in a particular CAM process. However, additional questions need to be answered once the data signal a behavior, indicating that perhaps we need more than one data channel to be certain we have found a behavioral signature of that CAM process. For example, eye-tracking data might indicate the student is making a content evaluation, a metacognitive judgment that assesses the relevancy of the content to the current subgoal. In response, we can be confident that it is a content evaluation or we can turn to additional information for support, which would require the use of other aligned data such as assessing the student’s emotions (or facial action units) at the time the eye-tracking gaze pattern was found. This then raises another issue: What additional data should we turn to for extra support and to provide contextual information (e.g., screen recording) to increase researchers’ inference accuracy regarding the presence of specific CAM processes? Therefore, it is important to align all the collected data; however, the next step involves determining which of those data to use as indicators of CAM processes.

It is evident that using multiple data channels can help us to be more certain about which CAM processes a student is engaging in; however, there can be a downside to using multiple data channels as well. When all the data channels align to indicate the same CAM process, this can be beneficial; however, when the data yield conflicting results, indicating different CAM processes, this can lead to challenges in interpreting the data, thus causing uncertainties about which data to use. In addition, if these data yield conflicting results and we want to return to the data to further investigate them, but the student had continued to do something else in the ALT, this also poses challenges for determining which data channel is the most accurate because the CAM process has already ended. Therefore, this poses issues regarding timeframes and windows for measuring CAM processes, what kind of data we can use to best indicate the use of CAM processes during learning, and how to measure the processes while they are still occurring. These issues raise several theoretical, methodological, and practical implications for designing ALTs, which are discussed in the next sections.

Future Directions

This chapter presented some of the major advancements in ALTs in terms of how their design and use are theoretically based on SRL and other theories. We presented arguments regarding some of the major conceptual, theoretical, methodological, and analytical issues still plaguing the field when considering the challenges in collecting, aligning, analyzing, and making inferences from multichannel data that differ along several key dimensions. Future research should address these serious challenges as researchers continue to explore interdisciplinary methods to collect multichannel data and use a myriad of analytical techniques, which have the potential to advance current SRL frameworks, models, and theories. For example, serious effort should be devoted to addressing the following issues: temporal alignment of data channels; lack of analytical techniques and debatable accuracy of inferences made from individual channels and across data channels; the role of contextual factors that might interfere with the effective use of CAM processes; mechanisms; level of granularity in coding and making inferences about CAM processes; distinguishing among macro-level processes, micro-level processes, and valence when considering theoretical augmentation and implications for adaptivity for both humans and machines; analytical challenges in determining the correct unit of analysis (e.g., frequency vs. quality of CAM SRL knowledge and skills); quantitative and qualitative changes in CAM SRL processes over extended periods of time; individual and combined contributions of CAM processes and their relation to domain and SRL knowledge and skills; examining the existence of robust multichannel behavioral signatures for specific CAM SRL processes; differentiating among declarative, procedural, and conditional SRL knowledge and skills learned during learning and problem solving with ALTs; and the potential of treating motivational processes (e.g., self-efficacy, interest, task value) as trace data that contribute to CAM SRL but which may fluctuate at a higher time scale (e.g., minute, hour, day, week).

Addressing these underlying issues will allow researchers to build CAM SRL-sensitive ALTs capable of providing intelligent individualized support in real time. As argued in the chapter, a major challenge is related to the use of real-time CAM trace data to make ALTs adaptive. More specifically, using these trace data can provide support for learners' CAM processes and domain learning in real time by making inferences based on the temporally unfolding deployment of the learners' CAM processes. A major concern remains regarding the lag time between capturing real-time deployment of CAM processes, inferences made by the ALTs to adapt to learners' needs, and the ALT's ability to effectively deploy the most effective intervention (e.g., adaptive scaffold by a virtual human) to address the learners' needs at that moment in time. This major area of research has already made considerable strides, as documented in this chapter. The next generation of adaptive intelligent ALTs will include embodied agents who are capable of monitoring and regulating their own and learners' external regulation over time (e.g., a virtual human self-regulates and modifies the timing, sequencing, and type of scaffolding of metacognitive judgments because scaffolding typically induces frustration in learners). In sum, the educational effectiveness of ALTs centers on researchers' ability to collect real-time CAM trace data by converging a myriad of interdisciplinary methods (e.g., eye tracking, videos of facial expressions) and analytical techniques (e.g., data mining, machine learning) to make accurate inferences regarding the underlying CAM processes, and modeling and embodying them to enhance learners' ability to effectively monitor and regulate their own CAM SRL processes and overall learning.

Implications for Practice

Using multichannel data to measure how students use SRL processes during learning with ALTs allows us to capture actual student behavior, as opposed to relying on students to report these behaviors themselves. Multichannel data integrate a wide variety of sensor technologies (e.g., electrodermal bracelets, eye trackers) with traditional approaches to representing student behavior in learning environments. This combination of rich data sources holds the promise of discovering observable events that correspond to underlying CAM processes (Azevedo et al., 2013, 2015, 2016; Harley et al., 2015, 2016). This section describes current multichannel data sources that have become widely available and relatively affordable in recent years. Typical approaches to combining data are also discussed, with important implications for how these representations aid adaptation to

the learner. Additionally, several techniques have recently been applied to analyze multichannel data while leveraging event sequences, as learning interactions unfold from moment to moment.

One prominent external data channel comes from eye tracking. These sensors identify eyes through reflection of infrared light. Combined with information about the display screen (e.g., size, distance from learner), these devices can be calibrated to show where the learner is looking at any moment. When AOIs are defined, a learner's eye movements can be quantified as fixations on these AOIs and are representative of attentional and cognitive processing. Eye fixations are particularly useful in quantifying reading behaviors, attention, and studying of graphical content such as videos or diagrams (Bondareva, Conati, Feyzi-Behnagh, Harley, & Azevedo, 2013; Jaques, Conati, Harley, & Azevedo, 2014; Taub et al., 2016a, 2016b, in press). For example, heat maps are also often used to produce visualizations of where individual learners or groups of learners fixated during display of particular content. Different parameters of heat maps can be adjusted to provide different insights into gaze behavior (e.g., to highlight shorter or longer periods of fixation) (Azevedo et al., 2017).

As learning environments have become increasingly sophisticated, the nature of system interaction has also evolved. ALTs now have more concerns than simply correctness of answers, as modern implementations include detailed system logs that provide a picture of how the learner interacts with each interface element at any given point in time. Thus, these learner–system interaction (or clickstream) data can provide information on whether students are taking time to work on a task based on their effective use of learning strategies or are simply advancing rapidly without consideration (perhaps by using hint-giving features) because they are not capable of making the accurate metacognitive judgments necessary to determine the relevance of the presented multimedia information.

Implications for Designing ALTs

All the above-mentioned issues have further important implications for designing ALTs with pedagogical agents or intelligent virtual humans that can detect, model, and foster students' CAM processes during learning. When designing these agents we must address these same issues regarding timing, because the agent must be provided with the appropriate threshold to detect the student's activity and provide helpful feedback based on student performance.

An additional challenge when designing agents deals with the type of intervention the agent provides. The agent can intervene by prompting the student to engage in a particular CAM process or by confirming it has correctly identified which process the student is engaging in. We consider this a challenge because to create agents that are capable of intervening by prompting, we need to understand student behavior; and if we have trouble doing so as humans, due to the complexity and unpredictability of human behavior, how do we expect to program agents to be capable of doing it using algorithms that are not respondent to individual human behavior? Thus, instead of making the inferences based solely on data, the agents can be programmed to intervene by engaging in dialogues with the students to confirm if what they are detecting in the data is correct. In addition, instead of waiting for the right amount of data, the agent can intervene to obtain the ground truth about the student's use of CAM processes and establish a rapport with the student to gain this ground truth. In principle, the more information the agent can obtain, the greater the likelihood it will be able to make accurate inferences regarding student behavior. Ideally, artificial agents should have access to multichannel data and be able to understand and reason from these data while determining how to adapt their own behavior to support learners' SRL. Recent advances in educational data mining and machine learning have tremendous potential to provide intelligent, adaptive, and individualized feedback and scaffolding to support learners' CAM processes as well as learning, problem solving, and performance with ALTs (e.g., Biswas, Baker, & Paquette, 2018/this volume).

Conclusions

Recent technological advances have allowed researchers to use interdisciplinary methods to collect rich multichannel trace data of learners' CAM processes during learning and problem solving with ALTs. As such, researchers from the fields of educational, learning, cognitive, affective, social, engineering, and computational sciences have made major strides in developing ALTs to play a dual role. First, ALTs are used strategically as research tools to collect rich multichannel trace CAM SRL data to enhance our current framework, models, and theories of SRL by providing evidence of the complex, temporally unfolding nature of CAM processes in real time. Second, as learning tools ALTs are theoretically and empirically designed to afford learners the ability to foster CAM processes with some constraints. In sum, advances in understanding and reasoning about real-time CAM processes to foster self-regulation with ALTs are necessary to augment conceptual and theoretical issues as well as design intelligent systems to detect, track, model, and foster learners' SRL.

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Notes

[1](#) We excluded motivational processes due to space limitations and the fact that using trace methodologies to measure, understand, and reason about these processes remains a major challenge for researchers and designers.

[2](#) We use the acronym CAM (instead of CAMM) throughout the chapter to denote our emphasis on cognitive, affective, and metacognitive processes only.

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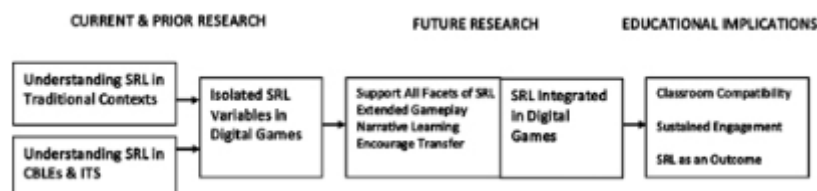
18 The Role of Self-Regulated Learning in Digital Games

John L. Nietfeld

The Role of Self-Regulated Learning in Digital Games

Educational research is beginning to mirror society’s fascination with digital games, particularly now that their potential for improving the efficiency of learning is being recognized. And this fascination does not appear to be a fad as there has been an exponential increase in the number of studies reporting on the use of games for learning purposes (Boyle et al., 2016). Using a computer game for instruction, once considered a questionable proposition, has now been legitimized by a number of recent meta-analyses revealing advantages of digital games over non-game comparison conditions (Clark, Tanner-Smith, & Killingsworth, 2016; Sitzmann, 2011; Vogel et al., 2006; Wouters, van Nimwegen, Oostendorp, & van der Spek, 2013). Designs to study the impact of digital games are becoming more sophisticated, yet there are still concerns that a majority of digital game studies are using simple gamification effects that promote and assess only lower-level learning outcomes (Boyle et al., 2016; Clark et al., 2016). The study of more complex skills is critical, particularly those that are self-regulatory in nature and equip students to learn more deeply within content domains and to become competent learners across contexts. In order to accomplish this goal, digital-game studies require designs that more fully integrate self-regulated learning (SRL).

The purpose of this chapter is to provide an overview on the current state of research related to digital games and SRL. [Figure 18.1](#) presents a visual organizer for the discussion to follow regarding current and prior research related to SRL and digital games, suggested pathways for future research related to SRL and digital games, and finally educational implications. The graphic and content in this chapter are far from exhaustive but highlight a few critical topics for the field. In particular, the message here emphasizes a move from an isolated to an integrated approach when considering SRL in digital games.



[Figure 18.1](#) SRL research in digital games

Relevant Theoretical Ideas

Defining Digital Games

Research involving educational games has suffered from a lack of consistency in terminology (O’Neil, Wainess, & Baker, 2005; Sitzmann, 2011). The term digital game-based learning environment was provided by Prensky (2001) to refer to a merging of games with educational curriculum to better represent 21st-century learning approaches. Games can be distinguished as those either built for educational purposes or for commercial purposes. Common terms for games built for educational purposes include serious educational games (Annetta, 2008), educational computer games (Mayer, 2011), and simulation games (Sitzmann, 2011). Mayer (2011) noted four themes common across educational games, describing them as rule-based, responsive, challenging, and cumulative. In short, he used the term educational computer game to refer to any game played on the computer “in which the designer’s goal is to promote learning in the player based on specific learning objectives” (p. 282). Similarly, Wouters et al. (2013) described serious games as being interactive, with a set of agreed rules and constraints, having a clear goal often set with a challenge, and within a program that provides constant feedback. Tobias and Fletcher (2011) considered other elements to be critical for games such as storylines, fantasy, competition, and role playing. Simulation games are unique in that they include gaming elements such as those listed above but also involve the user taking a role in a problem-solving context that attempts to approximate a physical or social reality (Gredler, 2004). The focus of the current chapter will be relegated primarily to researcher-developed serious digital games but also, in some cases, to commercial digital games that have been studied for their educational benefits.

Relevant Theory Underlying Digital Games

SRL, the effective regulation of one’s own learning in the pursuit of personal goals, is a broad construct that encompasses cognitive strategy use, motivation, emotion, and the metacognitive and metamotivational monitoring and control of learning (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). Prevalent cognitive (see Winne, 2018/this volume) and social-cognitive (Usher & Schunk, 2018/this volume) models of SRL emphasize phases of learning within “episodes” experienced by the learner (Winne, 2010). SRL skills are dynamic and malleable, impacting performance not only at the task level but also through domain-level expertise and aptitude or dispositional tendencies (Glaser & Chi, 1988; Nietfeld & Shores, 2010; Winne, 2010). Effective self-regulation requires the coordination of numerous cognitive and motivational processes that lead to improved academic performance and academic motivation (Pintrich & De Groot, 1990). SRL environments allow for autonomy and control (Pintrich, 2000), the freedom to set goals (Schunk, 1990), the use of cognitive tactics and tools (Winne & Hadwin, 2013), the opportunity to monitor and control learning (Nelson & Narens, 1990), and the encouragement of appropriate help-seeking (Karabenick & Knapp, 1991).

Digital games are ideal environments to examine self-regulation given that learners have a large degree of autonomy over their actions. This includes the freedom to determine their own goals that may or may not align with goals set by the game itself, and also to engage, disengage, or alter these goals over time within the game. Digital games, unlike traditional classroom instruction, are not regulated like traditional classrooms with teachers as leaders; therefore SRL becomes critical given that the learner’s choices largely determine the quality of learning that takes place. Even though the study of SRL is highly valued and well established in the educational and psychological literature it has not gained much traction thus far in studies related to digital games. A review of computer game studies in 2005 (O’Neil et al., 2005) reported none measuring self-regulation as defined by measuring metacognition, motivation, or both. Since this review a number of game-based studies have involved measurement of metacognition and motivation, yet there remain very few that have attempted an integrated approach to measuring SRL.

Evidence of Digital Games' Promotion of Academic Achievement and Motivation

Overall, current evidence suggests that the use of digital games is having a positive impact on academic achievement in relation to comparison conditions employing non-game-based instructional approaches. Clark et al. (2016) examined digital-game studies from 2000–2012 covering diverse disciplines focused on K–16 students and found an average overall 0.33 standard deviation improvement in learning outcomes for students in game conditions versus those in non-game comparison conditions. Game designs were particularly effective when they included multiple sessions that followed a spaced-learning design. More complex measures of learning such as creativity and critical thinking are currently understudied and will no doubt attract more attention in the literature in the coming years (see Kim & Shute, 2015, for an innovative approach encouraging creativity in Physics Playground).

The learning outcomes findings by Clark et al. (2016) are consistent with other meta-analyses and cross-study reviews (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Sitzmann, 2011; Wouters et al., 2013). However, results related to motivation vary. Clark et al. (2016) found positive effects for the broad domain of intrapersonal learning that included motivational constructs as well as intellectual openness, work ethic and conscientiousness, and positive core self-evaluation in games, both commercial and serious. Yet, Wouters et al. (2013) found no statistically significant advantage for serious games over other instructional methods. Wouters et al. (2013) suggested a number of possibilities for their findings, most notably that most serious games lacked effective instructional design techniques to integrate key learning features within game narratives and instead relied on overt learning prompts that interrupted the flow of the game. The authors also suggested a lack of autonomy for users both within the game and in the choice of when to play the game. Additionally, measurement may play a role as there has been a heavy reliance on the use of self-report scales. The only study in the Wouters et al. (2013) review that did not measure motivation via posttest self-report measures but rather by observations of students during gameplay showed statistically significant motivational advantages for the game over a comparison instructional treatment (Annetta, Minogue, Holmes, & Chen, 2009).

Evidence for Self-Regulation Improving Performance in Serious Games

The bulk of the existing digital games literature that employs an SRL framework has reported on isolated SRL variables and how they impact learning. In sum, these studies have made a number of important advances setting the stage for future work to integrate SRL more fully into gaming environments. Examples of contributions include an examination of goal setting and achievement goals, interest, self-efficacy, metacognitive and teacher scaffolding, strategy use, and metacognitive monitoring.

As in traditional or non-game environments, goal setting and goal monitoring is critical. It is important to carefully consider how goals are presented or generated in digital games, the level of goal specificity, and also who determines goals during gameplay. Kunsting, Wirth, and Paas (2011) studied the use of specific versus nonspecific goals using what they called an interactive computer-based learning environment that simulated a physics lab on buoyancy in fluids with high-ability high-school students. They found that nonspecific problem-solving goals led to greater use of a control of variables strategy than did specific problem-solving goals. Similarly, Feng and Chen (2014) reported advantages for nonspecific goals in their study of 6th grade students learning basic programming by developing their own digital game. Students given nonspecific goals scored higher on a test of programming comprehension. However, the nonspecific group was also advantaged in that they received metacognitive prompts to guide their actions. More studies related to goal assignment that examine a greater diversity of students are needed to clarify the specificity of goals. Moreover, studies are needed to examine student-generated versus researcher-assigned goals.

Clark et al. (2016) found positive effects for studies that included some form of scaffolding with the greatest effects coming from teacher scaffolding. Bulu and Pedersen (2010) revealed the unique contributions of both domain-specific (e.g., “On which world can the Akona survive?”) and domain-general (e.g., “What other possible

solutions can you suggest?") scaffolds in the game Alien Rescue with 6th grade students. Alien Rescue is a problem-based learning game environment where students help resettle aliens using their knowledge of the solar system. Students across conditions showed statistically significant content gains after 13 sessions of gameplay. Those in the domain-specific scaffolding conditions scored higher on the science posttest and also on problem representation measures than those in the domain-general conditions. Alternatively, students in the domain-general condition performed statistically significantly better on monitoring and evaluation measures, as students in these conditions more effectively evaluated their solutions, discussed drawbacks, and provided alternative solutions to the game-based problems.

Mayer and colleagues (Fiorella & Mayer, 2012; Johnson & Mayer, 2010; O'Neil et al., 2014) have taken a value-added approach to investigating digital games wherein base versions of games are compared to games augmented with instructional features. These features are largely focused on strategy and metacognitive prompts. For instance, O'Neil et al. (2014) found that added self-explanation prompts can be positive or negative depending upon how they are presented. In this case, 6th grade students playing a fractions game reached higher levels in the game when answering a prompt that connected game terminology with mathematical concepts, compared to those that answered more open-ended or overly easy prompts. Johnson and Mayer (2010) discovered that the manner in which college students provided reasons for their choices in their Circuit Game was critical to their performance on a transfer posttest. Students who selected their reason by clicking on one of the options provided in a menu scored significantly better than those who generated a written reason. Moreover, there were no differences between those who generated written reasons versus those in a comparison condition who provided no reasons for their responses. Fiorella and Mayer (2012) found that paper-based metacognitive prompts increased transfer rates for college students compared to their peers who did not receive the prompts on the Circuit Game.

In one of the few studies that attempted a more integrated approach at examining the influence of SRL in a gaming environment, Nietfeld, Shores, and Hoffmann (2014) found that SRL variables predicted in-game performance in a game called Crystal Island—Outbreak for 8th grade students even after accounting for prior knowledge. The game presents a narrative-based science mystery on an island with a research station where the researchers are falling ill. The goal for the player is to determine the source of the outbreak by talking to characters at the research station and by forming questions, generating hypotheses, collecting data, and testing hypotheses. A structured note-taking tool called the diagnosis worksheet is provided for the learner to track and organize information along with a device to communicate with other characters in the game. In order to solve the mystery and “win” the game, the student must submit a correct diagnosis worksheet with correct information about the source object, disease, and treatment. Results showed that significant independent contributions to in-game performance came from all three major SRL facets (Zimmerman, 2000) including cognitive strategy use (e.g., diagnosis worksheet tool), metacognition (e.g., monitoring bias), and motivation (e.g., perceived interest and self-efficacy for science). The strongest predictor of performance was the diagnosis worksheet, revealing the importance of including in-game tools to assist learners in the self-regulation process. In an earlier study using Crystal Island—Outbreak the effective use of the diagnosis worksheet was shown to compensate for low prior knowledge (Shores & Nietfeld, 2011). In that study, low prior knowledge 8th grade students who used the diagnosis worksheet effectively closed the posttest score gap with their high prior knowledge peers, whereas scores for the low prior knowledge students who did not use the worksheet effectively remained statistically significantly lower than their high prior knowledge peers at the posttest.

Metacognitive monitoring and the importance of being well calibrated are important for learners in serious digital games. Nietfeld, Hoffmann, McQuiggan, and Lester (2008) found metacognitive monitoring judgments to be significantly related to performance in Crystal Island—Outbreak as revealed by significant correlations of $r = 0.59$ with goals completed and $r = 0.74$ with in-game score. The Nietfeld et al. (2014) study pointed out the potential pitfalls of overconfidence as boys, but not girls, who were overconfident performed statistically significantly lower in the game and on a post-test of content knowledge, compared to their underconfident peers. Similarly, Brusso, Orvis, Bauer, and Tekleab (2012) found that a large goal-performance discrepancy for college students playing a first-person military mission video game on the first mission led to poorer performance on a

subsequent mission. Thus, the early evidence suggests that overconfidence or large goal-performance discrepancies appear to have profound negative effects on both learning and performance in digital games.

Evidence for Games to Improve Self-Regulation

Less frequent but emerging are studies that examine how digital games impact SRL variables. As mentioned previously, these studies are framed within SRL theory but typically consider isolated SRL variables as outcomes. Likely the most frequent SRL outcome studied in the context of digital games has been self-efficacy, which has been shown to increase as a direct result of playing serious games. Bergey, Ketelhut, Liang, Natarajan, and Karakus (2015) reported changes in self-efficacy for scientific inquiry in direct relation to performance on their assessment module for middle schoolers. Meluso, Zheng, Spires, and Lester (2012) reported significant pre- to posttest gains for self-efficacy and content knowledge for 5th grade students after four sessions of gameplay within *Crystal Island—Uncharted Discovery*. Sixth-graders who played *Alien Rescue* showed significant increases in self-efficacy for learning science after 15 daily sessions of gameplay (Liu, Hsieh, Cho, & Schallert, 2006). Jackson and McNamara (2013) found an increasing trend for self-efficacy over time for their game-based intelligent tutoring system *iSTART-ME*, as opposed to a decreasing trend for the traditional tutoring system *iSTART*. *iSTART* emphasizes self-explanation and comprehension strategy training for high-school students. *iSTART-ME* is the well-established *iSTART* program but with the addition of game-based features built on top of the program such as a point-based economy that includes leveling, as well as the ability to earn points and trophies, interact with new texts, unlock new features, play mini-games, and to personalize a character. Both programs showed equivalent learning outcomes but advantages for *iSTARTME* over time for motivation and enjoyment led the authors to conclude that the game-based components showed potential for sustaining engagement. This finding has significant implications as the field creates games that encompass a larger portion of school curriculum and skills.

One goal of digital games is for them to function as a “hook” or to provide a context that promotes situational interest that may eventually lead to sustained personal interest. Plass et al. (2013) examined how individual, competitive, and collaborative conditions impacted situational interest during a mathematics video game for middle-school students. Results revealed that interest was higher for students in both the competitive and collaborative conditions than the individual condition. A recent attempt to examine the relationships between engagement and in-game variables was undertaken by Ronimus, Kujala, Tolvanen, and Lyytinen (2014). They examined the impact of rewards and challenge for 1st and 2nd graders using a game to improve letter–sound connections. Surprisingly, they found that challenge did not influence students’ level of engagement. Moreover, rewards, in the form of in-game tokens, had only a short-term effect on engagement. Finally, Shores, Hoffmann, Nietfeld, and Lester (2012) examined the role of game structure, in this case quests that functioned as subproblems, on situational interest. In the game *Crystal Island—Uncharted Discovery*, 5th graders played three 60-minute sessions completing various quests in an immersive 3D environment related to landforms, map navigation, and map model curriculum. The quests were created as proximal goals or subproblems to help students more effectively manage the overall curriculum goals. The authors found that the total number of completed quests predicted situational interest even after controlling for pre- and posttest content knowledge measures. More research like this is needed to fully understand conditions in educational computer games that might impact situational interest or engagement more broadly and, in turn, lead to personal interest over time.

O’Rourke, Haimovitz, Ballweber, Dweck, and Popović (2014) have begun to investigate how to encourage growth mindset in elementary-school students using a game called *Refraction* that teaches fraction concepts. O’Rourke et al. created two versions of the game, one that attempted to reward players for strategy use, effort, and incremental progress with what they called “brain points” while also incorporating growth mindset language, and a second version that functioned as a comparison condition that awarded points only for advancing levels and used neutral language. The results showed increased levels of persistence, measured by gameplay time, and increased number of levels played for the treatment group. However, more controlled trials are necessary as the

researchers were limited to data collected from an educational website portal, and gameplay was limited to just a few minutes in most cases.

Van de Sande, Segers, and Verhoeven (2015) used trace data in a narrative-based problem-solving game for young children, ages 5–7, and found that executive control skills such as attentional and action control, both requiring inhibitory control (see Hoyle & Dent, 2018/*this volume*), impacted strategy use, staying on task, and sustaining goal-directed learning in the game. What is unknown is the extent to which this finding would generalize to more complex games and the role that inhibitory control plays across game settings. Snow, Jackson, and McNamara (2014) tested the impact of college students' prior literacy ability within their iSTART-ME game-based tutoring system. Using a repeated-sessions design they found that low prior ability students reduced the differences between themselves and their high prior ability peers over sessions to the point of non-significant differences in the ability to produce self-explanations. In the game low prior ability students tended to choose generative-practice activities (i.e., providing scaffolding and feedback) more frequently than high prior ability students and also tended to check achievement screens (i.e., providing progress feedback) more frequently. The authors suggested that these aspects of the gaming context may have functioned as a means of external monitoring that instigated control processes leading to improved performance over time.

Work by Barbara White and colleagues (White & Frederiksen, 2005; White, Frederiksen, & Collins, 2009) illustrates one of the more overt attempts to have students develop explicit awareness of SRL skills. They created the Inquiry Island and Web of Inquiry learning environments to assist students in the development of metacognitive inquiry-based skills in science. Inquiry Island is a narrative-based game that has students take on roles of advisors both specific to the inquiry task at hand and also as general purpose advisors. For instance, specific advisors might include Quentin Questioner or Ivy Investigator. Examples of general-purpose advisors might be Pablo Planner or Molly Monitor. Herein, the narrative roles encourage students to develop explicit understanding of both domain-specific and domain-general skills that assist in developing self-regulation skills on science projects. White et al.'s inquiry projects encourage the transformation of student metacognitive models from tacit to formal (Schraw & Moshman, 1995). The use of Inquiry Island in 5th grade classrooms resulted in statistically significantly higher scores on performance-based measures of metacognition and inquiry processes than for students in comparison classrooms who did not use Inquiry Island (White & Frederiksen, 2005).

Measuring Self-Regulated Learning in Digital Games

As in traditional learning environments, the measurement of SRL in digital games is in its infancy but shows great potential (Winne, 2010). Snow et al. (2014) stated the best indication of developing self-regulation in games comes by examining students' ability to control and regulate behaviors when presented with numerous options. The authors examined trace data and used transitional probability analysis to determine different regulatory patterns, as described above, used by high- and low-ability students in iSTART-ME. Gaming environments such as this that utilize trace data have the potential to dynamically assess learning and provide feedback in ways not possible to obtain in traditional learning contexts.

One of the strongest proponents for assessment in digital games has been Valerie Shute (2011), who has developed innovative stealth approaches to measure learning. Stealth assessment involves measuring performance of the learner within the narrative of the game and without disrupting the flow of the gameplay experience. Shute (2011) argued that stealth assessment can reduce test anxiety and also improve motivation because students are being assessed while engaged in a pleasurable yet challenging activity. Shute and her colleagues have validated this approach (Shute, Ventura, & Kim, 2013; Ventura, Shute, & Zhao, 2013) by showing relationships between in-game stealth assessment measures and external measures of the same construct (e.g., physics knowledge, persistence). The use of Bayesian models to update and customize the game environment as students play provides the potential to support adaptive learning, an approach that is currently unique to the field. Shute, Ke, and Wang (2017) provided a clear nine-step process of how to develop models and methods to dynamically assess learners while providing a worked example from the Use Your Brainz game. Models such as these are applicable across

gaming environments and reveal the potential that games have to provide customization not possible in traditional learning environments.

Future Research Directions

Due to the infancy of the field, digital games researchers should draw heavily on the existing literature in SRL to design and test game environments, and also on the more established literatures related to computer-based learning environments (see Moos, 2018/*this volume*) and intelligent tutoring systems (see Azevedo, Taub, & Mudrick, 2018/*this volume*). Four suggestions for moving the field forward are described briefly below.

Support All Facets of SRL

While the Nietfeld et al. (2014) study advanced the integration of SRL variables in a game environment, it still did not approach a fully integrated study. In order for full integration to occur the following suggestions should be considered in the implementation of the gaming environment: 1) provide support for the development of SRL skills and the ability to measure the facets of SRL including strategy use, metacognitive monitoring and control, motivation, and emotion; 2) provide extended practice with multiple gameplay sessions; 3) provide activities to assist learners in becoming explicitly aware of important self-regulatory skills that they develop in the game; and 4) measure performance for both content and SRL skills both within and outside (i.e., transfer) the game. These suggestions are informed by Pressley's (1995) characterization of SRL as a complex phenomenon that is developed over time, with training that should emphasize conditional knowledge and application of skills. Relatedly, the call made by Schunk and Ertmer (2000) for further research on the transfer of SRL skills from explicit instruction in content areas is applicable to learning in digital games. While complete integration as described by the four points above may not be feasible nor desirable in every context it seems to be a worthy goal to work toward for serious game researchers seeking to make a significant impact on learning.

Extended Gameplay

Both Wouters et al. (2013) and Clark et al. (2016) emphasized the effect of multiple training sessions in digital game studies. The Jackson and McNamara (2013) study described above was one of the first studies to cite trends for engagement over time matching a game-based program versus a non-game based program. Reiterating a long-standing issue facing research in SRL (Pressley, 1995), the design of programs and interventions that can be maintained over extended periods of time are required to make enduring changes in SRL skills. This is one of the primary challenges for studies of SRL and digital games to address in the near term.

Narrative Learning

One major challenge for digital game studies is the ability to encourage and scaffold engagement that facilitates learning without disrupting the flow of the game itself. For instance, this might involve the ability to seamlessly integrate attempts to encourage mastery goals or to facilitate accurate monitoring on the part of the students using implicit integration techniques that align with the narrative of the game (Nietfeld & Shores, 2011). In order to do this, a unique narrative-centered approach can be presented with "story-centric" problem-solving activities (Rowe, Shores, Mott, & Lester, 2010). This approach is common across many established serious game environments such as Quest Atlantis (Barab et al., 2007), River City (Ketelhut, Dede, Clarke, Nelson, & Bowman, 2007), and Crystal Island (Lester et al., 2014) that use rich narrative settings to contextualize inquiry-based learning scenarios.

Caution must be provided for this recommendation as narrative approaches are thus far not empirically supported when examined across the board (Adams, Mayer, MacNamara, Koenig, & Wainess, 2012; Clark et al., 2016; Wouters et al., 2013). Instead, early evidence has shown content learning advantages for games that provide simple schematics over those that present more realistic settings. A suggested reason for this is that rich narratives

have the potential to distract the learner from the central learning objectives. Clark et al. (2016) pointed out that game designers and educational researchers must ensure alignment between the game graphics, environments, and narratives with the assessed learning objectives.

Barab et al. (2007) provided a model of a design-based approach and classroom integration of a narrative version of Quest Atlantis for 4th grade students. The narrative was centered around an area called Taiga Park that was undergoing a water-quality dilemma. In order to solve the dilemma, students were required to engage in an inquiry-based approach testing water samples and examining various stakeholders' activities in the park. The research team found positive gains for both knowledge directly related to the games' curriculum and also on distal-level items that measured cross-context or transferable knowledge across two studies involving both high-achieving and low-achieving students. The studies included sessions spread out between two weeks and one month respectively. Between studies Barab et al. conducted an analysis of the narrative and made critical changes that involved implicating multiple groups of the Taiga Park users, creating more involvement with pedagogical agents, and more complex missions. The Barab et al. (2007) study was not specifically focused on SRL but presents an approach by which an SRL framework could be overlaid and applied in a classroom. Particularly noteworthy was the iterative approach taken to better align the narrative with the learning objectives.

Evidence of Games That Encourage the Transfer of SRL Skills

Given emerging evidence for their impact on content learning outcomes, one of the next major foci in the study of digital games will be on the transfer of learning to contexts outside of the game environment. For the study of SRL in games this translates to a focus on in-game scaffolds that facilitate the transfer of both content knowledge and SRL skills. At present there is a small but growing momentum for studying the transfer of content knowledge with digital games but none as of yet for research on the transfer of SRL skills. Early evidence for content-knowledge transfer is encouraging. Barzilai and Blau (2014) found that an external scaffold that preceded gameplay, as opposed to after gameplay, for children aged 6–14 on a business simulation game led to greater problem solving on a formal assessment outside of the game. The scaffold appeared to function as an advanced organizer to provide a framework for understanding relationships between the topics of cost, price, and profit that were included in the game. However, ability to solve the financial-mathematical word problems was low across groups outside of the game, prompting the authors to argue that there is a need to consider metacognitive scaffolds to encourage the explicit abstraction of principles from inside the game to contexts outside the game in order to ensure transfer. Moreno and Mayer (2005) investigated college students using the Design-A-Plant program that required an understanding of plant survival under different weather conditions. Conditions included variations of guidance (e.g., feedback on reasons for the correct answer) and self-reflection (e.g., justification of students' own answers). Explanatory feedback but not self-reflection resulted in better transfer, fewer incorrect answers, and fewer misconceptions, pointing to the need to make explicit the connection between the content and its potential application. These studies are examples of the incorporation of transfer measures; however, they are the exception rather than the rule. More emphasis should be placed on considering transfer during the design of the game, the design of studies, and from the perspective of cross-curricular learning.

Implications for Educational Practice

Developing Classroom-Compatible Digital Games

Digital games have the potential to become a part of the everyday culture within schools and become “classroom-compatible” but a number of considerations must be taken into account. First, games must align with important curricular goals and targeted academic skills determined by teachers. In most cases this requires that a game should include sufficient content depth and offer extended practice sessions. Second, games will have to be built for and tested with diverse groups of learners. Careful consideration should be taken so that games and assessments within games do not give advantages to those with more prior experience or higher computer game self-efficacy. Players should be able to adapt to gaming environments within a short period of time regardless of

incoming levels of gaming experience. Third, the game-design process should include an iterative development process with on-going collaboration between experts from various disciplines, teachers, and the students.

Sustained Engagement

Digital games hold the potential to sustain engagement over time for learning content and complex skills. The success of maintaining such engagement lies with features unique to games such as role taking, challenge, compelling narratives, and the opportunity to progress through more advanced levels. The game-based environment also allows for customized learning and continual feedback that is relevant to both academic skills and the gaming framework. These design factors can elicit emotional, cognitive, and perceptual processes that generate a sense of purpose or commitment to the game that is hopefully the impetus for the development of more sophisticated mental models and opportunities for transfer (Hacker, 2017).

Using Digital Games to Promote SRL Skills as Important Educational Outcomes

The unique qualities of games also increase the opportunity to promote SRL skills as outcomes. Consider games that require evidence of accurate monitoring, the use of multiple strategies, or indicators of growth mindset to earn badges, gain points, or unlock hidden game features. Digital games can be created to leverage the engagement that these features support and produce SRL variables as outcomes. The opportunity to study SRL variables as outcomes of digital games is currently wide open. Can playing digital games improve conditional knowledge and therefore learners' ability to understand when and why to apply strategies outside of the game? Can digital games help improve the domain-specific or general monitoring skills of learners? Can digital games, if played over many sessions, impact learners' mindsets or increase mastery approach goal orientations? Can games teach learners adaptive help-seeking skills that transfer outside of the game context? These are just a sample of questions that could have profound implications for digital games in practice.

Conclusion

Research in digital games related to SRL has yet to gain a strong foothold in the literature but appears to be at a tipping point. Numerous game-based studies framed by SRL theory and even more SRL studies from computer-based learning environments and intelligent tutoring systems are paving the way for the study of SRL in digital games. Current research shows great promise for SRL to impact learning in digital games; however, a more integrated approach to incorporating and targeting all facets of self-regulation is needed. SRL skills can have a significant impact for learning in games and can also be important products of games.

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19 Self-Regulation of Learning and Performance in Computer-Supported Collaborative Learning Environments

Peter Reimann and Maria Bannert

Introduction

Self-regulation of individual learning has a long tradition in educational psychology (Zimmerman & Schunk, 2011), and more recently in educational technology research (Azevedo & Aleven, 2013). Self-regulated learning refers to learners' strategic and self-regulated behavior to attain their learning goals (Schunk & Zimmerman, 1998). It is seen as a complex process that depends on the nature and sequencing of different self-regulated activities, such as planning, monitoring, and reflection (e.g., Azevedo, 2009; Boekaerts, Pintrich, & Zeldner, 2000; Efklides, 2008; Pintrich, 2000; Winne, 2018/this volume; Winne & Hadwin, 2008; Zimmerman, 2000). Self-regulated learning became a key topic in educational research because students, who perform these processes and activities spontaneously or even when supported by means of instructional scaffolds, show better learning performance (Azevedo & Hadwin, 2005; Bannert & Reimann, 2012).

Over recent years, self-regulation of learning in face-to-face (ftf) groups (Järvenoja, Järvelä, & Malmberg, 2015; Schoor, Narciss, & Körndle, 2015) and in groups that cooperate through a technology medium (Computer-Supported Collaborative Learning, CSCL; Järvelä & Hadwin, 2013; Kreijns, Kirschner, & Vermeulen, 2013) have become the subject of research (Hadwin, Järvelä, & Miller, 2018/this volume). This chapter looks at CSCL research from the perspective of support technology that can help a group of students to regulate their learning. Hence, using the terminology of Hadwin and Oshige (2011) and Järvelä and Hadwin (2013), the focus is on socially shared regulation of group cognition and group interaction. In general, it is assumed that successful regulation of collaborative learning requires the combination of regulation of one's own learning, helping specific group members via co-regulation, and the whole group to engage in shared regulation (Järvelä & Hadwin, 2013, p. 28).

As the analysis by Schoor et al. (2015) reveals, socially shared regulation is related to the situational view of learning (Greeno & Engeström, 2014). It is different from co-regulation where the social environment, such as a group, is used to help an individual with regulation. In socially shared regulation of group processes, the target is the group as a whole, not any individual member.

The chapter begins by introducing four key concepts: regulation, social interaction, collective cognitive responsibility, and coordination. Next, the research on group awareness tools (GATs) and representational guidance is surveyed. The main difference between the two is that awareness tools support regulation by providing

information in addition to whatever representations and tools are provided for getting the task done, whereas support through representational guidance is integrated into the objects that are used for problem solving and learning; group awareness tools are display-centric, whereas representational guidance is object-centric. Research on roles, prompts, and script—all prominent in CSCL—are not addressed as these can be seen as means more for external regulation than for supporting self-regulation. The chapter ends with identifying promising areas for future research and addressing major implications for educational practice.

Basic Concepts and Theoretical Approaches to Supporting Regulation in CSCL Environments

Regulation of Social Interaction

Technology is often used as a remedy for the problems collaborative learning groups face, including problems caused by the technology itself. Several problems are mentioned in the literature, such as the lack of (high-quality) contributions in online learning environments (Kreijns et al., 2013). Learning through the “social process of developing shared understanding through interaction” (Hiltz, 1994, p. 2) is arguably the most natural way for humans to learn, when applied in formal education and conducted online. However, and somewhat paradoxically, research shows again and again that interaction frequencies are low, and the contribution quality is often mediocre. Another often identified problematic area are socio-emotional processes: from lack of social presence (Walther, 1993) to aggressive behavior such as flaming (Reinig, Briggs, & Nunamaker, 1998). Numerous studies have focused on the difference between ftf and technology-mediated communications as the cause of both the cognitive and the socio-emotional problems (Dennis & Valacich, 1999).

Kreijns and colleagues (Kreijns et al., 2013; Kreijns et al., 2003) have developed a framework to account for the social side of learning in groups. They argue: “Only when the group development results in a social space where trust, sense of community, and strong interpersonal relationships exist can CSCL pedagogy be successfully applied” (Kreijns et al., 2013, p. 230). While trust has become a key concept in the design of socio-technical systems in general (Kolp & Wautelet, 2009), it may be particularly important in the context of online learning groups because, almost by definition, members of learning groups cannot (always) display competent behavior or (always) act with confidence.

Kreijns et al. (2013) argue that designing for socio-emotional processes is infrequently done in CSCL, with the focus of instructional design being on the cognitive aspects. Seldom do designers include concerns for the emotional needs of learners, such as the need for self-realization (Maslov, 1968) or the need for affiliation (McGrath & Tschan, 2004). Anyone designing for group work and group learning has to keep in mind the fundamental functions of groups: (a) to complete group projects, (b) to fulfill members’ needs, and (c) to maintain group integrity (Arrow, McGrath, & Behrdal, 2000).

Even in group learning research, interactions that are not cognitively task-oriented are often considered (and coded) as ‘non-task’ interactions, usually with a negative connotation (‘unproductive,’ ‘off target’). However, such a category of task-related socio-emotional interactions clearly exists, because these are necessary to fulfill member needs and to maintain group system integrity.

The framework suggested by Kreijns et al. (2013) sees social interaction as dependent on, and emergent from, three constructs: sociability, social presence, and social space. These elements are related as follows: Sociability is an attribute of the CSCL environment. It is defined as “the extent to which a CSCL environment can facilitate the emergence of a sound social space through socioemotional interaction.” A sound social space “is characterized by strong interpersonal relationships, trust, and a sense of cohesion” (Kreijns et al., 2013, p. 231). This construct is understood to be related to group (or classroom) atmosphere/climate (Wheelan, 1994), although the authors do not refer to this concept. Sociability is the potential of a CSCL environment to encourage socio-emotional interaction in its users. The extent to which this potential becomes reality, and the social space becomes sound, depends on the extent of the social presence of the participants: “The extent to which people experience each other as ‘real’ people in the communication” (Kreijns et al., 2013, p. 231).

Given the central role of sociability in this framework, how does one design CSCL environments, and more generally, social sites and groupware, for sociability? The answer to this question has been largely defined in terms of interface elements, such as including virtual hangouts and coffee machines on community websites. Thus, sociability is seen as a property of the technology. A different view sees sociability as a property of the social system, and suggests realizing sociability by providing the means for an online community to self-regulate. For example, Preece (2000) defines sociability as that characteristic of a community concerned with planning and developing understandable and acceptable social policies to support the community's purpose. (See also Kraut & Resnick, 2011, for more recent work on design guidelines for online communities.)

Clearly, the two interpretations of sociability complement each other. Kreijns et al. (2013) therefore suggest thinking of the tangible elements of CSCL environments, in terms of social affordances, as “those properties of the CSCL environment that act as social-contextual facilitators relevant to the learner's socioemotional interactions” (Kreijns et al., 2013, p. 233). Such affordances can be actualized, for instance, in the form of virtual spaces (e.g., a ‘meeting corner’) by adding awareness tools (Janssen & Bodemer, 2013) or by providing functionality for groups to define their own norms and processes (Fischer & Herrmann, 2011; Kildare, Williams, Hartnett, & Reimann, 2007).

Collective Responsibility

So far, the concepts introduced are regulation, with roots in the theory of feedback systems (Schoor et al., 2015), and social interaction; in combination, they lead to the concept of socially shared regulation. A further important concept from CSCL research is collective (cognitive) responsibility for knowledge building (Paavola & Hakkarainen, 2005; Scardamalia, 2002; Zhang, Scardamalia, Reeve, & Messina, 2009). As Scardamalia has originally suggested, in the knowledge society it is not sufficient to take on agency for one's own learning and development—to become a self-directed learner; in addition, one must take on agency for building knowledge together with others, and for others. Collective cognitive responsibility means responsibility for the state of public knowledge. This includes “reviewing and understanding the state of knowledge in the broader world, generating and continually working with promising ideas” (Zhang et al., 2009, p. 9). Cognitive agency in this context means contributing to the creation of knowledge objects—which are not identical with but are represented by such things as texts, models, formula, computer programs, etc.—that is, knowledge external to the brain/mind.

Coordination

The fourth foundational concept to introduce is that of coordination. From a complex system perspective, (working) groups are made up out of three types of elements: people who become group members, intentions embodied in group projects, and resources that the group can use, like technologies (Mcgrath, Arrow, & Berdahl, 2000). These elements need coordination in a complex network comprising a coordinated pattern of member–task–tool relations (Mcgrath et al., 2000, p. 98). The group network is comprised of six sub-networks: (1) In the member–member network, relationships such as friendships have to be coordinated. (2) Task–task relations pertain to coordinating the sequencing of (sub-)tasks. (3) The tool network refers to tool–tool relations, for example when specific computer hard- and software has to be coordinated. (4) Member–task relations, for example who is doing what until when, are coordinated in the labor network. Finally, (5) member–tool relations determine how members will do their tasks that are referred to in the role network, and (6) the job network addresses the task–tool relations, specifically, which tools are appropriate for specific tasks.

These networks give rise to complexity phenomena, such as non-linearity and self-organization, as developed in theories of complex systems (Jacobson & Wilensky, 2006). Using complexity theory for understanding coordination processes in groups has been suggested by Sawyer (2005) and more recently by Cress, Feinkohl, Jirschtzka, and Kimmerle (2016), among others. To help groups that do not work face to face improve their coordination, group awareness tools have been developed.

Group Awareness Tools

Successful CSCL poses high demands on a learner's individual regulation of learning as well as on group's regulation of the learning processes (Järvelä & Hadwin, 2013). Beside individual regulation of one's own learning, such as monitoring and control, group processes have to be regulated on different levels (Schoor & Bannert, 2012), such as monitoring and controlling the group's learning progress, motivating partners to participate and contribute, and detecting and solving conflicts in order to establish and keep a positive group climate. Although these demands apply for collaboration in ftf settings, too, the limitation of social presence in online learning settings (e.g., Weinel, Bannert, Zumbach, Hoppe, & Mahlzahl, 2011) may increase regulation problems in CSCL (Janssen & Bodemer, 2013). Hence, one major topic in current CSCL research is the design and investigation of tools to support online group regulation.

Concepts

There are different ways to maintain group regulation in online settings. The following distinguishes between support of guided communication by external regulation of learning versus tools that stimulate and enhance a group's internal regulation of learning. The first approach offers explicit instruction on different role assignments, such as scripted collaboration (Fischer, Kollar, Stegmann, & Wecker, 2013) by which roles, tasks, and sequences of task execution of the collaborators are externally structured and regulated by specific scripts. The less guided approach is provided by awareness tools which induce and support a learner's and group's coordination and regulation by offering information on different aspects of the group situation (Hesse, 2007). Group awareness tools (see Janssen & Bodemer, 2013) such as these induce and support the internal regulation of group learning, since collaborators have the choice to use them or not. This is the reason why group awareness tools are so promising for self-regulation since they do not restrict one's own regulation or group regulation compared to the assigned roles and activities of scripted cooperation.

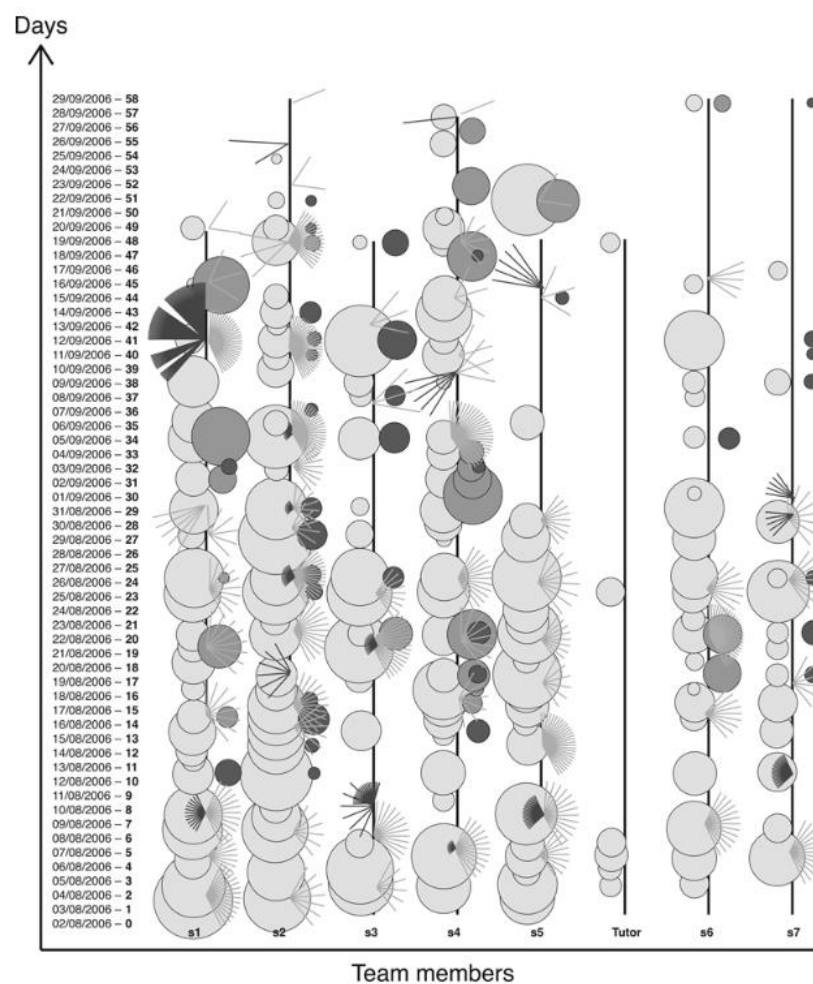
In general, group awareness refers to the perception and knowledge of social context information in a group. Because social cues are limited in online communication, awareness tools present information in order to improve the quality of interaction and to enhance group regulation.

Research on group awareness started by investigating the effects of information presentation on so-called spatial activities of group members (i.e., who is online, who works on which part of the screen) in computer-supported cooperative work settings. By implementing the concept in CSCL research, the focus changed to social and cognitive aspects of group collaboration (e.g., Buder, 2011). Social group awareness tools present information on participation rate, behavior, social status, and appearance of collaborators (e.g., Kreijns et al., 2013), which is usually not available in online communication. Cognitive group awareness tools, however, offer information about one's own knowledge, skills, and opinions about a topic as well as knowledge, skills, and opinions from the other collaborators, information that is not directly observable and hence even not available in ftf communication. Both kinds of group awareness tools aim to improve groups' sharing, elaborating, and acquiring knowledge.

A new and promising concept of group awareness tools was recently introduced by Järvelä et al. (2015), based on the idea of promoting CSCL collaboration. This can be achieved by explicitly increasing the awareness of an individual's and group's self- and shared regulation with CSCL regulation awareness tools (Laru, Malmberg, Järvenoja, Sarenius, & Järvelä, 2015).

The following presents some recent empirical research on group awareness tools and explains why they are necessary and helpful to facilitate regulation in CSCL. The next section will also describe how these awareness tools function and discuss whether or not they are effective. For a more detailed presentation, see recent research overviews by Janssen and Bodemer (2013); Kirschner, Kreijns, Phielix, and Fransen (2015); and Järvelä et al. (2015).

Social group awareness tools aim to increase the awareness of different social aspects of CSCL groups by gathering and presenting different social information to the group (e.g., Kirschner et al., 2015). Janssen and Bodemer (2013) refer to social group awareness as generated information about a group member's collaborative behavior (Janssen & Bodemer, 2013, p. 47). Most commonly, the degree of active participation (when, what, how, and why) is gathered from different sources (chat, email, task area) and visualized in different ways to enhance group coordination and regulation. For example, in a line of research at the University of Sydney, awareness tools have been developed that support students who learn to develop software in teams (Kay, Maisonneuve, Yacef, & Reimann, 2006; Reimann & Kay, 2010). Information on team performance was gathered from various places—a ticket system for task planning, a wiki, a software versioning system—and visualized in a variety of forms, such as social network diagrams and a new visualization called Wattle Tree (see [Figure 19.1](#)). It combines information across all the three activity areas into one comprehensive visualization. It was found that this kind of visualization was particularly valued by



[Figure 19.1](#) A Wattle Tree diagram

student team members who were in the role of the team leader, as it helped them to communicate individual team members' contributions and effort without having to use a normative language.

Empirical research demonstrates that presenting quantitative information about each member's participation (e.g., amount of contributions) increased activity of the whole group (see Dehler, Bodemer, Buder, & Hesse, 2011). Providing social information in a qualitative way, such as dis-/agreement with contributions (Leshed et al., 2009), positively affected group collaboration, too, but not group and/or individual performance. Janssen and Bodemer (2013) argue that in research of social group awareness tools, performance measures are often missing. Moreover, the kind and type of visualization of social information is highly critical. For example, presenting cumulative data on participation behavior was more effective in increasing member contribution in a CSCL setting compared to providing the same information as absolute data (Kimmerle & Cress, 2009). Here much more research is needed to give sound recommendations on how to present social information to not only positively affect group regulation but also to increase individual and group performance.

Cognitive Group Awareness Tools

Cognitive group awareness tools differ predominantly on which kind of and how information about collaborators' knowledge and opinions is gathered, on the individual and group levels, and on how it is presented to the collaborators.

Assessing the knowledge, opinions, and understanding is usually conducted by obtaining learners' subjective ratings (Dehler et al., 2011), using tests such as multiple-choice knowledge tests (Sangin, Molinari, Nüssli, & Dillenbourg, 2011), or self-constructed concept maps (Engelmann, Tergan, & Hesse, 2010). Presenting individual and group knowledge by means of each partner's knowledge scores or concept maps has frequently had positive effects on group coordination and communication (e.g., Dehler et al., 2011) and even on individual and/or group performance (Engelmann & Hesse, 2010). These positive effects of cognitive group awareness tools can be explained by the fact that comparisons of participating collaborators' knowledge, understanding, and opinions are directly available and easily derivable, thus triggering discussion and reflection of shared information and knowledge that, in turn, positively affects group regulation (Bodemer, 2011; Dehler et al., 2011; Gijlers & de Jong, 2009; Kirschner et al., 2015).

One line of research (Engelmann & Hesse, 2011; Engelmann et al., 2010; Schreiber & Engelmann, 2010) builds on information awareness research showing that the efficacy of groups, for both work and learning, depends, to some extent, on knowing what the others know (knowledge awareness) and what information the others have access to (information awareness). The experimental paradigm underlying the research in CSCL on this topic can best be described as a variant of the 'hidden profile' paradigm developed in social psychology research (Stasser, Vaughan, & Stewart, 2000). Studies have shown that group performance on problem solving and decision making is negatively affected by group members' reluctance to share relevant information—the information that only an individual member may have. Studies have been conducted showing that using distributed concept maps as a knowledge-sharing device increases knowledge sharing (Engelmann & Hesse, 2010, 2011; Schreiber & Engelmann, 2010), and this leads to better collaboration and problem-solving performance.

Self-Regulation Group Awareness Tools

Especially promising from the perspective of self-regulation is the newest approach of group awareness tools that aim to explicitly support socially shared regulation of learning in online communication. Järvelä et al. (2015) argue that traditional CSCL research has neglected the role of learners' being aware of their own learning and group learning. For successful socially shared regulation, authors recommend three design principles. The first principle—Awareness—aims at promoting a learner's awareness of individual and group learning processes. By means of the second principle—Externalizations—adequate visualization of the group's learning processes is provided, and with the help of the third principle—Prompting Regulation—a group's regulatory processes are increased by prompting. Empirical results demonstrate positive effects on shared regulation and collaborative learning. A closer look into process data revealed two groups with different advanced regulatory strategies (Laru et al., 2014). By means of the tools for socially shared regulated learning (SSRL tools), one group developed

superior regulatory strategies over time whereas the other groups of learners mainly focused on environmental and motivational challenges.

Although this research is still in the beginning stages, it shows that awareness of different aspects in CSCL (whether it refers to social, cognitive, or shared regulation information) is a necessary prerequisite for successful group regulation and learning. Nevertheless, only providing awareness tools in online environments is not enough from an educational point of view. Research on trainings of self-regulated learning (SRL trainings) indicate that informed training of individuals and groups is required, including why it is worthwhile to spend the effort in tool use, and the importance of providing enough time for exercises and feedback, in order to adequately use such tools across conditions (Bannert & Mengelkamp, 2013; Veenman, van Hout-Wolters, & Afflerbach, 2009).

Representational Guidance

Concepts

Representational guidance is regulation through artefacts or objects—documents in particular—rather than through explicit social interaction, such as talk and chat. Representational guidance is different from group awareness tools because it is realized through the work artefacts themselves rather than taking the form of (augmentation) tools that are separated from, and additional to, the work artefacts. An important aspect of representational guidance is that the representations are constructed by the learners themselves instead of being provided to them in the form of mirroring or guidance information.

The concept has been introduced to CSCL researchers by Suthers (Suthers, 2001; Suthers, Vatrappu, Medina, Joseph, & Dwyer, 2008). Originally, it has been considered as a concept to understand and a means to support regulation of cognition, but it can be seen as addressing regulation of social interaction as well. The concept of representational guidance is nowadays more discussed in Computer-Supported Cooperative Work (CSCW) research than CSCL, likely because the artefacts used for regulation are work- and task-specific.

Regulation of Cognition

Dan Suthers's work is around artefacts that have been developed for supporting learning in groups, which are different from artefacts for working in teams. They are more like representational tools rather than displays. For instance, while concept maps (Dehler et al., 2011) are used to visualize shared knowledge, the (pair) problem solving itself is not seen as being influenced by, or indeed dependent on, the concept map notation but on the content. Suthers's research is mainly concerned with how the representational notations work—their form and visual grammar, not only their content—both for facilitating interactions as well as solving problems. The representations become resources for conversation. When learner-constructed external representations become part of the collaborators' shared context, the distinctions and relationships made salient by these representations may guide their interactions in ways that influence learning outcomes (Suthers, 2001, p. 255).

A key concept to understanding the influence representations have on interaction and collaborative problem solving is salience of information—meaning how the representation facilitates processing of certain information (possibly at the expense of others). For instance, the absence of relations between elements is made particularly salient in tabular representations, because in tables missing relations appear as empty cells, whereas missing relations are less salient in textual representations.

Salience is related to constraints, to limits in expressiveness. A table or a graph is more constrained in expressiveness than free text, for example. More constrained representations make specific aspects of information more salient. Taken together, constraints and salience constitute representational guidance—"Each given representational notation manifests a particular representational guidance, expressing certain aspects of one's knowledge better than others do" (Suthers, 2001, p. 255).

Representational guidance has cognitive effects and a knowledge function at the level of the individual learner, in that it facilitates reasoning with external representations (Ainsworth, Bibby, & Wood, 1998; Kirsh, 2010; Larkin & Simon, 1987; Some-ren, Reimann, Boshuizen, & de Jong, 1998) and affects the encoding and retrieval of information (Mayer, 2005). When used in groups, external representations take on a coordinating function, in addition to a cognitive function; they become resources not only for problem solving, but also for interaction. Following Nicolini, Mengis, and Swan (2011), external representations, and objects in general, can perform three kinds of work: “they provide the motives and drive for collaboration to emerge, they allow participants to work across different types of boundaries, and they constitute the fundamental infrastructure of the activity” (p. 612). For instance, when pairs or groups of learners are co-constructing a concept map (Engelmann & Hesse, 2010), (a) the concept map qua object may motivate the learners to collaborate because each of them wants to see the concept map completed (Knorr Cetina, 1997, speaks of the libidinous, the epistemic function); it may (b) help group members to gain a shared understanding despite possibly massive differences in conceptions, interests, and epistemic beliefs (and thereby function as a boundary object; Star & Griesemer, 1989); and (c) concept maps, or concept-mapping tools more precisely, may provide the main medium through which to communicate, hence providing the infrastructure for communication (Star & Ruhleder, 1996).

As an analytical framework to understanding the role that objects (external representations) play for group performance and learning, it may be useful to build on conceptions developed on group modeling (Richardson, 2012; Vennix, 1999) and on research on reasoning with external representations (Suthers, 2001). These studies show that three elements contribute to successful problem solving: (1) When there is little overlap between students’ mental models and the object currently the focus of the group work, the model loses connection with students’ understanding. (2) If the overlap between the current model object and the principles governing the representational notation becomes too small, the external representation can become ambiguous and less useful for supporting a shared understanding. And (3) when formerly constructed objects are not sufficiently considered, the group runs the risk of repeating work, forgetting information, and does not develop a rationale for the representation.

Equipped with these concepts, here now is some of the empirical research on representational guidance, broadly conceived.

Empirical Research

Evidentiary Reasoning

Suthers and Hundhausen (2003) studied how differences in the way hypothesis–evidence relations were graphically displayed to groups of learners affected interaction and learning in those groups. Three graphical representations were compared: graph, matrix, and text. The information in these three representations was the same. Building on research on the effects of external representations for individual problem solving (Larkin & Simon, 1987; Zhang, 1997), Suthers and Hundhausen expected and found evidence for three functions of graphical representations that are unique to situations in which a group is constructing and manipulating shared representations that are part of a constructive activity: (a) initiating and negotiation of meaning, (b) serving as a representational proxy for gestural deixis, and (c) providing a basis for implicitly shared awareness.

Learning With and From Argumentative Diagrams

Collaborative argumentation based learning (CABLE; van Amelsvoort, Andriessen, & Kanselaar, 2007) is an intensively studied pedagogy, with roots in research on asynchronous discussion forums (Suthers et al., 2008) and on synchronous group discussions, which are mostly chat-based and often extend the chat channel with graphical notations for arguments (Schwarz & Asterhan, 2011) or other means, such as facilitation templates (Winne, Hadwin, & Gress, 2010). CABLE means something more specific than ‘having a discussion,’ though; in

CABLE, students learn by reasoning with information rather than merely retrieving it from memory and presenting it to others (Andriessen, Baker, & Suthers, 2003). In the course of argumentation, students need to make their knowledge explicit and look at it from different perspectives, thus “collaboratively constructing their knowledge of the space of debate” (van Amelsvoort et al., 2007, p. 486). A comprehensive overview of research can be found in Noroozi, Weinberger, Biemans, Mulder, and Chizari (2012).

In addition to the benefit resulting from the fact that relations are more salient in (network) diagrams (Suthers & Hundhausen, 2003), diagrammatic representations of arguments can help to understand and communicate arguments because they provide an overview of the structure of the argument (Schwarz, Schur, Pensso, & Tayer, 2010) and help to maintain focus (Schwarz & Asterhan, 2011). The reasons why these benefits occur are partially found in the representational guidance function that Suthers (2001) has elaborated and because diagrams are two-dimensional spatial structures that allow for non-linear perceptual processing (Kirsh, 2010). This can be particularly advantageous in the context of argumentation because argumentation is not linear (Coirier, Andriessen, & Chanquoy, 1999). Furthermore, even complex arguments can be expressed concisely in a diagram, thus allowing hiding details until they are needed. On a related note, diagrams make it easier to refer to elements of an argument by deixis as observed by Suthers and Hundhausen (2003), amongst others.

However, these features do not necessarily translate into benefits for argumentation and learning from argumentation. One challenge is that both talk and text are sequentially linear, which requires a translation from the non-linear to a linear representation (Coirier et al., 1999). Hence, despite their affordances for visual processing, diagrams may not necessarily fare better than alternative representations, particularly in text, at least under circumstances where the argument has to be linearized eventually, as in argumentative writing (van Amelsvoort et al., 2007). It is also not clear from the onset whether the benefits of diagrammatic representations occur when diagrams are inspected or if the construction process is additionally necessary to make them beneficial for argumentation and learning.

Van Amelsvoort et al. (2007) conducted a study that investigated the effects of the diagrammatic format compared to the textual format and of the construction of diagrams, compared to the diagram interpretation condition. They found that students who constructed a diagrammatic representation themselves explored the topic more than students in the other conditions (text only, and diagram provided, respectively). They further found that dyads who engaged in deep discussions used their diagrams as a basis for knowledge construction—the collectively generated text was more than the sum of the individual diagram—whereas dyads who discussed the topic only superficially used the individually constructed diagrams mainly for copying and pasting to the collectively generated text. The benefits of diagrams, hence, occurred only for those students who used them in a particular, namely co-constructive, way.

Schwarz and Asterhan (2011) looked at diagrammatic argument representations from the perspective of the teacher as the facilitator of a (classroom) discussion. They describe experiences with the Argonaut software, a research prototype designed to support moderators of online, synchronous discussions. Argonaut is an instance of the kind of software applications that have been pioneered particularly by Hoppe (e.g., Hoppe, De Groot, & Hever, 2009) to provide synchronously shared access to graphically rich yet semantically constrained interface objects. In Argonaut, students develop argumentation graphs (along with chat or voice communication), and moderators can not only see these graphs developing but are also provided with a number of awareness-increasing tools including basic semantic analysis of the arguments put forward by students. The design goal was to help the teacher in supporting multiple discussion groups in parallel. From their observations of two moderators, the authors noted that the diagrammatic representation helped to highlight specific contributions and to direct the attention of group members to important contributions. While this study is not strictly speaking about group self-regulation, providing the same information that the moderator receives to the group itself, and/or let the group decide to give one of the group members the role of a peer-moderator, would not be contradictory to the goals of group self-regulation.

Knowledge Building is a pedagogical concept that emphasizes the difference between learning as a change in mental state and “the out-in-the world production of designs, theories, problem solutions, hypotheses, proofs, and the like” (Scardamalia & Bereiter, 2014, p. 397). Building on Popper’s (1972) suggestion that knowledge is a kind of entity in its own right, different from mental and physical states, and on research on organizational learning (Ichijo & Nonaka, 2007), Scardamalia and Bereiter designed an approach to developing knowledge building competences in schools. In addition to pedagogical guidelines, a key element of their approach is knowledge building software: CSILE (Scardamalia & Bereiter, 1994) and Knowledge Forum (Scardamalia & Bereiter, 2003; see www.knowledgeforum.com).

In Knowledge Forum, users create content in the form of notes (which can contain multimedia elements); they organize notes by connecting them with links and clustering them into views. Notes are typed, belonging to scaffolding categories such as ‘My Theory,’ ‘I Need to Understand,’ and ‘New Information.’ Notes can be annotated, referenced, and built on. The latter action is particularly important in Knowledge Building pedagogy because learners are encouraged to collectively advance ideas rather than arguing about the pros and cons of existing ideas, which is more characteristic of learning from argumentation (Wegeriff, 2007). The specific and constrained ontology of notes and links in Knowledge Forum is disparate to concept maps, which do not impose a strict ontology on users. Knowledge Forum maps are in some ways similar to the hypothesis–evidence maps that Suthers has studied but are distinct from those in that Knowledge Forum supports the advancement of explanatory constructs (ideas, models, theories), in addition to being concerned with grounding these constructs in evidence.

From the perspective of group self-regulation, Knowledge Forum combines elements of representational guidance (Suthers, 2001) through the graph/network visualization with (epistemic) metacognitive prompting (Bannert & Mengelkamp, 2013) via the note types. While the focus is on cognitive–epistemic coordination (Kreijns et al., 2013), knowledge maps also have a motivating function and help to coordinate work. For instance, when a student places a ‘My Theory’ note, this may raise curiosity in others, particularly in cases where the proposed theory is at odds with one already posted or if it generalizes a number of existing ideas into a coherent, more powerful whole. In Knowledge Building parlance, this is called ‘rise-above’ and is highly sought after.

The driving element for self-regulation in Knowledge Building environments is the socio-cognitive norm of idea improvement. Every idea is seen, in principle, as improvable:

In such a sociocultural environment, “critical thinking” is manifested not so much by skepticism or argumentativeness as by the pervasive application of “design thinking” ... [the] continual application of a “make it better” heuristic rather than an “arguments for or arguments against” heuristic.

(Scardamalia & Bereiter, 2014, p. 400)

Ideas are thus the central epistemic entity in Knowledge Building pedagogy. The Knowledge Forum web application represents ideas as the central epistemic objects, by reifying them as ‘notes’.

A particularly strong aspect of Knowledge Building pedagogy is that it aims for sustained creative work with ideas—sustained over weeks and months (Zhang, Hong, Scardamalia, Teo, & Morley, 2011). Many projects in school classrooms on knowledge building have been conducted over comparatively long stretches of time, fully integrated into the (usually science) curriculum. For instance, in the study reported in van Aalst and Truong (2011) the intervention in a primary classroom lasted seven months. However, Knowledge Forum is rarely used as the sole means for supporting productive student interaction. In most cases (for an overview see Scardamalia & Bereiter, 2010, 2014), Knowledge Forum is used as a classroom technology rather than being used ‘online.’ This does not exclude the possibility that the software alone could sustain a longer engagement, but there is no direct evidence for that.

Sustained improvement of ideas is an important principle of Knowledge Building; there is no final state of perfection for ideas. Because Knowledge Building pedagogy “puts the emphasis on guiding principles rather than prescribed procedures” (Scardamalia & Bereiter, 2014, p. 403), the Knowledge Forum software needs to support this principle, along with the development of individual and classroom norms. One way to achieve this is through raising metacognitive awareness: Adding a ‘scaffold meter’ to Knowledge Forum helps to keep idea refinement going without the intervention of teachers (Resendes, Chen, Acosta, & Scardamalia, 2013). A scaffold meter is a simple graphical display of the frequency of note scaffolds (‘I need to understand,’ ‘My theory,’ etc.). Another, significantly more complex, way is to visualize the ‘rise-above’ relation in the user interface more explicitly. ‘Rising-above’ in Knowledge Forum means to create notes that increase the explanatory coherence of a set of existing notes. Computing explanatory coherence is a challenging task (Thagard, 1998) that is currently only approximately achieved in Knowledge Forum by combining social network analysis with semantic analysis of the relations between notes (Oshima, Oshima, & Matsuzawa, 2012).

Future Research Directions

This chapter portrayed the field of CSCL research on group self-regulation as largely falling into two categories: explicit support of regulation through group awareness tools and implicit regulation through representational guidance. The picture of the research landscape emerging from this generally supports the analysis provided by Järvelä and Hadwin (2013) that CSCL has so far been focusing on the knowledge construction level, be that individual or collective knowledge construction (learning or knowledge building). If this is the learning level, then an equal focus on the meta-learning level is missing—supporting groups in negotiating and defining learning goals, in monitoring performance against such goals, and in reflecting on goal and strategy choices as well as on group learning processes.

A conceptual challenge for theories of self-regulation is that groups’ meta-learning is different from individuals’ meta-learning—individual self-regulation—at least in terms of the classical cognitive paradigm with a ‘central’ processor and information processing as symbol processing (as for instance with the COPES model, Winne & Hadwin, 1998). In a group, there is no ‘central processor,’ and groups are known for negotiating the meaning of terms, a process that cannot be explained fully as information processing (Putnam, 1988; Searle, 1992). The fact that groups cannot be seen through the lens of the (cognitive) psychology developed for individuals (Stahl, 2006) could also be used as a reason to re-visit conceptions of individual self-regulation. With roots in the feedback theory and cognition as symbolic information processing, these are at odds with many theories in modern cognitive science and neuroscience (Barsalou, 2008; Clark, 2013). Coordination and self-organization is suggested as a more encompassing concept than ‘regulation’ at the group level, but also as a concept that can be applied to self- and co-regulation. The notion of regulation and the feedback loop (Schoor et al., 2015) provides the conundrum that feedback has a stabilizing effect, yet the aim is to foster learning, i.e., change. Coordination, especially in the form of self-organization, allows learning and development to be seen as self-extending processes.

Methodology and research design used in current CSCL research is mainly based on experimental comparisons between the supported experimental group learning with CSCL tools and the control group collaborating without such tools. Future research has to take a closer look at the specific features of these CSCL tools, e.g., awareness tools and particular conditions of their usage (Buder, 2011). Furthermore, as it was shown in Järvelä et al.’s (2015) recent approach, combining different awareness aspects in one CSCL environment seems promising as it may also be true for the combination of other different CSCL tools. Further research is needed on how this combination should be designed, for example, how should they be introduced and in which sequence should they be offered to the collaborators in the CSCL setting, in order to not overload them while facing very complex learning tasks. Finally, it should be pointed out that process analysis would be a fruitful and important methodological approach to investigate group regulation in CSCL settings in more detail (Bannert, Reimann, & Sonnenberg, 2014; Molenaar & Järvelä, 2014; Reimann, Markauskaite, & Bannert, 2014; Schoor & Bannert, 2012). Investigations that would help to offer improved tools in CSCL settings include exploring sequences of social regulatory

processes, especially coordination and self-organization during a CSCL task, understanding their relationship to individual and group performance, and, moreover, analyzing the learning processes supported by specific kinds of CSCL tools.

A major trend seen for the immediate future lies in the convergence of group awareness and feedback tools with learning analytics (Baker & Siemens, 2014; Baker & Yacef, 2009). This broadly connects CSCL environments closer with group regulation and coordination processes in numerous situations in the wild (Wise et al., 2015) but also grounds the more or less ad-hoc visualizations that CSCL has been developing for awareness creation in the larger disciplines of information visualization and human–computer interaction.

Implications for Educational Practice

The educational implications pertain mainly to the level of educational design. Given that the value of self-regulation for achievement has been established for individuals as well as for groups, the question is not whether one should include functionality for socially shared regulation in educational groupware, but how should these be designed, and how can they be implemented?

While regulation is an important prerequisite in individual as well as in group learning, it is seldom directly addressed in educational design. Hence, it can be claimed that teachers and instructional designers have to be informed about the outstanding importance of regulation and how it could be assessed and supported in their everyday classroom and learning settings. In addition, teachers, instructors, and designers have to carefully consider the concepts of social interaction, collective cognitive responsibilities, and coordination, and how they could be implemented in CSCL settings, due to their enormous effect on CSCL as sketched in this chapter.

A distinction has been made in this chapter between two approaches in CSCL that help with the regulation of group learning: awareness tools and representational guidance. Group awareness tools present social context information for online learning groups. This can be done by simply presenting information on collaborators' appearance, i.e., photos or selfies, their social status, and their behavior during the online learning sessions. In addition, presenting information of each group member's knowledge and competencies and information of individual and group regulation will improve the quality of interaction, coordination, group regulation, and learning.

Awareness tools add information to the task environment. For instance, Järvelä et al. (2015) add a 'radar tool' displaying information about individual group members' task perception in a writing environment with the objective to externalize and share self-regulation-relevant information, and they add a shared planning tool to aid in coordinating the approach toward a group's learning task.

In a representational guidance mode, coordination could be supported by displaying the writing task in a particular format, such as in a two-column table with section headings on the left and the name of the group member responsible on the right. Such a tabular format makes certain aspects perceptually salient (Suthers, 2001), such as the fact that some sections do not have writers assigned—some cells are empty.

Hence, an important decision for designers of collaborative learning environments is: Will the regulation-relevant information be integrated into the artefacts that are used to work on the task (a writing assignment, a design task, etc.), or will it be an 'add-on'? The 'or' is not exclusive, as the two approaches can be integrated: Perhaps improving coordination might best be realized by guidance features—i.e., integrated—whereas regulation (of emotions, group dynamics) might better be addressed in the form of awareness and planning tools that are distinct from the work artefacts. There is not much systematic research on the comparative strengths and weaknesses of this design.

Our research overview has identified that many motivational aspects of group learning are now considered in the design of CSCL environments (see also Järvelä et al., 2015; Kreijns et al., 2013). In our view, adding ‘motivating’ features to the technology such as ‘coffee places’ or gamification elements to a group-learning environment can be carried only so far. In addition, and likely more important, the tasks that groups work on should be motivating, specifically with attributes more intrinsic to the task than due to generic incentives such as higher marks (Waterman, 2005). While this may be seen as mainly a challenge for the pedagogical design, it also touches on media and tool design. This because the educational task can be formulated as designing tasks (assignments) and the epistemic objects for learners to work on to accomplish the task. Objects become epistemic “when they embody what one does not know yet” (Nicolini et al., 2011, p. 614). As such, they trigger a desire in people to work on and complete the task represented by the object. There is much to be learned from studies, such as Knorr Cetina’s (1997), regarding what makes objects desirable to invest effort in learning.

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20 Validity and the Use of Self-Report Questionnaires to Assess Self-Regulated Learning

Christopher A. Wolters and Sungjun Won

Models of self-regulated learning (SRL) are used to understand engagement, learning, and achievement in academic contexts from preschool through college (Perry, Hutchinson, Yee, & Määttä, 2018/this volume; Pintrich & Zusho, 2007; Usher & Schunk, 2018/this volume; Winne & Hadwin, 2008). In addition, fostering students' SRL has become an accepted goal among educators and thus a basis for developing instructional policies and practices designed to improve students' academic success (Cleary & Zimmerman, 2004; Dignath & Buttner, 2008; Graham, Harris, MacArthur, & Santangelo, 2018/this volume; Schunk & Zimmerman, 1998). The ability to reach important goals relevant to research and practice alike is predicated on having sound methods for assessing SRL.

In response to this essential need for effective measurement, many different methods have been developed for the assessment of SRL (Azevedo, Taub, & Mudrick, 2018/this volume; Winne & Perry, 2000; Zimmerman, 2008). For instance, researchers have established observational methods that involve monitoring students' behavior within the classroom, recording traces of their behavior when completing tasks, or using data provided by teachers or parents (Winne, 2010; Zimmerman & Martinez-Pons, 1988). As evidence that methods continue to evolve, micro-analytic methods and new forms of data mining have recently shown promise for drawing conclusions about students' SRL (Biswas, Baker, & Paquette, 2018/this volume; Cleary & Callan, 2018/this volume). Despite this diversity and innovation, self-report questionnaires (SRQ) have long been the most common method used to assess SRL (Winne & Perry, 2000). At the same time, and perhaps because of their prominence, criticisms of SRQ, including fundamental questions regarding the validity of the data they produce, are not uncommon (Karabenick & Zusho, 2011; Schellings & Van Hout-Wolters, 2011; Winne & Jamieson-Noel, 2003). Still, others continue to advocate for their use, at least within particular contexts (Butler, 2002; McCardle & Hadwin, 2015).

In light of these on-going tensions, our purpose within this chapter is to evaluate the usefulness of using SRQ for the assessment of SRL. Unlike previous considerations, we frame our discussion around the contemporary understanding of validity presented in the revised Standards for Educational and Psychological Testing (Standards; American Educational Research Association [AERA], American Psychological Association [APA], & National Council on Measurement in Education [NCME], 2014). To address this overall goal, the remainder of the chapter is divided into four sections. First, we provide a working definition of SRQ and identify strengths associated with this type of assessment. Second, we review key aspects of validity and consider the importance of each as it applies to the use of SRQ for assessing SRL. In the third section, we provide recommendations relevant to both researchers and practitioners for using SRQ to assess SRL. Finally, we draw some broader conclusions.

Relevant Theoretical Ideas Underlying the Use of SRQ for Assessing SRL

Defining SRQ

The term self-report applies to any assessment in which individuals respond to prompts that are designed to elicit information regarding the respondents' own attitudes, beliefs, perceptions, behaviors, abilities, or knowledge. This broad category includes such varied methods as verbal interviews, surveys, questionnaires, diaries, think-alouds, and stimulated recall (Greene, Deekens, Copeland, & Yu, 2018/this volume; Greene, Robertson, & Costa, 2011; McCardle & Hadwin, 2015; Zimmerman, 2008). Self-report methods vary with regard to the prompt used to elicit a response as well as the structure imposed on the information that individuals are asked to provide. Some self-report methods, for instance, rely on more elaborate or authentic prompts (e.g., stimulated recall) that ground students' responses to a specific context whereas other prompts might consist of a single word or phrase. Response formats can be more open-ended and permit greater latitude in the nature and amount of information students can provide (e.g., diaries, oral interviews), or they can require selection among a short list of alternatives. Although crisp distinctions among these alternatives often are not feasible, we focus our discussion on a specific type of

instrument termed SRQ. SRQ are instruments in which participants typically are presented with a set of specific statements, questions, or prompts and must respond to each by selecting one of several options provided on the instrument. SRQ can be considered off-line assessments because they are not completed concurrent to engagement in a task (Schellings, 2011; Veenman, 2011).

Appeal of SRQ

Several characteristics inherent to most SRQ make them appealing to researchers who study SRL. Even with large numbers of participants, SRQ are typically cheap to produce, administer, score, and convert into data that are ready for analysis. The ease and speed with which they can be completed allows researchers to assess a wide variety of distinct beliefs, attitudes, strategies, or behaviors within one administration. In many cases, the items on an existing SRQ can be easily adapted to novel contexts. An SRQ allows researchers to assess core facets of SRL that are not easily observable within any specific task (e.g., knowledge activation). As well, SRQ can be used to solicit information about behavior from across multiple contexts or for a broad time period.

Prominent examples of SRQ used by researchers studying SRL include the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1993), the Learning and Study Strategies Inventory (LASSI; Weinstein & Palmer, 2002; Weinstein, Palmer, & Acee, 2016), the Self-Regulation Strategy Inventory—Self-Report (Cleary, 2006), and the Regulation of Learning Questionnaire (McCardle & Hadwin, 2015). One key point about most SRQ, including those cited above, is that they are not intended to assess SRL as a whole but rather particular aspects or components of SRL. Most commonly, SRQ are used to assess motivational beliefs and attitudes associated with SRL and/or students' use of learning or self-regulatory strategies central to SRL. In addition, SRQ have been used to assess SRL or facets of SRL in particular groups, particular academic contexts or domains, or with regard to specific tasks (Crede & Phillips, 2011; Dignath & Buttner, 2008; Duncan & McKeachie, 2005).

Validity

Theoretical understandings regarding the nature of validity, how it is established, and how it should be discussed are not without important points of debate (Newton, 2012b). Still, most contemporary views tend to discuss validity in comprehensive terms with construct validity serving as a unifying theme (AERA, APA, & NCME, 2014; Kane, 2006; Messick, 1989, 1995; Newton, 2012a). From this perspective, overall construct validity is increased or strengthened through various types of evidence that support particular claims or purposes associated with a particular instrument. In line with this perspective, it is not appropriate to refer to different types of validity, or to argue that a particular instrument is or is not valid. Rather there are types of evidence that support various intended uses of the scores from an assessment that together reflect the unitary concept of validity (AERA, APA, & NCME, 2014). Claims about validity are a function of the instrument along with the particular circumstances and purposes for which it is being used. That is, validity arises not from a specific instrument, but from the way in which data from an instrument are interpreted and used for specific purposes. The viability of using SRQ for the assessment of SRL, therefore, rests on whether there is sufficient evidence for validity with regard to the particular purpose(s) for which it is utilized. It would be most fitting, therefore, to consider the evidence of validity for a particular instrument when it is used with regard to particular purpose. Given the scope and purpose of this chapter, however, it is not feasible to narrow our focus to such a degree. Instead, we review the various types of validity evidence and discuss the application of each when using SRQ to assess SRL.

Research Evidence Bearing on Validity and the Use of SRQ

The revised Standards identifies five core types of evidence that can be used to support overall construct validity (AERA, APA, & NCME, 2014). These types of evidence are based on content, response processes, internal structure, relations with other variables, and consequences of the testing. The remainder of this section is divided into sections representing each of these five types of evidence. Within each section, we first describe the type of

validity evidence. Second, we review research using SRQ used to assess SRL that illustrates each type of validity, and we evaluate the strength of the extant support for each type of validity. Finally, we consider challenges that researchers may face in producing additional evidence relevant to each type of validity.

Evidence Based on Content

Evidence of validity based on content is grounded in an appropriate alignment between the theoretically important aspects of SRL and the components that are covered by a particular assessment (AERA, APA, & NCME, 2014). Support for this aspect of validity is necessary to avoid construct-underrepresentation, or when an assessment is too focused and fails to include all relevant dimensions of a construct. For instance, an SRQ may lack this aspect of validity if researchers develop it as a general measure of learning strategies but include items that tap into rehearsal but no other types of strategies (e.g., organization, elaboration). Attention to this aspect of validity also inhibits content irrelevant variance or when an assessment is overly broad and captures variance based on content beyond what is intended (Messick, 1995). For instance, if an assessment intended to assess how frequently students' use particular learning strategies includes items that pertain to students' motivational beliefs, or whether students simply know about the learning strategies, these items contribute content irrelevant variance. To the extent that aspects of SRL (e.g., strategy use) are expected to vary across tasks, contexts, or subject areas, then the relevant content that should be assessed also varies along these factors. Hence, an SRQ developed and tested with regard to a particular task in one subject area (e.g., writing for Language Arts) may lack content validity when used to study the same task within another subject (e.g., writing for science), or different tasks within the same domain (e.g., reading comprehension in Language Arts).

Consistent with the rigorous steps advocated for effective questionnaire development (Gehlbach & Brinkworth, 2011), evidence that supports claims about adequate coverage of a relevant content domain is commonly produced when an SRQ is initially developed. As an early step in the development process, insights about a content domain emerge from efforts to assess students with more open-ended or qualitative forms of data collection. For instance, Wolters (1998) administered open-ended items and got written responses from college students regarding the tactics they might use to sustain or improve their effort when faced with various academic situations. These responses were first used to identify particular types of strategies and later to construct forced-choice items for an SRQ to assess students' use of motivational regulation strategies (Wolters, 1998; Wolters & Benzon, 2013). Other researchers have followed a similar process to create new SRQ relevant to SRL (Cleary, 2006; McCardle & Hadwin, 2015). Along with this step, or somewhat less optimally in place of it, researchers may have experts in a field review items and endorse those that seem most representative of a construct. The purpose common to both of these efforts is to ensure coverage of all of the important dimensions, parts, or facets of the particular construct that one intends to assess.

Important validity evidence based on content also can be pursued after an SRQ is established. For instance, Urdan and Mestas (2006) administered a popular instrument intended to assess the personal achievement goals adopted by secondary students. They followed up with open-ended interviews of the same students that were also designed to assess these goals. Comparisons of the information produced by these two methods raised questions about whether the established SRQ adequately represented the most important types of goals students actually pursued. Hulleman, Schrager, Bodmann, and Harackiewicz (2010) accomplished something similar by comparing several different SRQ used to assess students' achievement goals. Their analyses revealed key discrepancies in the types of achievement goals assessed by different instruments, suggesting issues of content coverage for all of them.

Unfortunately, common practices among researchers who study SRL can easily and quickly reduce the strength of validity evidence for an SRQ based on content. One of these practices, for instance, is when an SRQ established with one population (e.g., college students) is administered and used in an effort to understand SRL among other populations (e.g., secondary students). These commendable attempts at generalization easily can lead to concerns about the evidence of content coverage. As an example, Wolters (1999; Wolters & Rosenthal, 2000) administered the motivational regulation items derived from college students to samples of students in middle and high school.

The overall validity of this application to a younger population rests on the tenuous assumption that the array of strategies assessed by the instrument developed for college students completely overlaps with the set of strategies that are used by younger students (i.e., that no strategies are exclusive to younger or older students). Note too that evidence of internal consistency (e.g., Cronbach's alpha) or internal structure (e.g., confirmatory factor analysis) with a novel population does not address the need for validity evidence based on content. The high alphas for the motivational strategies reported by Wolters and Rosenthal (2000), for instance, indicated that students responded to conceptually related items in a consistent way, but in no way supported the claim that all motivational strategies relevant to younger students were represented on the instrument.

Another frequent practice that can jeopardize the available validity evidence associated with content is when researchers use abridged versions of existing questionnaires. For instance, researchers often use a reduced set of the strategy use scales from the MSLQ or a subset of items from the original self-efficacy scale (Duncan & McKeachie, 2005). Both of these practices undeniably reduce the content that is covered by an assessment. To the extent that the original versions provided appropriate coverage, the use of subsets also would weaken the validity evidence based on content coverage. Evidence for this aspect of validity is reduced without careful consideration of whether all aspects of the underlying construct domain is sufficiently represented.

Evidence Based on Response Processes

Evidence of validity regarding response processes concerns the need to show that the cognitive or psychological processes people utilize when completing an assessment are consistent with the claims for that assessment (AERA, APA, & NCME, 2014). Responding appropriately to an SRQ is dependent on students' engagement in five distinctive steps (Duckworth & Yeager, 2015; Schwartz & Oyserman, 2001). First, respondents must understand the content of the item and what information it is asking to be reported. Items that include unknown words, poor grammar, double-barreled construction, or other similar issues disrupt this step. Second, respondents must search and recall relevant information from their memory. This step is made more challenging when items concern rare or distant events (Winne & Perry, 2000). Third, respondents must consider all the information they have activated and integrate it into a coherent response. Research suggests that both searching and integrating information from memory are subject to biases from prompting and reconstructive interpretations that distort the accuracy of respondents' responses (Veenman, 2011). Fourth, respondents must match this integrated knowledge of their own behavior or beliefs to one of the available response options. This step is made more difficult when response categories are not clear (e.g., how frequent is "often") or fail to include options students want to select (e.g., no "neutral" option). Finally, respondents must consider whether to actually select the apparently correct response, which they may avoid if, for example, they are affected by social desirability concerns.

Many of the most common concerns with the use of SRQ for SRL can be understood as the need for additional evidence supporting this aspect of validity. Most obvious are claims that SRQ are deficient because respondents do not interpret the words or intent of items in a way that is consistent with the assumptions of the questionnaire developers (Castillo-Diaz & Padilla, 2013; Schellings, 2011). For instance, Berger and Karabenick (2016) gave an SRQ to assess use of metacognitive strategies (e.g., planning, monitoring, regulating) and then interviewed students about their understanding of the items. Findings indicated that students did not interpret the meaning or purpose of an item in a consistent way, especially for the planning items. Left unchecked, pervasive misunderstandings of what an item is asking compromise claims about the validity of a scale by introducing content irrelevant variance through this response process.

Concerns that have been raised about grain size and domain specificity (Lonka, Olkinuora, & Mäkinen, 2004; Winne & Perry, 2000) also can be understood through their relation to validity evidence related to response processes. Domain specificity refers to the extent that an SRQ focuses on assessing SRL with regard to a wider (e.g., school, math) or more particular academic context or situation (e.g., math assignment, math class on Tuesday). Grain size reflects the degree of specificity used when operationalizing a construct. It can range from very broad (e.g., using self-regulation strategies) to narrower (e.g., using planning strategies) or more exact (e.g.,

using to-do lists). SRQ that use a high degree of specificity with regard to grain size or domain suffer from concerns about generalizability of findings. In contrast, SRQ that assess SRL with regard to general domains or larger grain sizes can be criticized because they place unreasonably high demands on the memory search and integration processes students must complete in order to provide a response about their attitudes or behaviors. It is easier for students to recall what they did when reading a text just five minutes previously than what they have done when reading texts during an unknown number of study sessions across the course of the semester. These issues may be alleviated by stronger evidence that students can competently search and integrate information about their own strategic behaviors or other aspects of SRL.

Evidence Based on Internal Structure

Evidence based on internal structure concerns the need to demonstrate that the relations among items, components, or dimensions on an assessment of SRL are consistent with theoretical assumptions regarding SRL (AERA, APA, & NCME, 2014). This type of evidence includes consideration of whether items or components of an assessment must be combined or must be kept separate in order to be consistent with a particular theoretical model. If a model of SRL contends that planning and monitoring are distinct processes, for example, then this aspect of validity is only supported if items on an SRQ produce separate factors for each. Conversely, if two processes are substantially equivalent within a particular theoretical model, then an SRQ should not produce separate factors for each. Likewise, this aspect of validity is weakened if a researcher uses an assessment to generate a summed or total score in the absence of a theoretical assumption that SRL is a unitary construct that can be represented by a single score.

Researchers often conduct and report on analyses that address this aspect of validity, especially when first developing an instrument, or when an instrument has been transformed in a major way (e.g., translated into a new language). Exploratory and confirmatory factor analysis, for instance, has been used frequently to evaluate the internal structure of responses to the MSLQ, and has included samples from outside the United States and from unique student populations (Duncan & McKeachie, 2005). In many, but certainly not all, cases, these studies have confirmed theoretical propositions about the distinction among major internal components of SRL. However, the importance of examining these issues becomes apparent when noting that findings can substantially weaken the validity claims for certain instruments. For instance, both Cano (2006) and Melancon (2002) tested and failed to support the ten scales described within the LASSI manual (Weinstein & Palmer, 2002). Similarly, conceptual distinctions that were supported when the MSLQ was developed with college students sometimes disappear when studied with younger students (Pintrich & De Groot, 1990). A less common but still important form of evidence that supports this aspect of validity comes from analyses establishing measurement invariance when comparing scores across groups (e.g., Malpique & Simao, 2015). These analyses establish that the internal structure produced by an instrument is consistent across distinct groups of respondents (e.g., high and low achievers).

A more endemic issue arises from one core advantage associated with SRQ. As noted, it is relatively simple to modify an SRQ to fit new situations, novel populations, or particular theoretical needs. Changes to an existing SRQ can be relatively subtle (e.g., change “math” to “science”) or more severe (e.g., deleting entire scales). Creating substantially new instruments is a fairly easy and common occurrence. Optimally, any modifications should be supported with efforts to show that the internal structure of responses produced with the final instrument is consistent with theoretical assumptions. Unfortunately, this is often not the case. As just one example, Schellings (2011) administered a learning strategies questionnaire to a sample of 190 secondary students and calculated reliabilities and correlations between scales. She did not, however, provide more compelling evidence to support the structural aspects of validity for the new instrument (e.g., confirmatory factor analysis).

Evidence Based on Relations With Other Variables

Among the five broad types of validity evidence presented in the new Standards (AERA, APA, & NCME, 2014), one concerns relations of an assessment with other variables. We consider convergent relations, discriminant relations, and predictive relations separately, although each falls within this larger category.

Convergent Relations

Evidence for validity based on convergent relations refers to the need to show that one assessment of SRL is associated in theoretically consistent ways with other accepted measures of SRL. For instance, evidence supporting this aspect of validity comes when researchers link students' responses on an SRQ of planning to other established SRQ or to other methods used to assess planning.

Many researchers have contributed vital evidence of convergent relations by investigating the associations between students' responses on SRQ assessing SRL and other established SRQ or alternative methods of assessing SRL (Cleary & Callan, 2014; Schellings, 2011). Muis, Winne, and Jamieson-Noel (2007), for example, had students complete three SRQ designed to assess various aspects of SRL (e.g., MSLQ, LASSI) and then evaluated the relations among factors produced from these different instruments, as well as the relation of these factors and other variables. McCardle and Hadwin (2015) explored convergent relations by examining how responses from a new SRQ were related to weekly reflections students provided via a written diary. In a similar vein, Braten and Samuelstuen (2007) administered an SRQ for strategic processing immediately after and in reference to a reading task, and compared scores to physical traces of the strategies that students used during the task. Findings showed good correspondence between scores on the task-specific SRQ regarding strategies that had clear observable counterparts and trace measures of those same strategies. The development of computerized tasks with trace methods, micro-analytic methods, and data mining provide new opportunities to produce evidence regarding the convergent validity of SRQ for SRL.

Discriminant Relations

Validity evidence derived from discriminant relations with other constructs is established when students' responses to an assessment of SRL are related to theoretically dissimilar constructs in a manner that is consistent with expectations (AERA, APA, & NCME, 2014). For example, findings that show that scores on an SRQ exhibit the expected negative relations with constructs considered antithetical to SRL (e.g., procrastination, impulsivity) add to the evidence for this aspect of validity. Support for discriminant relations also comes from studies confirming a lack of association between scores on an assessment of SRL and constructs that are theoretically unrelated (e.g., religiosity). Evidence supporting discriminant validity is also provided when empirical findings show that measures of theoretically distinct aspects of SRL (e.g., use of elaboration and motivational strategies) are not related too strongly. Evidence supporting claims about these theoretical relations strengthens the argument that an instrument assesses only the theoretical constructs it is purported to measure.

Research supporting the validity of SRQ for assessing SRL by documenting expected divergent relations is limited. In one example, Wolters (2003) used an SRQ to test the relations between various aspects of SRL and students' procrastination. In two samples of college students, he found that students who reported increased use of metacognitive strategies tended to report lower levels of procrastination. Muis, Winne, and Jamieson-Noel (2007) addressed this aspect of validity when they found generally low correlations among disparate types of strategies assessed within and between three prominent SRQ.

Predictive Relations

Evidence of validity based on predictive relations with other variables is augmented when researchers demonstrate that responses to an assessment of SRL can be used to predict theoretically consistent criteria (AERA, APA, &

NCME, 2014). For instance, findings that show that students' responses to an SRQ for assessing SRL can be used to predict improved academic engagement, grades, or performance add to this aspect of validity. Evidence based on predictive relations are particularly important if one intended purpose of an assessment is to develop theoretical models of academic engagement and success.

Empirical evidence regarding this aspect of validity is among the most commonly pursued by researchers using SRQ to assess aspects of SRL. Researchers have consistently examined the relations between students' responses to the MSLQ and their classroom grades or overall grade point averages (Duncan & McKeachie, 2005). In addition, researchers have linked students' self-reported use of metacognitive strategies with increased academic performance in several studies (Dent & Koenka, 2016). Along these same lines, other researchers have examined whether groups of higher-and lower-achieving students exhibit mean level differences on SRQ associated with SRL (Cleary & Chen, 2009; Greene, Moos, Azevedo, & Winters, 2008; Hong, Peng, & Rowell, 2009; Ley & Young, 1998; Zimmerman & Martinez-Pons, 1990). In addition to grades, aspects of SRL have also been studied as potential predictors of emotions, well-being, adjustment, standardized performance, as well as performance on non-academic or experimental learning tasks and computerized study tasks (Ben-Eliyahu & Linnenbrink-Garcia, 2015; Bjork, Dunlosky, & Kornell, 2013; Greene, Moos, Azevedo, & Winters, 2008; Pekrun, Goetz, Titz, & Perry, 2002; Schutz & Davis, 2000; Webster & Hadwin, 2015; Winters, Greene, & Costich, 2008).

The expected relations between measures from SRQ of SRL and students' performance in the classroom sometimes have failed to materialize. This limitation was highlighted in a recent meta-analysis in which Crede and Phillips (2011) concluded that there was not strong support for the expected positive relations between subscales from the MSLQ and instructor-assigned grades. Similarly, Braten and Samuelstuen (2007) found that a general measure of reading strategy use failed to predict reading performance, whereas a more task-specific measure of strategy use did predict performance on the referenced task.

One challenge to providing this type of validity evidence is the multi-dimensional, interconnected, and reciprocal systems that are used to characterize SRL. This situation means that the predicted outcomes for some aspects of SRL are primarily other aspects of SRL. For instance, most views of SRL now include the assumption that motivational processes are an inherent aspect of what is necessary to engage in SRL or to be a self-regulated learner (Winne & Hadwin, 2008). At the same time, one outcome of these motivational processes is students' engagement and use of strategies that are themselves emblematic of SRL. This situation encourages studies that rely on a single SRQ to assess all variables within an analysis; a practice that allows for criticisms regarding method variance issues and biased findings (i.e., that relations are a function of using the same assessment method more so than the actual relation between the constructs).

Evidence Based on the Consequences of Testing

Evidence for validity based on the consequences of testing concerns the soundness of any interpretations or claims that are made based on scores from an assessment (AERA, APA, & NCME, 2014). Consequences that follow from students' scores on an SRL assessment may lead to both intended and unintended consequences. For instance, teachers may purposefully use scores on an assessment of SRL to identify students who would benefit from a particular instructional intervention. Although less intentionally, this assessment might also reduce students' confidence as a learner by making them aware of how little they know about and use certain study strategies. Findings that support the soundness of the former consequence, or the rarity of the latter, would serve to support this aspect of validity. Although this facet of validity is relevant when an SRQ is used to develop and test theoretical models, it may be more critical if responses are used as a basis for making important educational decisions.

The LASSI represents one fitting example of the need for evidence supporting this type of validity. The LASSI is presented as useful for diagnosing and providing prescriptive feedback to students about their relative strengths and weaknesses as a learner (Weinstein & Palmer, 2002; Weinstein, Palmer, & Acee, 2016). Hence, the

consequences for students who complete this SRQ can be substantial. Completing the LASSI might result in students receiving, or not, important instructional supports from a teacher or school. As well, the feedback provided as part of completing the LASSI is supposed to impact students' perceptions of their own strengths and weaknesses in a way that improves their academic success. The diagnostic and prescriptive claims that lead to these consequences (i.e., that the LASSI provides an accurate diagnosis and that the feedback serves to improve students' learning), however, are not well supported by empirical findings. For instance, the latest User's Manual fails to identify any specific effort to evaluate formally whether the feedback made available to students has positive consequences for their later behavior or learning. Given the apparently large numbers of students who complete this assessment each year, it is essential to test whether the diagnostic feedback provides an accurate representation of students' actual skills, is perceived by them as useful, and actually serves to change their beliefs and behavior for the better. Similar issues arise when other SRQ are used for diagnostic or gatekeeping purposes (Hofer, Yu, & Pintrich, 1998).

Recommendations for Researchers and Practitioners

Given the many potential benefits of using SRQ, it is perhaps a foregone conclusion that they will continue to be a common method used to assess SRL. The challenge ahead, therefore, is to ensure that SRQ are used responsibly, in ways that continue to build evidence of their validity. In this section, we identify recommendations for theoretical and applied research using SRQ to assess SRL that are designed to help achieve this goal.

Clearly Articulate the Relevant Theoretical Model of SRL

Generating evidence to support many aspects of validity is dependent on referencing a well-articulated model of SRL. It is not possible, for instance, for findings to support the content, structural, or discriminant aspects of validity without a corresponding theoretical model of SRL that identifies clear expectations regarding these points. In addition, examining support for proposed relations with other variables is best done in the context of a theoretical model that clearly proposes what relations to anticipate. Hence, one recommendation is for researchers to clearly identify and refer to a particular theoretical model when utilizing any particular SRQ. Along with this, researchers should strive to provide unambiguous conceptual definitions of any constructs they assess within a given study.

There are at least two reasons this recommendation may be especially relevant for researchers studying SRL. One reason is the number of, and a lack of hegemony among, models of SRL. Although most models of SRL agree on some basic assumptions (Pintrich, 2004), there are also unique characteristics that differentiate one model from another. The ways in which researchers conceive of motivation and its relation with SRL illustrates this point. Some models of SRL propose an integrated view in which motivation is an intricate process within a larger system of SRL (Winne & Hadwin, 2008). In contrast, others seem to regard motivation more as a critical but theoretically distinct antecedent process in relation to SRL (Bjork, Dunlosky, & Kornell, 2013). The type of evidence needed to support validity is clearly affected by how one views the centrality and relation of motivation to other aspects of SRL. McCardle and Hadwin (2015), for instance, made clear that their newly developed instrument is limited because it falls short of providing a full representation of motivation. In short, validity evidence flows more readily when research is conducted with reference to a particular theoretical model.

A second reason that clearly articulated models of SRL are needed is that SRL is typically viewed as a complex, multi-dimensional construct that is sometimes understood as a process, or event, and other times viewed as more of a personal attribute (Winne & Perry, 2000). Any single model of SRL, therefore, typically includes many essential dimensions that need to be assessed with a high degree of validity. In theory, as a general method, SRQ should be well suited to this situation because they can be used to assess a large number of constructs in a relatively short period of time. However, it is difficult to exploit this advantage without a clear theoretical model to follow. In addition, theoretical assumptions about SRL as more of a process versus an attribute have critical implications for its assessment (Klug, Ogrin, Keller, Ihringer, & Schmitz, 2011). Stipulating a theoretical model including

assumptions regarding this distinction is necessary for evaluating the validity of a particular SRQ and understanding whether this method of assessment is even appropriate.

Note that this call for greater attention to theoretical models does not equate to a call for a hegemonic view among researchers. It is not necessary for researchers to adopt a single invariant model of SRL in order to improve the use of SRQ. Rather, what is necessary is for those that develop or use SRQ to clearly specify the particular theoretical model of SRL that serves as the basis for a study and the assessments that are utilized. Of course, it also is necessary to recognize and use SRQ in a way that is consistent with the theoretical model for which they were developed originally.

Follow Best Practices When Developing New SRQ

Although always significant, concerns about investigating and supporting claims related to validity should be paramount when researchers elect to develop new instruments. Modifications to existing SRQ also should be treated similarly to the development of new instruments. In both situations, researchers should follow the established best practices for self-report instrument development (e.g., Gehlbach & Brinkworth, 2011). The steps reflected in these practices include, for instance, conducting a literature review to better define the theoretical nature of particular constructs, and conducting interviews and focus groups to ensure that items reflect an understanding and meaning that is consistent with the target population. Gehlbach and Brinkworth (2011) also called for expert validation and cognitive pretesting of items, as well as pilot testing that provides insights from conditions that are similar to those likely to be used in research. In the end, rigorously following these best practices will serve to strengthen the various types of validity evidence. Most importantly, addressing the need for validity evidence during the development process will serve to avoid many of the issues that plague the use of SRQ for assessing SRL. The ability to generate evidence of validity at a later time is often a function of the process through which an instrument was designed and developed.

Be Vigilant and Enthusiastic About Expanding Validity Evidence

According to the revised Standards (AERA, APA, & NCME, 2014), “the validation process never ends, as there is always additional information that can be gathered to more fully understand [an instrument] and the inferences that can be drawn from it” (p. 22). Consistent with this message, one recommendation that arises from the present discussion is the need for the pursuit of various forms of validity evidence to be a consistent on-going and enthusiastic goal for researchers and practitioners alike. Two particular implications follow from this recommendation.

One implication is that researchers should conduct studies that actively focus on producing particular types of validity evidence. At its core, validity is built upon testable claims such as what responses a particular assessment measure, as well as how they are related to responses on other parts of the assessment and to other variables. Similarly, the validity of SRQ rests on testable claims that students’ responses derive from appropriate engagement in processes such as comprehending an item, searching their memories, and integrating information across relevant contexts, episodes, or domains. Research on SRL benefits greatly when researchers directly test these proposed assumptions, for instance when researchers evaluate an instrument thoroughly (e.g., cognitive interviewing), evaluate relations among different SRQ (Muis, Winne, & Jamieson-Noel, 2007), or use other types of assessments (e.g., think-aloud, diaries, traces) to evaluate whether assumptions about an SRQ are supported (Braten & Samuelstuen, 2007).

A notable corollary to this recommendation is that editors, reviewers, funding agencies, and others who serve as gatekeepers to what research is conducted and published must also be vigilant about demanding evidence of validity. Apparent from the present discussion, reporting internal consistency statistics (e.g., Cronbach’s alpha), noting that a particular SRQ has been used previously, or even general statements that an SRQ has “been shown to be valid in prior work” provide weak and insufficient evidence of validity. Authors should be required to

provide more detailed, relevant, and theoretically grounded evidence for different aspects of validity. For instance, how strong is the evidence that students like those in a particular study are aware of and can report accurately on their use of monitoring strategies? Or, how much support is there for the conclusion that the self-reported strategies assessed by a particular SRQ represent what students will actually do when engaged in a relevant task? As an author, it is easy to avoid these topics because they often bring up more issues than they resolve. Yet, researchers must hold each other accountable or the longer pursuit of greater understanding of SRL and how it can be used to improve students' academic success is likely to include more wasted time and missteps than are necessary.

Use SRQ in Ways That Are Consistent With Their Strengths

Contemporary perspectives stress that validity is a function of the way in which responses to SRQ are interpreted with regard to a particular purpose (AERA, APA, & NCME, 2014). A specific SRQ should not be considered valid or not; rather validity should be evaluated in light of how responses are used with regard to a particular purpose. Consistent with this argument, many criticisms of SRQ arise from how researchers use and interpret scores and not because of how SRQ are designed or what they are intended to assess. Our recommendation, therefore, is that researchers should take greater care to ensure that they use and interpret scores from SRQ in a way that is consistent with theory and supportive of validity.

Certain implications of this recommendation are fairly straightforward. Researchers should not make claims about assessing SRL based on scores from an SRQ that really only assesses a limited number of metacognitive strategies. Similarly, researchers should not add, remove, or modify items (e.g., change domain specificity) on an SRQ scale without acknowledging that the construct represented by the resulting responses may have shifted in a meaningful way. In these cases, it is incumbent upon researchers to provide sufficient empirical evidence (e.g., alphas, correlations, confirmatory factor analyses), reasoned argument, or other forms of support for the validity of the revised scale. Other implications of this recommendation are less evident but perhaps even more important. Notably, researchers and practitioners must understand that SRQ may never be appropriate for some purposes that are important to the broader understanding of SRL (Butler, 2002). For instance, assessing aspects of SRL that reflect subtle contingent relations, automatic processing, or unconscious decision-making may best be addressed with other methodologies.

Concluding Thoughts

After more than 25 years, SRL has matured into an established framework used to understand, predict, and improve many factors that are critical to students' engagement, learning, and overall academic success. Yet, fundamental concerns about the effectiveness and utility of one primary method of assessment continue to burden any advancement in the research and practice in SRL. Our central purpose for this chapter was to address these concerns by considering the weaknesses and strengths of SRQ as a method for assessing SRL. We couched our efforts to reach this goal in a contemporary understanding of validity (AERA, APA, & NCME, 2014; Kane, 2006; Messick, 1989, 1995; Newton, 2012a). This perspective provides a way of considering the types of claims or purposes for which SRQ have been or might best be suited. Hence, it highlights the need to determine not whether SRQ are useful or not, but rather when or under what conditions they can best be utilized to advance SRL theory and practice. In this framework, decisions about using SRQ are conceived as whether there is stronger or weaker evidence to support using SRQ for particular purposes, in particular situations, for particular goals, or when pursuing particular questions. Even more importantly, this framework provides a path forward that researchers can follow to promote increased evidence of validity, and greater confidence regarding the understanding and ability to promote SRL. This path calls for additional purposeful efforts to consider and extend the evidence supporting different aspects of validity. In addition, this path highlights that the effort to strengthen the validity evidence begins as research is planned and continues through efforts of reviewers, editors, and funders to ensure that SRQ are not used without careful consideration of the validity evidence.

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21 Capturing and Modeling Self-Regulated Learning Using Think-Aloud Protocols

Jeffrey A. Greene, Victor M. Deekens, Dana Z. Copeland, and Seung Yu

In the first edition of this handbook (Zimmerman & Schunk, 2011), Greene, Robertson, and Costa (2011) detailed relevant history, methodology, and scholarship on the use of think-aloud protocols (TAPs; Ericsson & Simon, 1993) to assess the various aspects and processes constituting self-regulated learning (SRL; Zimmerman, 2000). They argued that the dynamic nature of SRL, involving the planning, monitoring, control, and evaluation of numerous cognitive, metacognitive, behavioral, motivational, and emotional processes (Azevedo, 2014; Efklides, Schwartz, & Brown, 2018/this volume; Usher & Schunk, 2018/this volume; Winne, 2018/this volume), requires data collection methodologies that can capture this processing as it occurs and changes from moment to moment (Winne & Perry, 2000). As opposed to self-report methodologies, which ask participants to reflect upon and summarize their SRL processing retrospectively, TAPs are a concurrent method, involving verbal reports where participants say aloud what they are thinking and doing throughout their engagement in a task. Despite still being enthusiastic about the rich, predictive data that result from TAPs, in this chapter we begin by moderating the stance taken by Greene et al. (2011). We advocate for a “right tool for the job” approach to SRL data collection and analysis methodologies (Karabenick & Zusho, 2015). For example, some motivational and dispositional aspects of SRL may be best captured by self-report data (cf. Wolters & Won, 2018/this volume) or by case studies (cf. Butler & Cartier, 2018/this volume), whereas more transient, dynamic, task-specific aspects may be best captured by TAPs or educational data mining techniques (Efklides, Schwartz, & Brown, 2018/this volume; Biswas, Baker, Paquette, 2018/this volume). The viability and validity of a method of data collection is ultimately established by the utility of research produced using that method, and in this chapter, we argue for the use of TAPs as one powerful tool, among many, for capturing and modeling the dynamic aspects of SRL processing.

The now-voluminous evidence that SRL processing is a key mediator between individual characteristics and academic achievement (e.g., Azevedo, 2005; Dent & Koenka, 2015) has led to a shift in the field from studying the role of SRL in learning to investigating how to foster productive SRL among those who would otherwise not adaptively monitor and control their progress toward learning goals (Dignath & Büttner, 2008; Kistner et al., 2010). Such investigations have revealed that the nature of “productive SRL” can and does vary across academic disciplines, learning contexts, and sociocultural settings (e.g., Eilam & Reiter, 2014; Greene et al., 2015; Greene, Dellinger, Binbasaran Tuysuzoglu, & Costa, 2013). Therefore, whereas the importance of planning, monitoring, controlling, and evaluating learning transcends context, exactly how these processes are and should be enacted varies by context. Such findings highlight the importance of accurate measurement and analysis of SRL within and across contexts, so that interventions can be tailored for greatest efficacy.

In this chapter, we briefly review the relevant theoretical ideas and established methods of using TAPs to capture SRL processing. Readers interested in more detail on these topics should consult the chapter in the first edition of this handbook (Greene et al., 2011). To distinguish the chapter in this handbook from the one in the former, we review current scholarship on how to analyze TAP data, and in particular focus on the challenges associated with properly modeling these data within and across disciplines and contexts. This discussion of challenges provides background for our updated review of SRL scholarship utilizing TAPs, where we synthesize findings within and across disciplines. Finally, our updated focus on modeling and capturing TAPs points to a number of important directions and implications for future research.

Relevant Theoretical Ideas

Verbal protocol analysis is an umbrella term for a number of different data collection methodologies (Ericsson & Simon, 1993). The rich data provided through both concurrent and retrospective (i.e., verbalizing and reviewing thought after completing the task) verbal reports offer a multitude of opportunities for data exploration. However, Ericsson and Simon (1993) argued that concurrent reports produce the most accurate data regarding cognition, a position that has been supported in the literature (Fox, 2009). One type of concurrent verbal report, TAPs, has a

history that begins before the SRL literature, with implications for how TAPs can be used to study self-regulation of learning and performance.

The use of TAPs to study expertise and learning dates back to the early 1980s (Ericsson & Simon, 1980). Greene et al. (2011) highlighted much of the relevant history leading up to Ericsson and Simon's development of verbal protocols, such as concerns that requesting participants to engage in introspection (i.e., reflection upon one's own mental processes) might change the nature of their thinking (i.e., reactivity), as well as concerns about the accuracy of such introspections. Ericsson and Simon (1980) created TAPs as a way to gain accurate insight into thinking without creating reactivity.

Ericsson and Simon (1993) described three types of verbalizations that could be made during a performance task. Type 1 verbalizations entail voicing conscious, verbal cognitions with the use of language that is immediately accessible and directly represents the cognitions themselves. Type 2 verbalizations make explicit cognitions that are not inherently verbal. Converting sensory information into language that is then voiced (e.g., "I see three hyperlinks here") is an example of a Type 2 verbalization. Type 3 verbalizations are those that participants would not normally produce, such as explanations of their thinking, decisions, or actions (e.g., "I reread that paragraph because in the past I have found I benefit from reading complicated text multiple times").

Ericsson and Simon (1993) presented evidence that Type 3 verbalizations can affect the sequence and nature of participants' cognitive processing and performance, whereas eliciting Type 1 or Type 2 verbalizations does not interfere with cognitive processing on well-structured tasks. In their later research, including cognition research in diverse fields ranging from medicine to chess, Ericsson and Simon (Ericsson, 2006; Ericsson & Simon, 1993) consistently found no substantive differences in performance or strategy use between participants asked to produce Type 1 or Type 2 verbalizations and those in a control group asked to complete similar tasks without thinking aloud. Fox, Ericsson, and Best (2011) conducted a review and meta-analysis of studies utilizing TAPs to further investigate the reactivity concern. Their review of articles involving direct comparisons of the performance of participants asked to think-aloud with those who were not revealed no significant effects on cognition or performance beyond a slight increase in the time required to complete the task, when Ericsson and Simon's methodology was properly followed. Researchers who have used TAPs to study SRL (e.g., Azevedo, 2014; Bannert & Mengelkamp, 2008; Greene et al., 2012; Veenman, Elshout, & Groen, 1993) have found similar evidence that TAPs do not disrupt cognition in meaningful ways. Further, SRL TAP data have been shown to be a better predictor of problem-solving performance than data from self-report measures (Jacobse & Harskamp, 2012). In sum, the research shows when proper methods are carefully followed, TAPs do not result in reactivity concerns.

Think-Aloud Protocol Methodology

Eliciting Participants' Thinking-Aloud

Ericsson and Simon's (1980, 1993; Ericsson, 2006) work, as well as the research in SRL using TAPs, has highlighted the importance of following particular methods when eliciting TAPs. The research environment itself must be carefully designed to decrease the likelihood of Type 3 verbalizations. To do this, researchers must (1) provide participants with a carefully designed environment and clear, specific directions regarding TAPs, (2) allow those participants to practice the TAP before data collection begins, and (3) prompt verbalizations in ways that decrease the likelihood of reactivity.

Designing Research Environments and Instructions for Participants

The research environment should be free of distractions and arranged in such a way that the participant is not encouraged to interact with the researcher (e.g., having the researcher sit out of the participant's line of sight; Ericsson & Simon, 1993). Instead, researchers have suggested that participants be told to think aloud as if speaking to themselves (Ericsson & Simon, 1993). Likewise, eliciting Type 1 and Type 2 verbalizations

necessitates carefully instructing participants to speak as they think and do, because verbalization delays of more than five seconds can lead to less accurate data (Ericsson & Simon, 1980). Instructions that suggest the participant is talking to the researcher (e.g., “Just tell me what you are doing”) are more likely to elicit Type 3 verbalizations. On the other hand, participants benefit from specific examples of appropriate verbalizations (e.g., “That looks interesting, I’m going to click on it”) so that they understand what kinds of Type 1 and Type 2 verbalizations are desired (Cotton & Gresty, 2006).

Practicing Thinking Aloud

Following a clear presentation of directions, participants need practice to become familiar with the activity of thinking aloud, and they need to become familiar with the tools and contextual features of the learning task (Eveland & Dunwoody, 2000). Practice is particularly important for minimizing unwanted effects like distraction and disorientation during the intended performance task. Features of the practice session should be designed to resemble or match features of the learning session under study, but the practice task should involve different content than what is being studied. Through practice, the researcher can affirm the participant’s adherence to the TAP, and provide corrective feedback if needed.

Prompting During the Learning Task

After beginning the learning task, researcher interaction with participants should be kept to a minimum (Cotton & Gresty, 2006; Ericsson & Simon, 1993). If and when participants stop verbalizing, the researcher should use very simple prompts such as “Keep talking” that remind participants to verbalize, but do not suggest a limitation on the kinds of verbalizations requested (e.g., “Say what you are thinking”) or encourage participants to describe or explain their thinking to the researcher (e.g., “Tell me what you are doing”).

Coding Think-Aloud Protocol Data

TAP data are usually collected via audio or video recording, and then transcribed. In some cases, these transcriptions are treated as cases amenable to qualitative analysis, where inferential methods are used to code and thematize the data for evidence of SRL processing (cf. Butler & Cartier, 2018/this volume). In this chapter, we focus upon methods to segment and quantify these SRL TAP data in preparation for quantitative analysis (Chi, 1997), with particular attention to advances in methods for analyzing what is often a relatively large number of SRL codes or variables.

Coding Schemes

The majority of SRL researchers using TAP data have first segmented the transcriptions into codable units, and then used an a priori coding scheme to categorize each segment as evidence of a particular SRL process (e.g., Azevedo, Cromley, & Seibert, 2004; Bannert & Reimann, 2012; Greene, Costa, Robertson, Li, & Deekens, 2010; Moos, 2013). These coding schemes can be derived from theory (e.g., Azevedo & Cromley, 2004) and refined through use across multiple datasets (cf. Greene et al., 2013). SRL codes can include various kinds of planning (e.g., setting goals), or strategy use (e.g., taking notes), as well as different types of monitoring such as judgments of learning (JOL). Coding schemes can vary from relatively few codes (e.g., Dinsmore, Loughlin, Parkinson, & Alexander, 2015) to 50 or more codes (e.g., Greene et al., 2015). Azevedo, Taub, and Mudrick (2015) and Chi (2006) have argued that coding schemes should vary by task. For example, acquiring simple declarative knowledge, learning procedural knowledge, and engaging in critical thinking are all different tasks that are likely to elicit dramatically different SRL processing, thus requiring different kinds of codes.

Likewise, some researchers have advocated for coding not only the kind of SRL process enacted, but also its valence (Azevedo et al., 2015). Valence can indicate the participants’ verbalized assessment of the success of SRL processing, such as when a JOL is valenced as either indicating that participants believe they will remember

a concept on a test (e.g., JOL+) or believe they will not remember it (e.g., JOL-). Valence can also be used to indicate whether or not the researcher believes the SRL process is appropriate for the task overall, or for use at that particular point in the task (e.g., Dinsmore & Alexander, 2016). Some researchers have begun using multinomial or continuous ratings of the quality of the enactment of an SRL process as valences (Bannert & Reimann, 2012; Jacobse & Harskamp, 2012; Wang, 2015).

Coded SRL TAP data are often used to count how often particular processes are enacted (e.g., Azevedo, Taub, & Mudrick, 2015; Greene et al., 2011). However, these data can be used to infer other aspects of SRL processing as well (Azevedo, 2014). TAPs can be used to capture data on (a) when particular SRL processes are enacted, or not, over the course of a learning task (i.e., temporal analyses; Johnson, Azevedo, & D'Mello, 2011); (b) the order of SRL processing (i.e., sequential analyses; Bannert, Reimann, & Sonnenberg, 2014; Sonnenberg & Bannert, 2015); (c) the conditional nature of SRL processing (i.e., contingent analyses; Binbasaran Tüysüzoglu & Greene, 2015); or (d) how the enactment of one SRL process affects the likelihood of another being enacted (i.e., dynamic analyses; Ben-Eliyahu & Bernacki, 2015).

Interrater Reliability and Validity

The growing complexity of coding schemes has led to increased focus upon interrater reliability and validity of inferences from SRL TAP data (Greene et al., 2011). The recognition of the domain- and even task-specific nature of SRL (Alexander, Dinsmore, Parkinson, & Winters, 2011) may warrant a return to Chi's (1997) early recommendation to code TAP data twice; first inferentially to develop a coding scheme and then a second time to test whether the scheme can be successfully implemented with acceptable interrater reliability. Chi also recommended calculating interrater reliability at several steps of the coding process, such as after segmenting the data, as well as after coding those segments. SRL researchers using a priori coding schemes have typically asked two or more raters to code some portion of the data (Azevedo et al., 2015; Bannert et al., 2014; De Backer, Van Keerm & Valcke, 2012; Greene et al., 2015). After these raters have shown sufficiently high interrater reliability on a subset of data, some researchers allow raters to code the rest of the data individually (e.g., Bannert et al., 2014; De Backer et al., 2012). Other researchers have had two raters code all of the data, and reported interrater reliability over the entire dataset (e.g., Azevedo et al., 2015). However, high interrater reliability does not necessarily imply that the inferences made from those data have strong evidence of validity. Many researchers have shown that their coding schemes produce data with predictive (e.g., SRL processing predicting learning gains; Greene et al., 2012) or discriminant validity (e.g., De Backer, Van Keer, & Valcke, 2015), but there have been fewer examinations of the construct validity of SRL coding schemes (e.g., Greene, Bolick, & Robertson, 2010).

Summary of Coding Data

The quantitative coding of qualitative TAP SRL data requires theory regarding not just what SRL processes might be relevant to capture for a particular learning task, but also their success or appropriateness, when they are enacted, in what order, and in what sequence, as well as how likely one process is given previous SRL processing. Dent and Hoyle (2015) argued that given the many different ways to code SRL data, researchers must carefully align theory, measurement, and analysis techniques to ensure that the best data are gathered for a given research question. Furthermore, the generalizability of findings across contexts and individuals likely has a somewhat inverse relationship to the level of specificity, dynamics, and contextuality of the coding scheme.

Modeling Coded Think-Aloud Protocol Data

Eliciting and coding TAPs can often result in a tremendous amount of data per participant, including many SRL process codes that could be used as variables in analyses. At the same time, TAP data are also resource-intensive to collect, meaning that many samples have a rather low participant-to-code ratio, often resulting in statistical analyses that are underpowered (Greene et al., 2013). Numerous methods have been used to deal with low

participant-to-code ratios, including group comparisons (e.g., Azevedo & Cromley, 2004; Ericsson, 2006; Sonnenberg & Bannert, 2015) and various forms of data aggregation (e.g., Azevedo et al., 2015; Greene & Azevedo, 2009; Greene et al., 2015; Moos, 2011, 2013). Another complexity of SRL TAP data is that when frequencies or counts of different SRL processes are used, these data are often non-normally distributed, which can lead to inaccurate results in standard ordinary-least squares analyses (DeMaris, 2004). Therefore, researchers have investigated statistical analysis techniques specifically tailored for count data (e.g., Greene et al., 2011) as well as the use of non-parametric methods and process mining (Bannert et al., 2014).

Group Comparisons

Much of the early research using TAPs in the expertise literature compared the kinds and frequencies of enacted cognitions and behaviors between experts and novices (Chi, 2006; Ericsson, 2006; Wineburg, 1991). Similar comparisons have been conducted in the SRL literature, such as examining differences in the relative frequency of various kinds of SRL processing between participants who received SRL training and those who did not (e.g., Azevedo & Cromley, 2004), successful and unsuccessful students (Bannert et al., 2014), and within-subjects examinations of SRL processing during familiar and less familiar tasks (Moos & Miller, 2015). These comparisons can reveal distinctions in the types and frequency of SRL processing that may inform training interventions. However, Bannert and colleagues (2014) cautioned that differences across groups may be idiosyncratic to those individuals or context, therefore replications and repeated studies with systematic variations in context are needed before inferring that the path from novice to expert can be accelerated by training the former on what the latter uniquely do (Alexander, 2004; Ericsson, 2006).

Data Aggregation

Greene and Azevedo (2009) argued that whereas SRL models often focus upon relations among macro-level aspects of SRL (e.g., planning, monitoring, strategy use), TAPs and other forms of concurrent SRL data are often collected at a more microlevel, consisting of specific instances of planning (e.g., identifying goals), monitoring (e.g., monitoring progress toward goals), and strategy use (e.g., taking notes). These micro-level data present numerous analytic challenges. First, researchers often capture numerous micro-level codes, leading to participant-to-code ratio problems. Second, the frequency of these micro-level codes may be highly idiosyncratic: one novice may prefer taking notes to acquire information but never use organizing strategies, whereas another might prefer the opposite, resulting in unclear relations between the frequency of each strategy and learning. Finally, the frequency of monitoring micro-level processes (e.g., JOL) may vary greatly depending upon participants' prior knowledge, introducing noise into bivariate analyses of micro-level codes and learning.

Given these challenges, Greene and Azevedo (2009) argued that the frequency of use of specific micro-level processes may be less informative, and generalizable, than the frequency of all instances of micro-level processes within a particular macro-level category, such as planning, monitoring, or strategy use. They proposed what has since been called full aggregation methods (cf. Greene, Yu, & Copeland, 2014), wherein counts of all micro-level codes within a macro-level category are summed (i.e., aggregated) into a single macro-level variable. Doing this greatly reduces the number of SRL variables to analyze (e.g., Greene and Azevedo's [2009] five micro-level planning processes were aggregated into a single planning macro-level variable), which addresses the participant-to-code ratio issue. Aggregated macro-level variables are also more likely to be normally distributed, and therefore amenable to ordinary least squares analyses. Aggregation can also account for unimportant idiosyncrasies across participants, such as differences in the frequency of equally useful strategies (e.g., taking notes and organizing).

Full aggregation methods have been used in many studies to examine posited relations among macro-level SRL processes and various phenomena of interest including learning gains (Greene & Azevedo, 2009), task definitions (Greene et al., 2012), cognitive load (Moos, 2013), and SRL training (De Backer, Van Keer, & Valcke, 2011, 2012). The predictive validity of particular macro-level variables has been strong, such as monitoring (Greene &

Azevedo, 2009; Greene et al., 2012) and strategy use (e.g., Moos, 2013). However, full aggregation methods assume that all micro-level SRL processes are equally important, and all share the same predictive relationship with learning, usually positive.

Greene et al. (2013) questioned these assumptions. Instead, they argued that task analyses and investigation of the predictive validity of micro-level SRL codes often reveal only a subset of these micro-level codes are predictive of learning gains, with some positively related to learning, others negatively, and some not at all. Summing the frequency of all of these codes into a single macro-level variable may lead to excessive noise, and biased or inconclusive findings. Instead, they argued for a two-tiered approach to aggregation, where an analysis of relations between micro-level SRL processes and learning would inform more nuanced aggregation and analysis methods. Greene et al. (2014, 2015), using these data-driven aggregation methods, found that only a subset of microlevel SRL processes were related to learning, and indeed some were positive predictors of learning gains, and others negative predictors. Aggregating just these subsets of micro-level SRL processes into macro-level variables (e.g., an adaptive SRL variable and a maladaptive SRL variable) led to models with better predictive validity than models using full aggregation. Further, Greene et al. (2015) found the micro-level processes comprising these subsets differed across academic disciplines (i.e., history and science). Researchers are beginning to explore the question of the appropriate level of aggregation for SRL TAP data (e.g., Sonnenberg & Bannert, 2015), but there is mounting evidence that analyses at multiple levels of aggregation may be necessary to understand how SRL does and does not differ across samples, domains, tasks, and contexts.

Modeling Count Data

Statistical models have assumptions, and if the data do not meet those assumptions, the findings are suspect. Researchers interested in how the frequency of various kinds of SRL processing varies across groups, or mediates relations between individual characteristics and learning, must examine the distributions of their SRL TAP data to determine whether they are non-normally distributed, which count data often are (DeMaris, 2004). Greene et al. (2011) showed how, in many cases, traditional regression, ANOVA, and latent variable techniques do not produce the best fitting-models for SRL TAP data. Instead, there are classes of these techniques specifically designed for the distributions commonly found in count data (e.g., Poisson, Negative Binomial distributions) that better estimate relations between these data and other variables of interest (DeMaris, 2004). Likewise, some SRL processes are unlikely to be deployed at all by participants, or are only likely to be deployed by a select few, such as advanced problem-solving strategies commonly known only by experts. Analyses of the frequency of such processing must account for the high number of zero counts in the data by using zero-inflated versions of count models. Ultimately, the distribution of the data determines the best model to use when analyzing them and researchers should carefully scrutinize the distributions of their data, and test multiple models of analysis to find those best fitting their data.

Some data are not normally distributed, nor are they distributed as counts (e.g., ratings of SRL quality as low, medium, or high). Such data can and should be modeled using non-parametric methods, which in these cases are more powerful than their parametric counterparts (Gibbons & Chakraborti, 2010). Numerous SRL researchers have used such models (e.g., Dinsmore & Alexander, 2016; Dinsmore et al., 2015; Poitras, Lajoie, & Hong, 2012). The one disadvantage of these models is that the array of modeling options tends to be more limited than the kinds of parametric analyses that can be done (e.g., mixed ANOVAs).

Modeling Sequential, Contextual, and Contingent Relations

Progress is being made on ways of analyzing not just how often participants enact SRL processes, but also under what conditions. Much of this work is being done from an educational data mining framework using trace data from users' interactions with computer-based learning environments (see Biswas et al., 2018/this volume). However, there have been some analyses of sequential, contextual, and dynamic relations among SRL processes using TAP data. For example, Johnson et al. (2011) divided their learning task into four 10-minute segments, and

then showed how the frequency of planning and learning strategies processing differed across segments. They also found evidence of particular sequences of SRL processing being more likely than others, such as monitoring behaviors leading to the enactment of learning strategies. Bannert et al. (2014) used process mining of TAP data to identify and characterize sequential and temporal patterns of SRL processing across high- and low-performing groups of participants. Finally, Binbasaran Tüysüzoglu and Greene (2015) used contingent analyses to show how changing learning strategies after monitoring a failure to understand (i.e., adaptive metacognitive behavior or control) was associated with increased learning performance, whereas failing to change strategies (i.e., static metacognitive behavior or lack of control) was negatively related to learning.

Research Evidence

TAPs, and the myriad of approaches necessary to model these data, have been used to study SRL in multiple academic domains including reading, science, math, and history. This cross-disciplinary research has lent additional support to the idea that students who effectively self-regulate their learning tend to perform better on a variety of learning outcome measures (Zimmerman, 2000). TAPs have also been utilized to measure the efficacy of SRL-based interventions to enhance student learning across academic domains, age ranges, and contexts.

Reading

A plethora of recent research has explored the processes, both cognitive and metacognitive, employed by readers learning from traditional texts as well as digital learning environments. Fox (2009) reviewed 45 studies involving TAPs to analyze the role reader characteristics, such as ability, knowledge, experience, and interest, play in learning. Overall, Fox found a positive correlation between these characteristics (e.g., reading ability) and both the quality of the mental representations students attained as well as the learning gains they experienced. In another study focused on reading, Schellings and Broekkamp (2011) investigated SRL using TAPs as participants engaged in goal-directed reading of texts to prepare for a future performance. These TAPs measured how effectively the students assessed the task at both the global (i.e., concerning the task as a whole) and the local task levels (i.e., thinking about specific parts of the text). Overall, the findings indicated that a lack of task awareness was negatively related to text selection. These studies indicated the utility of TAPs to assess readers' online decision making, provided insight into cognitive and metacognitive processes that were uniquely predictive of learning, and demonstrated the positive role of SRL in reading achievement.

Science and Mathematics

TAPs have also been utilized to capture online SRL processing during science learning. Azevedo (2005) pioneered much of this work, including early studies of the SRL processing that differentiated those who successfully constructed a mental model of complex science concepts from those who did not (e.g., Azevedo et al., 2004; Greene & Azevedo, 2009; Moos & Azevedo, 2008a). Findings indicated that conceptual understanding in science was more likely when participants used high-level learning strategies (e.g., knowledge elaboration) as opposed to low-level ones (e.g., rereading; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), activated prior knowledge and established subgoals relevant to their learning, planned their time and effort carefully, and frequently monitored their growing understanding. Such findings were supported in later work involving different levels of data aggregation (e.g., Greene & Azevedo, 2009; Greene et al., 2010; Greene, Moos, Azevedo, & Winters, 2008), as well by work showing prior knowledge predicted the efficacy of SRL processing and learning (e.g., Moos & Azevedo, 2008b). In addition, Azevedo and colleagues have used TAP data to show how training and externally supported regulation leads to improved SRL processing and learning gains in science (e.g., Azevedo, Moos, Greene, Winters, & Cromley, 2008; Moos & Azevedo, 2008b). Moos and Miller (2015) utilized TAPs to investigate differences in SRL when participants learned about two separate scientific topics. They found that learners exhibited similar amounts of extrinsic motivation and control beliefs across the two topics, but that learners' assessment of their own self-efficacy and the value of the task were different depending on the subject matter. TAPs have also been used to study SRL in mathematics. For example, Muis (2008) utilized TAP data to

determine if there were relationships among mathematics problem solving, SRL, and epistemic beliefs. Muis found differences in participants' SRL processing, including planning, monitoring, and control, due to variance in their epistemic beliefs.

History

Poitras, Lajoie, and Hong (2012) used TAPs to investigate the efficacy of a technology-rich learning environment designed to provide metacognitive assistance and aid learners to use SRL while conducting historical inquiry. Learners who utilized a metacognitive tool increased their recall of text information but not their performance on questions designed to test comprehension. Interestingly, Poitras et al. did find evidence of reactivity in their study, which begs the question of whether there are domain differences in the likelihood of reactivity when utilizing TAPs. Greene et al. (2010) used TAPs to investigate the role of SRL and the acquisition of historical knowledge in a hypermedia learning environment. They found that high school students' frequency of engagement in SRL planning processes was predictive of learning. Greene et al. (2015) used TAPs to investigate similarities and differences in SRL processing as students learned either a science or history topic. High-level strategies such as corroborating sources, knowledge elaboration, and prior knowledge activation were predictive of learning gains across domains and tasks. On the other hand, there were other strategy, planning, and monitoring processes whose predictive validity differed across domains; for example, JOL predicted learning gains in science, but not in history. This research suggests that SRL interventions may have to be tailored to domain, or possibly even task.

TAPs and SRL Interventions

TAPs have been utilized in multiple settings and across academic domains and student age ranges to assess the efficacy of various SRL-based learning interventions in both naturalistic and laboratory settings. For example, De Backer et al. (2011, 2015) utilized TAPs to measure the effects of a semester-long reciprocal peer tutoring (RPT) intervention on college students' metacognitive knowledge and metacognitive skills. They found that students who participated in the RPT intervention increased their use of monitoring progress and evaluation when compared with students in a control group, leading the authors to recommend that higher education instructors incorporate RPT into their instruction. Panadero, Tapia, and Huertas (2012) utilized TAPs in a laboratory setting to assess the effect of (1) different self-assessment tools, (2) different types of instruction, and (3) different types of feedback on high school students' self-regulation, self-efficacy, and learning. They found that participants who were assigned to use either a script or a rubric as a self-assessment tool performed better on the learning outcome than students in the control group who did not utilize these tools. Students assigned to utilize a script enhanced their SRL more than students who were assigned to use a rubric. Moos (2011) also utilized a combination of self-report and TAP data to measure the effects of feedback on students' SRL while they learned using a hypermedia environment. Students assigned to either a questions or a questions plus feedback condition engaged more frequently in monitoring and prior knowledge activation than students in the control condition. Participants in the questions group performed better than those in the questions plus feedback group on the learning outcome.

In sum, TAPs continue to provide a valuable means of capturing SRL within and across academic domains (Alexander et al., 2011). Increased use of various levels of aggregation of SRL TAP data may better reveal what aspects of SRL are commonly predictive of learning across domains or tasks, and which are unique (Greene et al., 2015). Likewise, SRL interventions can be used to investigate the utility of various SRL processes across contexts.

Future Research Directions

There are a number of important future research directions for using TAPs to study SRL. First, despite being mentioned in the first handbook chapter, there continues to be a need to explore the validity of inferences from SRL TAP data. We do not doubt the utility of SRL TAP data, but there remain questions about what kinds of SRL processes are best captured and modeled using TAPs (e.g., strategy use) and which might be better captured

using other assessments methods (e.g., motivation using self-report measures). Triangulation across multiple measures is a promising area for future research into this issue of validity (Cleary, Callan, Malatesta, & Adams, 2015).

The participant-to-code ratio issue for SRL TAP data remains a challenging one. As the domain- and task-specificity of SRL continues to manifest in research (e.g., Alexander et al., 2011; Greene et al., 2015), the need for ever-growing numbers of codes to capture this specificity presents serious resource and analysis problems. We believe data aggregation is one way to address this resource problem, but data-driven methods must be triangulated with theory-driven ones (Greene et al., 2013). Examinations of the person-by-task interactions of micro-level SRL processing must be rigorously conducted, with careful manipulation of tasks to determine which SRL processes are truly macro, or person-specific, and which are task-specific (Efklides, Schwartz, & Brown, 2018/this volume).

Likewise, there is a clear need for within-subjects investigations of how SRL processing does and does not vary across contexts and tasks, within and across academic disciplines. Such analyses can be usefully combined with investigations of the sequential, contextual, contingent, and dynamic relations among SRL processing (Ben-Eliyahu & Bernacki, 2015). Simple counts of SRL processing, between subjects, can be informative in terms of what differentiates the successful learners from those who struggle. On the other hand, the path to expertise likely involves teaching learners how and when to enact SRL processing given context, and also is likely contingent upon internal (e.g., prior knowledge) and external factors (e.g., time allotted). Collecting sufficient data for such analyses can be particularly challenging, suggesting that researchers who use TAPs to study SRL would benefit from some coherence across coding schemes, so that datasets could be usefully compared, and perhaps even combined.

Implications for Educational Practice

In Greene et al. (2011), numerous implications for educational practice, based upon TAP methods and findings, were presented. Those implications remain relevant and relatively unexplored, particularly how TAPs can be used to encourage students to engage in the kinds of self-explanation predictive of retention and positive learning outcomes (Dunlosky et al., 2013). In addition to these implications, our current vantage point on the literature reveals three potentially beneficial areas for exploration. First, the domain-and task-specificity of certain aspects of SRL are even more pronounced in the current academic literature than they were in past years (e.g., Greene et al., 2015). TAPs allow educators to better understand how students' SRL can and should vary across such contexts, compared to other methods that presume the key factors upon which students can vary (e.g., surveys with forced-choice items). Therefore, educators would benefit from tracking this newer literature. Second, as SRL research becomes more attuned to domain- and task-specificity, it becomes more relevant and tractable for educators. SRL interventions are best delivered during the instruction of content, and educators may be better able to see the connections between SRL and content as research on the former better takes into account the latter (Zimmerman, 2000). Finally, the growing list of potentially relevant phenomena identified in SRL TAP coding schemes is also a viable resource for educators looking for new ways to help students understand why their current ways of learning are not working, and what could be substituted instead; indeed, this is the heart of the self-regulated part of learning and performance.

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22 Assessing Self-Regulated Learning Using Microanalytic Methods

Timothy J. Cleary and Gregory L. Callan

The concept of self-regulated learning (SRL) has received an extensive amount of attention by researchers in multiple fields and disciplines over the past few decades. Broadly defined as a contextualized, dynamic process through which individuals attempt to purposefully initiate, manage, and adapt their strategic pursuit of personal goals (Boekaerts, Pintrich, & Zeidner, 2000; Efklides, 2011), SRL has been linked to adaptive academic, mental health, and physical health outcomes, and has been identified as a core 21st-century learning skill (Clark, 2013; Greene, Moos, & Azevedo, 2011; Suveg, Davis, & Jones, 2015). SRL processes are particularly relevant to educational contexts because of the continually shifting demands and challenges that students encounter as they progress through school and because SRL processes are malleable and thus can be modified or enhanced through instruction or intervention. Although interest in SRL intervention applications is quite strong (Cleary, 2015; Zimmerman & Schunk, 2011), the methods and approaches used to assess SRL have also garnered much interest and attention. In fact, over the past decade there has been a proliferation of assessment methodologies that have enabled researchers to develop greater insights into the different dimensions and nuances of SRL processes (Butler, 2011; Zimmerman, 2008).

Conceptually, this growing set of assessment tools can be classified into two general categories: (1) aptitude measures (i.e., global or broad SRL approaches), such as self-report questionnaires, teacher or parent rating scales, and certain types of interview formats; and (2) event measures (i.e., fine-grained, contextualized measures), such as think-aloud protocols, personal diaries, direct observations or traces, and microanalytic interviews. The distinction between these two assessment categories can be made in terms of overall scope and purposes, assessment formats and protocols, and level of situational-specificity and granularity in interpretation. As an example, while self-report questionnaires (aptitude measure) target students' retrospective ratings about their regulatory beliefs or actions and utilize broad-based, aggregate scores of these ratings for interpretation, SRL microanalytic protocols (event measure) are designed to gather situation-specific information about students' regulatory processes as they approach, engage in, and reflect on their behaviors and performance on particular tasks.

Although researchers have relied on both aptitude and event SRL measures, there has been increased emphasis in recent years on developing and refining event forms of measurement (see Bernacki, 2018/*this volume*; Greene, Deekens, Copeland, & Yu, 2018/*this volume*). Professor Dale Schunk aptly captured this paradigm shift in his 2013 keynote address to the Studying and Self-Regulated Learning Special Interest Group of the American Education Research Association, noting that researchers have recently become interested in examining “the operation of self-regulated learning processes in depth as learners employ them and relate moment-to-moment changes in self-regulated learning to changes in outcome measures” (Schunk, 2013).

In this chapter, our primary focus is on one type of event measure called SRL micro-analysis. Before proceeding, however, it is important that we underscore a couple of important caveats regarding our basic assumptions and overall objectives when crafting this chapter. First, we do not advocate that SRL microanalysis, or any particular assessment method for that matter, is the best or most ideal approach to measure SRL in all circumstances or contexts. Rather, we adopt the viewpoint that many SRL measures within both the aptitude and event SRL categories can contribute to our understanding of human regulation because they each address important, albeit distinct, aspects or dimensions of SRL. Whereas aptitude measures address “To what extent does this student typically, or on average, exhibit adaptive regulatory actions or beliefs within a general domain?”, event measures are structured to examine “How does this student apply, monitor, and adapt strategic thinking and action during a particular activity in that specific context at this moment in time?” We view these two questions as complementary rather than as contradictory or opposing viewpoints.

Second, while there is clearly “between-category” (aptitude vs. event) variance among assessment tools, there is also considerable “within-category” variability for each of these two broad categories. As an example, behavioral traces and SRL micro-analysis are both types of event measures and thus seek to generate fine-grained, contextualized, process-related information about student SRL. However, these approaches utilize distinct formats (structured interview vs. trace observations) that generate different types of data or information (students’ self-reported task-specific beliefs and regulatory processes vs. instances of actual behavior during task performance). Thus, although all event measures overlap in several respects, each possesses unique qualities and characteristics.

With these caveats in mind, we address several specific issues in this chapter. Initially, we provide a brief overview of the historical context and core characteristics of SRL microanalysis. We then present two empirical lines of research employing microanalytic assessment techniques. The first area of inquiry explores the level of convergence between aptitude and event measures; specifically, we focus on research that examines the relations between students’ strategic regulatory processes exhibited during a particular task (as measured with SRL microanalytic protocols) with aggregates or broad indicators of their strategy use across different situations and tasks (as measured with student self-report questionnaires and teacher ratings). We then review research that explores the predictive validity of microanalytic protocols (in terms of achievement outcomes), when considered as a sole predictor and in conjunction with other SRL measures. In short, we examine whether there is “added value” to using multiple measures when attempting to understand how students engage in regulation and whether SRL processes influence important performance and learning outcomes. We end the chapter by discussing applications of SRL microanalysis to educational contexts and offer several directions for future research.

Overview of SRL Microanalytic Methodology

Historical and Theoretical Context

Microanalysis is an umbrella term that has been used to describe fine-grained types of assessment approaches that target specific processes or behaviors as they occur in particular situations. Researchers in the domains of human development and counseling have used microanalytic assessment approaches to observe micro-level behaviors exhibited during interpersonal interactions, such as relations among family members (Gordon & Feldman, 2008), mother-infant attachment (Peck, 2003), and therapist-client exchanges (Strong, Zeman, & Foskett, 2006). Microanalysis has also been used as an approach to assess fine-grained instances of individuals’ motivation beliefs and regulatory processes. In the 1970s, Bandura introduced the term micro-analysis to describe a process for examining shifts in adults’ self-efficacy beliefs and how these shifts corresponded to behavioral performance during anxiety-reduction interventions (Bandura & Adams, 1977; Bandura, Reese, & Adams, 1982). In short, he sought to isolate and study fine-grained processes (in this case self-efficacy beliefs) as individuals engaged in a series of anxiety-provoking behaviors linked to interacting with snakes.

These early self-efficacy studies were instrumental to the conceptual foundation of contemporary SRL microanalytic approaches because of their emphasis on assessing individuals’ task-specific judgments and beliefs at specific points during learning or performance. However, it was not until the late 1990s and early 2000s when social-cognitive researchers began to expand “self-efficacy” microanalysis procedures to encompass a more comprehensive assessment approach targeting multiple motivation and SRL processes. This development was spearheaded by the refinement and expansion of social-cognitive models, which typically define SRL as a goal-directed, task-specific, cyclical process (Schunk, 1998; Zimmerman, 2000). Zimmerman (2000) operationalized this process in terms of three interdependent, sequential phases: forethought (i.e., processes preceding efforts to learn or perform), performance control (i.e., processes occurring during learning efforts), and self-reflection (i.e., processes occurring after learning or performance). These phases are hypothesized to be interdependent in that changes in forethought processes impact performance control, which in turn, influences self-reflection phase processes. This model has served as the primary theoretical and conceptual influence of the development of SRL microanalytic methodology because it provides a highly practical and explicit framework from which one could

study specific regulatory processes as they emerge and change during virtually any clearly defined learning activity.

Essential Features of SRL Microanalytic Methodology

SRL microanalysis is a context-specific, structured interview designed to examine the cyclical phase subprocesses of SRL as individuals engage in authentic learning or performance activities. Given that comprehensive descriptions of SRL microanalytic characteristics and features have been presented elsewhere (see Cleary, 2011; Cleary, Callan, & Zimmerman, 2012), we highlight and provide a brief overview of a couple of the most important features.

Task-Specific Assessment

SRL microanalytic protocols are designed to assess how individuals approach, perform, and reflect on their skills and performance relative to specific learning tasks or activities. Over the past couple of decades, SRL microanalytic protocols have shown tremendous versatility and flexibility in application across domains, learning activities, and populations. Although applications of microanalysis to motoric tasks within the sports realm (e.g., basketball free-throw shooting and dart throwing) were originally emphasized, in recent years the focus has shifted to academic domains (e.g., sentence composition, reading, mathematics, test reflection) and clinical contexts (e.g., vene-puncture and diagnostic reasoning; see [Table 22.1](#)).

To be able to administer microanalytic protocols in an effective way, one needs to first identify and understand the nature of the task for which one wants to assess SRL. Relevant characteristics include the inherent demands and challenges of the task as well as the extent to which the task has a clear beginning, middle, and end. Along a similar vein, because microanalytic methodology was developed to capture cyclical regulatory thinking and action (i.e., forethought, performance, and reflection) as individuals perform a task, there is an extremely close correspondence between task demands and characteristics with the process of administering the microanalytic questions. Specifically, microanalytic protocols are structured so that the fore-thought phase questions are administered before one begins the task, performance phase questions are administered during the task, and reflection phase questions are administered after learning or performance. By merging SRL theory (i.e., three-phase model), task characteristics, and a focus on contextualized assessments, microanalytic protocols have the potential to enable researchers to examine theoretically grounded regulatory processes at different points of an authentic learning activity or situation (Cleary et al., 2012).

[Table 22.1](#) Examples of applications of SRL microanalysis across domains and tasks

Domain	Type of task	Study
Sports	Dart throwing	Zimmerman & Kitsantas (1997); Kitsantas & Zimmerman (1998); Kitsantas, Zimmerman, & Cleary (2000); Kitsantas & Zimmerman (2006); Kolovelonis, Goudas, & Dermitzaki (2011)
	Basketball shooting	Cleary & Zimmerman (2001); Cleary, Zimmerman, & Keating (2006)
	Volleyball serving	Kitsantas & Zimmerman (2002)
Academic	Sentence combining	Zimmerman & Kitsantas (1999)
	Reading and studying in science	DiBenedetto & Zimmerman (2010); DiBenedetto & Zimmerman (2013)
	Test reflection and preparation	Cleary, Callan, Malatesta, & Adams (2015)
	Math problem solving	Callan & Cleary (2014)
Clinical	Venepuncture	Cleary & Sanders (2011)
	Diagnostic reasoning	Artino, Cleary, Dong, Hemmer, & Durning (2014); Cleary, Dong, & Artino (2015)

Structure of Microanalytic Questions and Nature of Data

Microanalytic questions are developed based on theoretical definitions of SRL subprocesses (e.g., goal setting, attributions) delineated in the three-phase model of SRL and the broader SRL literature. Most microanalytic questions utilize open-ended or free response formats to target students' regulatory processes, such as goals, plans, strategy use, attributions. Traditionally, students are required to provide oral responses to these questions, although written responses have been encouraged when students are evaluated in small groups (Cleary, Velardi, & Schnaidman, 2017; Cleary & Platten, 2013). Sample microanalytic questions include, "What do you think you

need to do to get the question correct?” (strategic planning), “Do you have a goal in mind as you prepare to read the textbook?” (goal setting), “Why do you think you did not pass your last exam?” (attribution), and “What do you need to do in order to make the next shot?” (adaptive inferences). The open-ended format of microanalytic questions is distinct from the questionnaire or rating-scale formats because the former requires respondents to generate qualitative responses at a particular moment in time during completion of a specific task without receiving leading prompts about specific regulatory behaviors (as is the case with questionnaires). To facilitate interpretation, examiners use a structured scoring and coding manual to code the qualitative responses into meaningful categories. Although there is often considerable overlap in the coding schemes used to assess a given regulatory process (e.g., goal setting, planning), coding schemes will typically vary across studies because of differences in the nature of the target tasks and the strategies needed to perform that task (e.g., strategies needed to perform a venipuncture activity are distinct from the demands and strategies used to shoot free throws in basketball).

Metric or quantitative microanalytic questions are also used but such questions tend to target students’ motivation beliefs and affect, such as self-efficacy, interest, and satisfaction, as well as their calibration accuracy or self-evaluative judgments of learning (see Chen & Bembenutty, 2018/this volume). These closed-ended questions utilize Likert scale formats and thus naturally elicit quantitative scores. Examples of these types of closed-ended questions include, “How confident are you that you can score a bullseye with each dart?” (self-efficacy), “How interesting is serving a volleyball over-hand to you?” (task interest), “How satisfied are you with your performance during this practice session?” (satisfaction), and “How well do you think you learned about the three phases of tornado development?” (self-evaluation).

Emergent Lines of Research Using SRL Microanalysis

Over the past couple of decades, researchers have used SRL microanalytic protocols to reliably differentiate achievement or expertise groups (Cleary & Zimmerman, 2001; DiBenedetto & Zimmerman, 2010; Kitsantas & Zimmerman, 2002), to measure intervention efficacy (Cleary et al., 2006; Cleary et al., 2017; Kolovelonis et al., 2011; Zimmerman, Kitsantas, & Cleary, 2000), and to explore theoretical relations among cyclical phase processes (Cleary et al., 2015; DiBenedetto & Zimmerman, 2013). Researchers have also shown interest in examining the level of overlap or convergence between microanalytic assessment protocols and other SRL measures (i.e., self-report questionnaires and teacher rating scales). This latter line of research is important because of its potential to shed light onto the different dimensions or level of granularity of SRL processes. Another important trend in the literature involves investigating the predictive validity of SRL microanalytic data and exploring whether multi-method approaches to SRL assessment enhance the prediction of academic and performance outcomes. It is to these latter two emerging lines of research that we focus our attention in this chapter.

Convergence Between Microanalysis and Other Measures of SRL

The relations between event and aptitude measures have been a topic of interest among researchers. One important theme to emanate from this line of research is that self-report questionnaire data (aptitude measures) do not closely correspond to data generated from event measures, such as behavioral traces and think-aloud protocols (Veenman, Prins, & Verheij, 2003; Winne & Jamieson-Noel, 2002). Although studies utilizing microanalytic protocols have addressed a similar theme, they have contributed uniquely to the field by including different types of aptitude measures (i.e., self-report questionnaires and teacher ratings) and by examining the relations among aptitude measures and specific SRL processes. Because most of the microanalytic studies have emphasized strategic planning and strategy use processes (Callan & Cleary, 2014; Cleary et al., 2015; DiBenedetto & Zimmerman, 2013), we focus our attention on the level of convergence between these two strategic microanalytic processes with broad estimates or aggregates of students’ strategies as reflected in self-report questionnaires and teacher rating scales (see Wolters & Won, 2018/this volume).

Cleary et al. (2015) was the first study to examine the link between SRL microanalysis and an SRL self-report questionnaire. Using a sample of 49 college students from an introductory educational psychology course, the authors investigated whether students' microanalytic strategic planning processes, including time management, effort regulation, help seeking, elaboration, and organization strategies, correlated with various subscales from the Motivated Strategies for Learning Questionnaire (MSLQ). To enhance the comparability and situational-specific focus of both types of measures, the directions and/or wording of specific questions were customized to reflect test preparation for the specific college course. Further, the microanalytic coding scheme was closely aligned with the types of regulatory strategies targeted by the MSLQ sub-scales to enhance similarity in content addressed by the two types of measures. Two microanalytic strategic planning questions were used: "Are there specific things you are currently doing or will do to make sure that you are learning all of the information that might be on your next test?" and "Are there things that you are currently doing or will do to make sure that your study sessions go smoothly?" A key finding was that despite the overlap in content (i.e., SRL strategies), context (i.e., same college course), and data source (i.e., student reports), nearly all of the correlations between these two types of SRL measures were small to negligible, with most ranging in size from .02 to .07 (Cleary et al., 2015).

DiBenedetto and Zimmerman (2013) addressed a very similar issue, but used teacher ratings of student SRL (rather than student self-reported data) and focused on a high school student population. Fifty-one high school students were asked to read a short passage about tornadoes and to respond to microanalytic questions as they approached, performed, and reflected about their performance on this activity. The authors administered a comprehensive microanalytic protocol, but for the specific purposes of this chapter we focus on two key questions: strategic planning (i.e., "Do you have any particular plans for how to read this passage and take the test?") and strategy use (i.e., "Can you explain to me how you are preparing for the test? What exactly are you doing?"). Correlation analyses revealed numerically larger relations than in Cleary et al. (2015; $r = .22$ to $.24$ versus $r = .02$ to $.07$); however, these relations were still relatively small in magnitude and did not reach statistical significance. Thus, across both of these initial studies, the data suggest that broad indicators of students' strategic behaviors, regardless of whether students or teachers serve as the source of data, do not correspond closely with task-specific or "in the moment" microanalytic data about their strategic thinking and action.

To extend this line of research, Callan and Cleary (2014) administered both types of aptitude measures (i.e., student questionnaire, teacher rating scale) along with an SRL microanalytic protocol to a sample of 100 middle school students from an urban school district. Although this study had multiple objectives, the authors sought to investigate whether the relations between the two aptitude measures were comparable to the relations observed between measures across categories (e.g., microanalysis and questionnaires), and whether the convergence between the microanalytic and aptitude measures varied based on the difficulty of the target task linked to the event measure. As part of a practice session, students were asked to solve three mathematics word problems that ranged from easy to difficult. The practice session represented the task around which the SRL microanalytic questions were administered.

Similar to the previous two studies, Callan and Cleary (2014) focused on students' microanalytic strategic planning and strategy use. Regarding strategic planning, after the students previewed the set of mathematics problems but before they began completing the problems, an interviewer asked students, "Do you have any plans for how to successfully complete these math problems?" In contrast, the strategy use question was administered twice during the practice session, immediately following completion of the first (easy) and the third (difficult) mathematics problems presented during the practice session. For the strategy use measure, the interviewer asked, "Tell me all of the things that you did to solve this problem." Following the practice session, the authors asked the students to complete the self-report questionnaire, while their teachers were asked to complete the rating scale.

As expected, the within-category relations (i.e., student questionnaires, teacher ratings) were statistically significant and of a medium size ($r = .34$, $p < .05$), whereas most of the between-category relations were not statistically significant. Regarding the strategic planning microanalytic question, its relations to both the questionnaire ($r = .15$) and teacher ratings ($r = .16$) were not statistically significant. A fairly similar yet interesting pattern emerged for the strategy use measure. Because this measure was administered twice during the

mathematics practice session (following the easy and difficult problems), the authors examined whether the relations between the aptitude measures (student and teacher ratings) and microanalytic strategy use varied across task difficulty. Consistent with most other research, the microanalytic strategy use measure did not converge with student self-report questionnaires regardless of the difficulty level of the problem (easy, $r = .05$; difficult, $r = .02$). Although similar results were observed between the strategy use microanalytic measure and teacher ratings (easy, $r = .08$; difficult, $r = .19$), it is interesting that the effect size for the difficult mathematics problem was within the small range rather than being negligible. Given that research suggests that regulation tends to emerge when students encounter challenging situations or when task demands change or fluctuate (Cleary & Chen, 2009; Hadwin, Winne, Stock-ley, Nesbit, & Woszczyna, 2001), exploring whether complexity of task demands affects the relations between event types of measures and more broad aptitude measures is an interesting area of future research to explore.

Although the initial set of studies reviewed in this section support the premise that aptitude measures do not closely converge with microanalytic questions, it is important to recognize that much of the research to date has focused on a narrow set of microanalytic processes. When other types of SRL microanalytic processes have been considered, a different and perhaps more complicated pattern of results emerge. For example, DiBenedetto and Zimmerman (2013) investigated the relations between teacher ratings of student SRL classroom behaviors and microanalytic measures of metacognitive and self-evaluative judgments. The authors described metacognitive monitoring in terms of students' judgments of learning for a short-answer test and a conceptual test about tornadoes. The self-evaluative measure targeted how well the students believed that they learned the details about tornado development during the session. In contrast to the negligible relations observed between the teacher ratings and the microanalytic strategy planning and strategy use questions, statistically significant and medium to large correlations emerged when teacher ratings were used in relation to metacognitive monitoring ($r = .41$, $p < .05$) and self-evaluation ($r = .48$, $p < .05$). Callan and Cleary (2014) also considered metacognitive monitoring questions as part of their study. Interestingly, they reported that students' judgments about their mathematical problem solving performance did not relate to self-report questionnaires ($r = -.03$) or teacher ratings ($r = .08$). Given these mixed findings and because research in this area is still in its infancy, much more work needs to be done to examine the extent and circumstances under which different types of SRL microanalytic data and broad-based assessments of SRL either converge or diverge.

SRL Microanalytic Data as a Predictor

Another important line of inquiry involves the strength of the relations between microanalytic measures and student outcomes in various contexts (e.g., volleyball serving, diagnostic reasoning, mathematics problem-solving; Artino et al., 2014; Callan & Cleary, 2014; Cleary et al., 2015; DiBenedetto & Zimmerman, 2013; Kitsantas & Zimmerman, 2002). Many of the studies reviewed in the prior section also addressed this predictive validity issue. Broadly speaking, across tasks and domains, SRL micro-analytic processes have been shown to reliably differentiate ability and achievement groups (Cleary & Zimmerman, 2001; Kitsantas & Zimmerman, 2002; DiBenedetto & Zimmerman, 2010) and to serve as reliable predictors of a plethora of performance outcomes (Artino et al., 2014; Chen & Zimmerman, 2007).

Kitsantas and Zimmerman (2002) conducted one of the earliest investigations of the predictive validity of a microanalytic protocol. Using a college-aged sample consisting of expert, non-expert, and novice volleyball players, the authors administered a comprehensive microanalytic protocol consisting of 12 regulatory processes to the participants before and after they practiced volleyball serving skills. Although the authors were primarily interested in examining SRL differences across expertise groups, they also examined the extent to which a composite of all 12 regulatory processes predicted volleyball serving skill at posttest. Based on hierarchical regression analyses, the authors reported that the microanalytic data generated during the practice sessions accounted for 90% of the variation in volleyball serving skill measured at posttest.

Although these results were impressive, the majority of microanalytic studies have examined predictive validity of specific SRL processes (e.g., strategic planning, goal setting) rather than an aggregate or composite of processes (Artino et al., 2014; Callan & Cleary, 2014; Cleary et al., 2015). Again, because most of these studies have explored the extent to which strategic planning and strategy use measures predict these outcomes, we focus our attention on whether these strategic processes have accounted for unique variance in student outcomes after controlling for other types of SRL processes.

A fairly consistent finding has been that the quality of students' task-specific strategic thinking reliably predicts performance on those tasks but also on more distal and global outcomes. In medical education, Artino et al. (2014) administered an SRL microanalytic protocol targeting medical students' planning, goal setting, and metacognitive monitoring processes as they completed a clinical reasoning activity. In this study, the medical students were first asked to read a case scenario regarding a fictional patient's presenting concerns and symptoms. Before prompting students to begin working up potential diagnoses, an examiner administered questions targeting students' forethought phase processes, goal setting ("Do you have a goal(s) in mind as you prepare to do this activity?"), and strategic planning ("What do you need to do to perform well on this activity?"). Following these initial questions, the students were instructed to use a post-encounter form (PEF) to facilitate the development of diagnoses. During the task, the participants were also prompted to answer a metacognitive monitoring question ("As you have been going through this process, what has been the primary thing you have been thinking about or focusing on?").

The authors used regression procedures to examine whether the three SRL micro-analytic processes predicted different types of outcomes in medical school after controlling for prior achievement (i.e., MCAT scores and first year GPA). The primary outcomes included student grades in a diagnostic reasoning course, the U.S. Medical Licensing Examination (USMLE; taken approximately one month after the course), and the National Board of Medical Examiners examination (NBME; taken approximately 6 to 12 months after the course). Although students' microanalytic goals and metacognitive monitoring did not predict any of the outcomes, the quality of students' strategic plans (i.e., specific elements of the diagnostic reasoning process) emerged as a fairly sizable predictor of all outcomes. Specifically, the strategic planning measure predicted between 8% and 10% of the variance across all outcomes.

Cleary et al. (2015) generated additional predictive validity evidence of microanalytic questions in a study with college students enrolled in an introductory psychology course. The authors used a multi-method SRL assessment approach that consisted of microanalytic strategic planning and MSLQ subscales and sought to determine whether both aptitude (MSLQ) and event measures (microanalysis) accounted for unique variance in students' final exam grades—that is, whether there was "added value" to using both questionnaire data and SRL microanalytic data. In short, the authors found that there was no added value. That is, the self-report questionnaire did not account for any variance in final exam grade but the microanalytic strategic planning measure accounted for approximately 9% of the variance.

DiBenedetto and Zimmerman (2013) addressed a similar issue but used a different assessment battery and target activity. The authors focused on high school students as they performed a science-based reading and studying activity. They also used teacher ratings of student SRL rather than student reports as the aptitude measure. Across two outcome variables (i.e., a Tornado Knowledge Test (TKT) and a Conceptual Model Test (CMT)), correlation analyses showed that the strategic planning and strategy use microanalytic measures exhibited medium relations with the two outcomes: strategic planning (TKT, $r = .32$, $p < .05$; CMT, $r = .34$, $p < .05$); strategy use (TKT, $r = .40$, $p < .01$; CMT, $r = .40$, $p < .01$). Unlike Cleary et al. (2015), however, the aptitude measure (i.e., teacher ratings) also exhibited medium to large relations with the two outcomes: CMT ($r = .45$, $p < .01$) and TKT ($r = .51$, $p < .01$). Although the regression analysis results presented in the manuscript did not specifically determine the "added value" of using the two assessment types, because the teacher rating scale and the two microanalytic strategy measures showed small inter-relations ($r = .22$ and $r = .24$) yet moderate-to large-sized relations with the two outcomes, it is possible that there is some added value in concurrently using multiple measures.

Callan and Cleary (2014) utilized a research design that enabled a more robust examination of the unique contribution of different types of SRL measures across three levels of academic outcomes: a set of three mathematical word problems solved during the practice session, a 15-problem posttest of word problems, and a broad standardized test of mathematics skill. The SRL assessment battery included microanalytic measures along with two aptitude measures (i.e., student self-report and teacher ratings). Using regression analyses across each of the three achievement outcomes, the authors found that the pattern of observed results varied across assessment type and outcome. In terms of the microanalytic measures, while the strategy use measure did not emerge as a statistically significant predictor of any of the three mathematics outcomes after controlling for other SRL measures, the microanalytic metacognitive-monitoring measure accounted for unique variance in all three of the outcome measures. In terms of the two aptitude measures (self-report questionnaire and teacher ratings), the self-report questionnaire did not account for unique variance in any of the three mathematics outcomes, whereas teacher ratings predicted two of the outcomes (i.e., posttest, standardized measure).

In sum, initial research examining the links between SRL microanalytic and aptitude measures suggests that strategic planning and strategy use are typically, but not always, linked to performance outcomes and appear to be stronger predictors of these outcomes than self-report questionnaires. The fact that similar findings have emerged across different studies utilizing various tasks and student populations underscores the importance of these microanalytic processes. However, our analyses should not lead one to conclude that event forms of measurement are superior to aptitude measures or vice versa. It is important to recognize that the focus of our chapter was fairly narrow in that it pertained primarily to the role of microanalytic strategic planning and strategy use measures. Prior microanalytic research has shown that aggregates of microanalytic responses (DiBenedetto & Zimmerman, 2013; Kitsantas & Zimmerman, 2002) and other specific types of microanalytic processes (i.e., metacognitive monitoring) are also robust predictors of achievement and that under certain conditions, aptitude measures (i.e., teacher ratings) may serve as an important and unique predictor of achievement.

Areas of Future Research

SRL microanalytic methodology is a highly structured yet flexible approach for evaluating the nature of students' SRL processes during specific learning activities. It has been used to differentiate achievement groups and to predict both short-term and long-term achievement outcomes, and has been frequently used as an outcome measure in intervention research. From our perspective, however, research on microanalytic protocols is still in the early stages and thus much more work is clearly needed in this area.

Most of the studies examining the convergence between microanalytic and aptitude measures have focused specifically on microanalytic strategic planning and strategy use, with a couple of studies also considering metacognitive monitoring. Because microanalytic protocols can be structured to assess a wide array of SRL processes, such as goal setting, causal attributions, and self-evaluation, future research targeting concurrent and convergent validity issues should develop and utilize more comprehensive microanalytic protocols. Further, although a primary objective of microanalytic protocols is to generate diagnostic information about individual regulatory processes, it might be of interest to also calculate composite microanalytic scores (see Kitsantas & Zimmerman, 2002) when exploring issues of convergence among SRL measures and when attempting to maximize prediction. For example, by calculating a composite or global microanalytic metric one can address the issue of whether students' overall regulatory approach relative to a specific learning task (microanalysis) corresponds with their overall regulatory approach across learning tasks and time (aptitude measures).

More research is also needed to more closely examine the use of multi-method SRL assessment approaches and to identify the circumstances, contexts, and student populations for which event and aptitude measures can best complement and enhance the prediction of outcomes. Thus, as a general recommendation, future research needs to not only consider the specific microanalytic measures of interest but also the nature of the tasks and contexts within which the studies are grounded.

Finally, as interest in applying SRL interventions to academic contexts continues to grow (Graham, Harris, MacArthur, & Santangelo, 2018/this volume; Kramarski, 2018/this volume; Poitras & Lajoie, 2018/this volume), it is important for researchers to go beyond examining intervention efficacy at posttest or follow-up. It is quite relevant and potentially revealing to use microanalysis and other forms of event measures to examine how and when shifts in SRL occur during the intervention (Cleary & Platten, 2013). Along these lines, future research can address how changes in regulatory processes within one phase of the SRL cyclical loop (i.e., forethought, performance, or self-reflection) predict changes in regulatory processes across other phases. Addressing this latter issue is important because it can help to clarify and explain the sequential nature of the three-phase cyclical process of SRL.

Applications of SRL Microanalysis to Educational Contexts

One of the key purposes of SRL microanalytic protocols is to yield data that educators and practitioners can use to diagnose SRL deficiencies in their students and to subsequently modify instructional or remedial activities for those struggling in school. Cleary and colleagues have used microanalytic protocols as part of an intervention program, called the Self-Regulation Empowerment Program (SREP), to periodically evaluate shifts in middle school and high school students' strategic and regulatory thinking. The SRL coaches administering the intervention have been able to use the microanalytic information in a formative way to guide future intervention activities and to structure individualized conversations with students (Cleary & Platten, 2013; Cleary et al., 2017).

Peters-Burton and Botov (2016) used SRL microanalysis for a similar purpose but in the context of professional development for teachers. In this study, the authors provided professional development training to a group of elementary school teachers. As part of the training, the authors administered microanalytic questions to formatively assess the teachers' approaches, thinking, and reactions while attempting to learn about inquiry-based instruction. By the authors' account, the microanalytic data enabled them to adapt and improve their instructional pedagogy to enhance professional development experiences for the participants.

The application of SRL microanalytic protocols can also be easily extended to classroom teachers in K–12. Much of the feedback that students receive from teachers is corrective in nature; that is, it informs students about their overall performance level as well as the specific errors or mistakes they may have made. Because process-oriented feedback tends to be largely neglected in school contexts and because SRL microanalytic probes generate process-oriented data about how students approach, think about, and reflect on their learning (Hattie & Timperley, 2007), this type of assessment approach holds much potential for serving as a feedback-generation mechanism for teachers.

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23 Advancing Research and Practice about Self-Regulated Learning

The Promise of In-Depth Case Study Methodologies

Deborah L. Butler and Sylvie C. Cartier

Introduction

Many challenges face contemporary researchers seeking to advance understanding about self-regulated learning (SRL) and how to support it (Schunk, 2008). For example, researchers are increasingly sensitive to how SRL processes are situated and context-dependent (e.g., Järvenoja, Järvelä, & Malmberg, 2015). Correspondingly, contemporary researchers seek methodological strategies that enable investigating how individual, social, and contextual factors interact to influence learners' engagement in SRL (e.g., Hadwin & Oshige, 2011). Another challenge is that SRL is an integrative, multi-componential theory (see Butler, 2015; Zimmerman, 2008). It follows that researchers need approaches for studying how multiple components associated with SRL co-relate dynamically to shape learning-in-action. As a final example, SRL has long been described as a process that is iterative and adaptive (e.g., Winne, 2018/this volume; Winne & Hadwin, 1998). It follows that researchers need frameworks for investigating dynamic processes as they unfold through learning episodes. In light of these theoretical challenges, our first goal in this chapter is to explain how and why case study designs can support studying SRL as a dynamic, multi-componential, and situated process that is constituted through both individual and social processes (Cartier & Butler, 2016).

Practically speaking, another kind of challenge faces researchers and educators alike. That is, while research across three decades has identified qualities of SRL-promoting principles and practices, it remains difficult to mobilize what is known about SRL in ways that have a sustained and meaningful impact on policy or practice (Butler & Schnellert, 2012; Cartier, Butler, & Bouchard, 2010). Thus, our second goal in this chapter is to explain how case study designs can help, not only in advancing understanding about SRL-promoting practices, but also in mobilizing knowledge about SRL for the benefit of school systems, educators, and learners.

In short, our goals in this chapter are to identify the promise of case study methodologies to advance theory and practice related to SRL (see also Butler, 2011; Cartier & Butler, 2016). To achieve these goals, we start by introducing case studies as a methodological framework. Next, to ground the remaining discussion, we introduce a situated model of SRL. We then build from that model to identify challenges facing contemporary SRL researchers and provide examples of how researchers have been using case study designs to address them. We conclude by identifying important research directions and implications for practice.

What is a Case Study Design?

In a previous chapter Butler (2011) described in some detail how educators can design case studies to investigate SRL. As a complement to that more elaborated discussion, here we briefly describe key characteristics of case

study designs. Our purpose is to help researchers imagine the potential of case studies in addressing contemporary challenges in the study of SRL.

Case Studies as Investigating a Bounded System

Researchers take up case study designs when they want to develop an in-depth understanding of some kind of entity as it is situated in an authentic context (Yin, 2003). These entities, or “cases,” are typically described as a bounded system. Bounded systems tend to represent some kind of unity, such as a person, a place, a phenomenon, or a social unit (Merriam, 1998). For instance, in research on SRL, a case might be identified as a particular student, a particular classroom, or a professional learning community.

As one example, imagine that a researcher wanted to study how or why a particular kind of pedagogical practice can foster effective forms of SRL by students and, correspondingly, better learning outcomes. One choice would be to design a single case study of one teacher’s classroom (e.g., Özdemir & Pape, 2012). Single case studies allow for in-depth examination of multiple external and internal influences as they interact within one bounded system. In a classroom-level case study, a researcher might document how adults (teachers, educational assistants, consultants, parents, or others) were collaborating to design and enact SRL-promoting practices; correspondingly, the researcher could trace how students’ engagement in SRL and learning shifted in relation to practices over time. In a single case study design, a researcher can create opportunities to investigate how and why pedagogical practices are associated with students’ engagement in more effective forms of SRL in a naturalistic setting in real time.

Depending on their questions, case study researchers can include one or more cases in any given investigation (e.g., six to ten students; two to three classrooms), although the numbers tend to be small to allow for in-depth study of each case (see Yin, 2013). For example, instead of choosing a single classroom as a case, a researcher might conduct multiple, parallel case studies across several classrooms or teachers (e.g., Butler, 1998; Martel, Cartier, & Butler, 2014). Doing so can help in identifying the conditions under which findings apply (i.e., are similar patterns observed in cases that differ in important ways?). Or, a researcher might study a set of nested cases, such as a selection of classrooms nested within a subset of schools nested within a single district. This kind of study could be useful for studying contextual influences, or change processes, at a systems level (e.g., Butler, Schnellert, & MacNeil, 2015). One way or another, a key first step in designing a case study investigation is to define the boundaries of and relationships among all cases.

Case Studies as a Design Framework

Case study methodology provides a comprehensive and rigorous framework for conducting research (Yin, 2003). As in other methodological frameworks, case study researchers need to make thoughtful decisions in order to generate evidence and warrant conclusions related to a particular research question (Butler, 2011). For example, like other methodologists, case study researchers need to (a) be clear about the theoretical and methodological assumptions they bring to a research study; (b) identify data collection and analysis strategies appropriate to their research questions; (c) collect and interpret evidence to generate findings related to their research questions; and (d) carefully warrant any conclusions by applying any one of an array of strategies that ensure the credibility of the work (see Merriam, 1998; Yin, 2013).

An important decision in all research, including case studies, pertains to sampling. As described earlier (p. 353), in case study designs, sampling includes selection of the one or more bounded system(s) that will constitute the case(s). In addition, in any given case, it is not possible to study all possible actions, processes, relationships, or contextual conditions in equal depth at the same time. Thus, sampling decisions are also necessary to delimit the scope of investigation. Most commonly, case study researchers employ purposeful or purposive sampling, which involves making decisions that will allow for learning the most given the research questions in hand (Stake, 2006). For example, in a classroom-level case study, researchers might narrow attention to a particular kind of

pedagogical practice (e.g., assessment for learning) within a particular kind of activity (e.g., inquiry-based projects) as instantiated in one or two classrooms over a defined period of time (e.g., one lesson sequence) with particular students.

Case Studies as Offering Unique Opportunities for Evidence Collection and Interpretation

Because case study designs investigate a bounded system holistically, they can support researchers in collecting, assembling, and relating multiple kinds of evidence. For example, consider again how researchers might study how or why a particular kind of pedagogical practice can foster effective forms of SRL by students. In [Table 23.1](#), we suggest how the researchers could profitably assemble a wide variety of evidence (e.g., from documents, interviews, observations, journals, surveys, think-aloud protocols, etc.) to inform understanding about (a) contextual influences (e.g., classroom, school, from home); (b) pedagogical goals and principles an educator had in mind to guide design of classroom practices; (c) pedagogical practices as enacted in a given situation; (d) what students are bringing to contexts, such as perceptions of self-efficacy or conceptions about academic work; (e) students' appraisals, interpretations, and reactions to environments and activities; (f) students' engagement in SRL, alone or in collaboration with others, as activities unfolded; and (g) benefits and challenges for teachers (e.g., shifts in learning or practice; obstacles encountered or overcome) and students (e.g., gains in beliefs, perceptions, knowledge, achievement).

Notable is that different kinds of data collection methods can be used deliberately and strategically to inform understanding about different topics at the same time. For

[Table 23.1](#) Assembling multiple sources of evidence to study SRL as situated in context

Information about ...	Possible kinds of evidence: Examples				
	Background information	Records of classroom life	Self-reports	Individuals' thinking in practice	Traces of work
Contextual influences	Documents (e.g., on programs, policies), displays (e.g., school, classroom), stakeholder interviews	Observations of context(s), photos, video/audio	Interviews or surveys with teachers, parents, students, administrators, consultants, policy-makers	Teacher journals, reflections in practice, cued reflection	Teacher displays or documents generated, photos, videos
Teachers' pedagogical goals & principles	Documents (e.g., lesson plans), displays (e.g., classroom), teacher interviews	Observations of practice, photos, video/audio	Teacher interviews	Teacher journals, reflections in practice, cued reflection	Teacher displays or documents generated, photos, videos
Practices as enacted	Documents (e.g., lesson plans), displays (e.g., classroom), teacher interviews	Observations of practice, photos, video/audio	Interviews or surveys with teachers and/or students	Teacher journals, interviews in practice, cued reflection	Displays or documents generated, photos, videos
What students bring to contexts	Documents (e.g., IEPs, past academic record, reports)	Observations of students, photos, video/audio	Interviews, journals, or surveys	Think-alouds, cued reflection	Displays or documents generated, photos, videos
Students' appraisals, interpretations, & reactions	Records of past learning in activities (e.g., a portfolio)	Observations of students' reactions	Interviews, journals, portfolios, or surveys	Student journals, interviews in class, think-alouds, cued reflection	Student work samples, process traces
Students' engagement in SRL	Records of past learning in activities (e.g., a portfolio)	Observations of action, photos, video/audio	Think-alouds, cued reflection	Student journals, interviews in class, think-alouds, cued reflection, portfolios	Student work samples, process traces
Benefits and challenges	Records of past learning in activities (e.g., a portfolio), records of learning plans or what has worked previously	Observations of practice, learning shifts, or obstacles	Interviews or surveys with teachers and/or students	Observations of work, interviews in class, cued reflections	Copies of teacher and student work, portfolios, grades

example, classroom observations can inform understanding about classroom practices as enacted in relation to students' reactions to them. Further, by gathering multiple forms of evidence in tandem as they emerge over time, researchers can observe and interpret links between processes and outcomes (e.g., how students' engagement in SRL and associated learning evolved through a lesson sequence). They can also triangulate multiple sources of evidence to generate and refine conclusions (e.g., Whipp & Chiarelli, 2004).

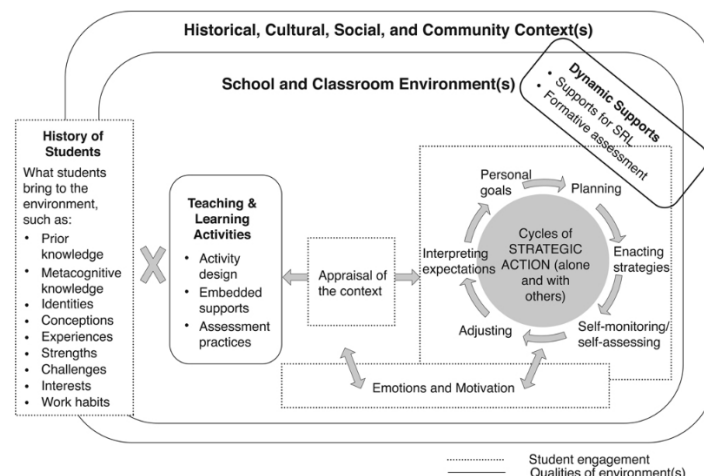
In actual practice, creating a table of this sort to plan and document available evidence is helpful when designing and delimiting the focus for a case study. By gathering multiple sources of evidence in situ and over time, a case study investigator creates rich opportunities to identify relationships among multiple contextual, social, and individual processes as they unfold dynamically in relation to one another. Researchers also have opportunities to build from and interpret different kinds of evidence fairly in relation to research questions, for example by juxtaposing what teachers or students think about teaching and learning (e.g., through self-report measures) and what they are actually doing as activities unfold (e.g., through observations, lesson plans, or student work samples) (Butler, 2011; Martel et al., 2014).

A Situated Model of SRL

Many theoretical lenses have been applied to the study of SRL. Correspondingly, authors have offered many representations of SRL components, each of which tends to foreground particular kinds of influences or processes (e.g., Boekaerts, 2011; Usher & Schunk, 2018/this volume; Hadwin, Järvelä, & Miller, 2018/this volume; Winne, 2018/this volume; Winne & Hadwin, 1998; Zimmerman, 2008). In the rest of this chapter, we draw on a situated model of SRL (Butler & Cartier, 2004; Cartier & Butler, 2004, 2016) as depicted in [Figure 23.1](#). In this section, we introduce key features of this model as relevant to defining the promise of case study methodology in the study of SRL.

First, this situated model foregrounds how students' engagement in SRL depends on individual-context interactions. As Järvenoja et al. (2015) emphasize, "learning does not happen in a vacuum but takes place in constantly changing contexts and is reformed every time" (p. 204). Correspondingly, in [Figure 23.1](#) we depict how SRL in a given situation at a particular time emerges from a complex interplay between what students are bringing to a learning environment (i.e., the "history of students") and the opportunities and limitations defined by the context(s) in which students are living and learning (from the broader historical, cultural, social, and community contexts to the more local features of particular schools and classrooms). Further, within school and classroom environments, we identify two important kinds of contextual influences on SRL: (a) teaching and learning activities, including how activities are designed, as well as how supports for SRL and assessment practices are constituted within activities; and (b) dynamic forms of support provided for SRL as activities are unfolding, both within classrooms and community environments (e.g., through homework). Overall this situated model of SRL suggests that learners' engagement in SRL is shaped by the intersection between what the various students coming together in a learning environment are bringing to the table and the multiple features of contexts as constituted at multiple and/or intersecting levels.

Second, in this model we suggest that students' engagement in SRL is continually mediated by their on-going appraisal of the situation (e.g., as safe or threatening), and by their experiences of emotion and motivation (e.g., Boekaerts, 2011). For example, a



[Figure 23.1](#) A model of SRL as situated in context

(Adapted from Cartier & Butler, 2016)

student with a history of reading challenges may have developed low self-perceptions of competence in reading, experience stress when asked to read, appraise the activity and environment as threatening (e.g., as likely to reveal weaknesses publicly to peers), and so may choose to prioritize personal goals for preserving well-being rather than engaging actively in learning.

Finally, at the heart of this situated model is students' engagement in the iterative, dynamic cycles of strategic action so central to SRL, including interpreting expectations, setting personal goals, planning, enacting strategies, self-monitoring, and adjusting (i.e., control). In this depiction, we signal how students are typically engaged in strategic action cycles both on their own and with others. Indeed, social factors are strongly influential in how self-regulation unfolds as individuals negotiate tasks in learning environments (Järvenoja et al., 2015). Thus, as part of strategic action, we explicitly identify how students need to successfully navigate not only learning processes (e.g., for reading, writing, or researching), but also their emotions, motivation, and successful engagement with tasks and others (Boekaerts, 2011; Zimmerman, 2011).

In sum, in this section we have provided a high-level overview of key components built into this situated model of SRL. In the discussion to come, we build from this model to identify contemporary challenges in the study of SRL and to illustrate how researchers can and have been employing case study designs to take up those challenges.

How are Case Studies Being used to Advance Research and Practice Related to SRL?

Across time, researchers have been taking up case study designs to explore topics of interest to SRL researchers. For example, case studies have been employed to study students' experiences with, conceptions about, and engagements in academic work (e.g., Alvermann et al., 1996; Hopwood, 2004; Ivey, 1999). They have also been used to investigate links between classroom practices and students' learning and development (e.g., Aulls, 2002; Cartier, Chouinard, & Contant, 2011; Cartier, Contant, & Janosz, 2012; Martel, Cartier, & Butler, 2015; Martel & Cartier, 2016; Schuh, 2003). In this section, we illustrate ways in which investigators have been using case study designs to address important theoretical and practical challenges facing today's SRL researchers.

Challenge One: Studying SRL as Situated in Context

[Figure 23.1](#) highlights many ways in which students' engagement in SRL is influenced by the context in which it unfolds. In this section, we illustrate the promise of case studies to help in studying SRL by affording study of how and why (a) forces beyond the local environment influence learners' engagement in SRL, and (b) pedagogical practices as situated in classroom environments can foster students' engagement in more effective forms of SRL.

Contextual Influences as More Than Local

Our situated model suggests that individuals' engagement in SRL depends on more than what is happening locally in a classroom. Instead, students' engagement is heavily influenced by what they and others are bringing to contexts, based on their past experiences, and the qualities of the contexts in which they are living and working. It follows that, to advance theory and practice related to SRL, contemporary researchers need to investigate how individual histories interact within context(s) to influence engagement in learning.

Case study designs can be particularly useful in uncovering the varying, intersecting, or layered contextual influences on students' engagement in learning. For example, in their case study research, Haines, Summers, Turnbull, Turnbull, and Palmer (2015) investigated how self-regulation was fostered for a 4-year-old boy from a refugee family who was navigating "two parallel worlds" as a preschooler from a refugee family enrolled in a

Head Start program (p. 36). As a backdrop to their study, they identified how refugee families sometimes struggle if they are unfamiliar or at odds with teaching and disciplinary practices in the United States, are not involved with their children's education in ways that schools expect, and/or have behavioral expectations for their children that differ from expectations at school. Their research question was, "How do Head Start staff and a refugee family foster self-regulation and engagement skills of a young child at risk for disability?" (p. 29). To address their question, they used a combination of observations, semi-structured interviews, and documents to trace how adults were fostering SRL by the child across the home and a Head Start environment. What they found were differences in the ways in which adults supported the child in home and school environments along three dimensions (restriction-freedom; levels of adult direction; affective responses). Still, in spite of those differences, the child's self-regulation improved in both environments over time. This research illustrates how a case study design can be employed to uncover the experience of children who, as they develop capacities for self-regulation, are learning how to navigate contrasting practices and expectations, in this case from home and preschool environments.

Case study research is also particularly useful in revealing how what individuals are bringing to contexts interact with features of environments to shape students' engagement in SRL. For example, in her multiple case study, Tang (2009) investigated how nine 9th-grade students engaged in help-seeking or help-avoidance, as a self-regulatory process, based on a combination of their prior experiences with schooling in different countries and the classroom context (across a regular Humanities class and a support classroom for English Language Learners). What she found was that individuals' willingness to engage in help-seeking depended on complex interactions among their experiences with help-seeking in previous schooling, their perceptions of the benefits and costs associated with seeking help, and the "culture" or "norms" for help-seeking as established in particular classrooms. In her research, Scott (2011) conducted multiple parallel case studies to study the self-efficacy perceptions of seven students engaged with SRL-promoting practices in the context of literacy activities. She found that individuals' perceptions of self-efficacy varied across literacy tasks and could be related to an interaction between personal (e.g., past history of reading difficulties) and environmental (e.g., opportunities to make choices) factors, particularly as those combined to shape students' perceptions about environmental conditions (e.g., whether a choice of writing topic was motivating or intimidating). Other researchers have also used case studies productively to uncover how and why personal and contextual influences intersect in learners' situated engagement in SRL (e.g., Cartier et al., 2012; Evensen, Salisbury-Glennon, & Glenn, 2001; Kaplan, Lichtinger, & Margulis, 2011; MacDonald, 2014). As Stake (2006) suggested, "when individual cases respond differently in complex situations, the interactivity of main effects and settings can be expected to require the particularistic scrutiny of case study" (p. 28).

Pedagogical Practices as Supportive of SRL

Building from over 30 years of research on SRL, [Figure 23.1](#) identifies two broad ways in which pedagogical practices support learners' capacities to engage in effective forms of SRL. First, ample research has documented how educators can design learning activities in ways that partner opportunities and supports for SRL (Cartier, 2007; Perry, 2013). For example, Butler, Schnellert, and Perry (2017) overview how activities create rich opportunities for learning when they work towards multiple goals, focus on large chunks of meaning, integrate content across subject areas, extend over time, include students in making choices, engage students in a variety of cognitive and metacognitive processes, include individual and social forms of learning, and/or allow students to demonstrate learning in a variety of ways. [Figure 23.1](#) also identifies how educators can offer dynamic supports for SRL responsively as needed while students are learning (e.g., through formative assessment). The challenge for SRL researchers is to study how pedagogical practices can be constructed to foster SRL, both in the initial design of activities, and as supports are provided dynamically while students are working iteratively through cycles of SRL.

Case study research is particularly useful for addressing questions related to how and why different kinds of pedagogical practices create opportunities and supports for students' engagement in SRL and, correspondingly, might have a positive impact on students' learning and achievement. Indeed, a sizeable body of case study

research has helped in advancing knowledge about pedagogical practices with promise to support SRL (e.g., Butler, 1995, 1998; Butler, Novak Lauscher, & Beckingham, 2005; Cartier et al., 2010; Malan, Ndlovu, & Engelbrecht, 2014; Martel et al., 2014, 2015; McCormick, 1994; Özdemir & Pape, 2012; Punhagui & de Souza, 2013; Tan, Dawson, & Venville, 2008).

For example, Özdemir and Pape (2012) conducted a case study of one 6th-grade teacher's classroom to investigate how SRL-promoting practices could be integrated meaningfully into mathematics instruction in a "real" classroom setting. More specifically, their goal was to examine the extent to which that teacher, who had participated in a two-year professional development on SRL in mathematics, built SRL-promoting practices into her teaching so as to foster student strategic competence. Data collected were gathered over a four-month period through 22 80-minute classroom observations captured using video- and audio-recordings and field notes, informal chats with students while engaged in work, and conversations with the teacher before and after lessons. Building on a combination of inductive and deductive analyses, the authors identified four types of practices enacted by the teacher with potential to foster students' development of strategic competence, including (a) the nature of tasks and activities, particularly when they supported students' autonomy, for example by positioning students as responsible for learning new concepts collaboratively with peers; (b) practices supporting understanding, for example by contextualizing concepts in real-life examples and providing multiple routes for students to express ideas; (c) practices supporting strategic knowledge and skills, for example by explicitly discussing strategic approaches with students and scaffolding their engagement in self-regulating processes in the context of collaborative problem-solving activities; and (d) practices supporting motivation, for example by acknowledging or praising students' ideas in constructive and specific ways. Their detailed descriptions and examples illuminated possibilities for situating SRL-promoting practices in a mathematics classroom.

In their case study research, Butler, Schnellert, and Cartier (2013) traced connections between 18 educators' engagement in professional learning, their use of practices designed to promote self-regulated "learning through reading" (LTR) within and across classrooms, and student outcomes. Data collected traced students' thinking about their engagement in LTR activities (emotions, motivationally charged beliefs, personal goals, task interpretation, perceptions of strategies used), students' actual engagement and performance in LTR activities, teachers' perceptions about their pedagogical goals, practices, and student outcomes, and practices as actually enacted. Findings documented gains for students in their LTR performance across the year. Further, based on their cross-case comparison, the authors concluded that students' development of more strategic approaches to learning was enhanced most when educators focused on more active LTR processes (e.g., drawing inferences), and when they (a) sustained attention to process goals over time, for example across a series of lessons; (b) integrated goals related to fostering SRL into curricula, for example by supporting students to take up more effective strategies in the context of curriculum-based LTR activities; (c) invested explicit attention in reading, thinking, and learning processes, for example by taking the time to talk with students about learning goals, strategies, progress, and next steps; and (d) bridged from guiding learning to deliberately promoting student independence, for example by co-constructing criteria and strategies with students.

The Özdemir and Pape (2012) and Butler et al. (2013) research reports combine to illustrate how case study designs are particularly useful for tracing classroom practices as instantiated in naturalistic settings. The Butler et al. (2013) study also demonstrated how case study designs can support linking practices to the qualities of student engagement and associated outcomes for teachers and learners.

Challenge Two: Studying Individual and Social Processes at Work in SRL

The situated model in [Figure 23.1](#) suggests many ways in which SRL is inherently social (Butler et al., 2017). For example, as described earlier (p. 356), classroom environments are shaped by intersecting layers of contexts that combine to support or constrain students' engagement in SRL. Further, many individuals (e.g., teachers, educational assistants, students) co-operate, individually and collectively, to create the culture of a classroom (Mottier Lopez, 2007, 2016). And there are many occasions when students are purposefully positioned to learn

with and from each other. Thus, to advance theory and practice, contemporary researchers need to study how SRL is shaped dynamically through rich combinations of individual and social processes within and across environments and activities (Hadwin & Oshige, 2011; Järvenoja et al., 2015).

Case study research is particularly useful here because of the potential created to identify how complex processes interweave dynamically in context. For example, although they do not characterize their research as a case study, Järvenoja and her colleagues have been using methodological tools and frameworks well aligned with case study research (e.g., Järvenoja & Järvelä, 2009; Järvenoja et al., 2015; Järvenoja, Järvelä, & Veermans, 2008). In this work, these researchers have carefully documented the dynamics of socially shared learning from motivational, emotional, and learning perspectives, particularly in the context of different kinds of collaborative learning tasks. Their work is highly informative in its uncovering of the interplay between individual and social processes in forms of co-regulation and socially shared regulation. Similarly, Grau and Whitebread's (2012) case study identified social aspects of SRL during collaborative learning, in this case for eight children working in two groups. Anderson, Thomas, and Nashon (2008) similarly examined individual and collective task actions in the context of collaborative learning in 11th-grade biology. Taken together, a growing body of qualitative case study research is helping to advance understanding about how individual and social processes intersect in students' engagement in more or less effective forms of SRL.

Challenge Three: Studying SRL as Dynamic and Iterative

Effective forms of SRL require learners to engage intentionally in goal-directed cycles of strategic action (Zimmerman, 2008). In [Figure 23.1](#), we provide an oversimplified heuristic representation of strategic action processes that need to be taken up flexibly and adaptively by self-regulating learners. These include interpreting expectations, setting personal goals, planning (time, resources, strategies), enacting selected strategies, and self-monitoring (or more formally, self-assessing) progress towards goals. Thus, to advance theory and practice, contemporary SRL researchers need to investigate how and why learners' engagement in cycles of strategic action unfold dynamically and iteratively, while working alone or with others.

Case study designs can be particularly useful for literally watching cycles of SRL unfold in relation to contextual factors and pedagogical practices enacted in real time in naturalistic settings. For example, in a series of over 100 longitudinal case studies, Butler (1995, 1998) collected data using a rich combination of questionnaires, think-alouds, observations, and work samples to trace the relationship between what post-secondary students with learning disabilities were bringing to contexts (e.g., conceptions about academic work, self-efficacy, attributions), SRL-supportive practices (e.g., the "Strategic Content Learning" approach to fostering SRL), students' engagement in cycles of strategic action, and outcomes (e.g., gains in learning, self-perceptions, meta-cognition, strategy development, transfer). Her use of a case study design enabled her to document how shifts in students' engagement in SRL could be directly related to a combination of personal, social, and pedagogical influences. Similarly, using a combination of questionnaires, rating scales, observations, and structured interviews, Cleary and Platten (2013) examined connections between students' engagement in SRL and their performance in biology. Their case study design enabled them to trace patterns among students' beliefs, participation in their Self-Regulation Empowerment Program (SREP), shifts in SRL processes, and performance (see also DiBenedetto & Zimmerman, 2013).

Challenge Four: Studying Multiple Components at Work in SRL

SRL researchers have long been concerned with the reciprocal relationships among motivation, emotions, and students' self-regulated approaches to learning (Boekaerts, 2011; Zimmerman, 2008, 2011). Thus, at the base of [Figure 23.1](#), we identify how emotions and motivation both shape and are shaped through individuals' engagement in strategic action cycles. For example, researchers have identified how students' motivationally charged beliefs, such as self-efficacy, undergird learners' effort, persistence, strategy use, and achievement; at the same time, positive self-beliefs and motivation develop and are sustained when learners associate success with

their effective engagement in cycles of SRL (e.g., Bandura, 2006; Zimmerman, 2011). Further, as described earlier (p. 356), students' appraisal of a situation as safe or threatening intertwines with their experiences of emotions and motivation to influence engagement (Boekaerts, 2011). It follows that, to advance research and practice related to SRL, contemporary researchers need to study SRL as a multi-componential process.

Case studies are particularly useful here again because they allow for gathering and coordinating multiple forms of evidence to trace the dynamic connections among multiple components of SRL. For example, in their in-depth qualitative work, Järvelä and Järvenoja (2011) studied how in the context of collaborative learning students socially constructed their regulation of both motivation and learning. Cleary and Platten's (2013) study of the SREP as applied in biology, mentioned earlier (p. 362), underlined the importance of taking up a multi-dimensional assessment approach to take into account multiple components of SRL simultaneously. Similarly, in their cross-case analysis of 31 classrooms, Butler, Cartier, Schnellert, Gagnon, and Giammarino (2011) identified four multi-dimensional SRL profiles that could describe the form of engagement by the 646 students in those classrooms, each of which encompassed cognitive, metacognitive, emotional, and motivational dimensions.

Mobilizing Knowledge in Policy and Practice

Research has shown that students benefit when educators take up SRL-promoting pedagogical practices (see Perry, 2013). However, research has also identified how difficult it is for educators to mobilize the best of what is known about SRL to inform policy and practice in authentic, naturalistic educational settings (e.g., Butler & Schnellert, 2012; Cartier et al., 2010). Taking up a final challenge for the SRL research community, in this section we consider the potential of case study designs to enable investigating (a) how educators can be supported to situate SRL-promoting practices in the contexts in which they are working; and (b) conditions necessary to foster systemic change in policy and practice related to SRL.

Situating SRL-Promoting Practices in Context

Case study research can be particularly useful in studying how educators can be supported to mobilize pedagogical principles in ways that are authentic and meaningful within their particular contexts, given the unique histories of their students, the layers of context in which their classrooms are situated, and the dynamic interactions unfolding among learners in their classes. For example, the case study by Özdemir and Pape (2012), described earlier (p. 360), took up this question by studying the ways in which a 6th-grade teacher engaged in two years of professional learning was able to take up SRL-promoting practices in her context. Similarly, Whitcomb (2004) explored how curriculum-planning strategies employed by teachers helped them in taking up the "Fostering a Community of Learners" pedagogical model.

In a series of case studies, Butler, Cartier, and Schnellert have been studying professional development processes in relation to educators' development of SRL-promoting practices in classrooms, districts, and school systems across both British Columbia and Quebec (e.g., Butler, Novak Lauscher, Jarvis-Selinger, & Beckingham, 2004; Butler & Schnellert, 2012; Butler et al., 2013; Cartier et al., 2010; Schnellert, Butler, & Higginson, 2008). For example, using a case study design, Schnellert et al. (2008) studied how teachers working in a community of practice co-regulated their learning and practice with the shared goal of promoting SRL by students. Cartier et al. (2010) investigated how a team of elementary school teachers working in a disadvantaged area worked to integrate SRL-promoting practices into their subject-area classrooms in light of their 123 5th- and 6th-grade students' needs. Cartier et al. identified both strengths and limitations in the practices teachers were enacting, for example in establishing practices that bridged from guiding learning to fostering independence. As a result, their study suggested where particular attention is needed in supports for educators in their building of SRL-promoting practices into their classrooms (see also Martel et al., 2014).

Earlier we argued that students' engagement in SRL is influenced by much more than just the local contexts in which they are working. In this section, we suggest that the same holds true when considering the experience, professional learning, and practice development by educators. Just as case studies are useful for studying students' SRL in the context of classroom-based learning, they are equally useful for understanding the multiple, often systemic, influences on teachers' engagement in professional learning and practice.

For example, in her research with colleagues, Cartier studied how teachers, pedagogical consultants, school and school board administrators, and researchers were working together in a community of practice with the shared goal of promoting students' self-regulated engagement in LTR activities (Cartier, 2016; Cartier, Arseneault, Mourad, Raoui, & Guertin-Baril, 2015; Cartier, Arseneault, Guertin-Baril, & Raoui, 2016). Although not characterized as a case study design, in their in-depth qualitative study, Stein and Coburn (2008) examined the usefulness of a communities of practice framework for studying how districts create organizational environments that foster teachers' opportunities to engage in professional learning around systems-level reforms. Similarly, in their multi-level case study, Butler et al. (2015) examined the self-perceptions of efficacy and agency at play in a district-level change initiative that supported teachers' engagement in professional learning.

Conclusions and Future Directions

Many theoretical perspectives have been applied to the study of SRL (e.g., Zimmerman & Schunk, 2001); these varying perspectives have inspired a plethora of empirical studies. Three decades on, evidence from multiple points of view is converging around some important conclusions. It is now abundantly clear that processes associated with self-regulation are essential to learners' success in all sorts of activities, both within and outside of schools (Zimmerman, 2008). There is also substantial evidence that certain kinds of principles and practices are helpful in fostering effective forms of SRL (e.g., Perry, 2013). Still, challenges remain for researchers interested in advancing theory and practice related to SRL. In this chapter, we have been describing the potential of case study methodologies to help researchers in addressing them.

Directions for Future Research

Throughout this chapter we have identified many important challenges that might be productively taken up by contemporary researchers in their study of SRL. Building from our situated model of SRL, we have suggested that contemporary researchers need frameworks for studying SRL as (a) constituted through individual-context interactions, with attention to the histories of learners in relation to intersecting and layered contextual influences; (b) fostered by pedagogical practices, with attention to how pedagogical principles can be situated meaningfully and authentically within local contexts to advance practice and learning; (c) inherently social, with attention to how SRL emerges through interactions between individual and social processes as constituted within a given environment and activity; (d) dynamic and iterative, with attention to how SRL unfolds over time, intentionally, flexibly, and adaptively, in light of the affordances and limitations in particular settings; and (e) a multi-componential process that depends on complex, dynamic interactions among motivation, emotion, behavior, and learning. In this chapter, we described and illustrated how case study methodologies have been used by researchers to take up these kinds of challenges in ways that are advancing understanding and practice related to SRL.

In our concluding remarks, we would be remiss if we did not also identify some of the challenges and limitations in the use of case study designs (see also Butler, 2011). For example, in this chapter we have identified the particular usefulness of case studies in taking up how and why questions. We have also identified the potential of case studies for investigating bounded systems in all their complexity. The flip side of these advantages is that case study research is often messy, time consuming, and complicated. Further, while case studies are productive because they allow for tracing complex relationships among many variables at the same time as they unfold over

time in naturalistic contexts, a corresponding challenge is that, unless care is invested in delimiting the focus of the study, it is very easy to become overwhelmed by data collection and/or interpretative processes. In addition, while case studies afford literally witnessing connections among factors (e.g., students' responses to particular pedagogical practices) when studying complex systems with multiple interacting and bidirectional processes, they are not typically designed to isolate causal influences. Finally, while case study designs are strong in supporting naturalistic or analytic forms of generalization (i.e., to another similar case or to a theory, respectively), they are not well aligned with a sampling logic that supports generalizing to a population (Yin, 2003).

In spite of these limitations, we close by urging SRL researchers to consider the potential of case study designs in taking up important challenges facing the field at this moment in time. In order to effectively link knowledge about SRL to policy and practice, researchers need to examine SRL processes in authentic, meaningful ways, as embedded in classrooms and schools. Case study methodologies are among an emerging set of methodological designs that have great promise for forging closer connections between research and practice for the benefit of teachers and learners in today's schools.

Implications for Practice

In this chapter we have described how case study designs are being used productively by researchers to investigate (a) the qualities of pedagogical principles with potential to advance SRL; (b) frameworks for supporting educators' professional learning and practice development; and (c) contextual supports and barriers to the systemic shifts in pedagogical principles. In these important respects, case study research is being used to advance understanding, not only about SRL-promoting practices, but also about how educators can be supported to meaningfully mobilize research findings in practice settings.

In addition, a unique opportunity afforded by case study designs is to support educators in imagining or visioning SRL, and supportive practices, in all their complexity. As Yin (2003) explains, a case study report "can itself be a significant communication device" (p. 144). For example, in contrast to research reports that provide more isolated and abstracted descriptions of learning processes as teased out through research, we have found that educators resonate with multi-dimensional case descriptions, grounded in research, that portray learning and teaching processes in all their complexity as situated in settings. In this respect, case studies are useful, not only in generating evidence that can be systematically and rigorously analyzed to advance understanding, but also in supporting communication of research findings in ways that preserve the complexity of learning processes as anchored in context(s).

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24 Examining the Cyclical, Loosely Sequenced, and Contingent Features of Self-Regulated Learning

Trace Data and Their Analysis

Matthew L. Bernacki

When learning takes place in technology-enhanced environments, interactions between a learner and the environment are often recorded in a log. These logs contain a transcript of trace data, so called because they can be used to “trace” a learner’s actions during a task. In this chapter, I describe the ways trace data can be used to observe learning processes, and how traced learning processes can be analyzed to test assumptions that underlie process models of self-regulated learning (SRL). To this end, I first summarize the assumptions that underlie process models of SRL (e.g., Pintrich, 2000; Usher & Schunk, 2018/this volume; Winne, 2018/this volume; Winne & Hadwin, 1998; Zimmerman, 2000) and demonstrate how trace data are particularly useful for examining such assumptions. I then describe the data and metadata that are logged when learners engage with common learning technologies and explore how methodological choices and technological features impact the validity of traces and the ways they may be used to test and refine assumptions of SRL theories.

Relevant Theoretical Ideas

SRL frameworks typically embrace the assumptions that a learner possesses a particular aptitude to self-regulate their learning, and that SRL can be observed as a series of events (Winne & Perry, 2000). In this chapter, focus is placed on tracing learning events and discussion thus emphasizes assumptions of conceptual models that depict SRL as a cyclical, sequenced, and contingent set of interrelated processes (e.g., Pintrich, 2000; Winne & Hadwin, 1998, 2008; Zimmerman, 2000, 2008, 2011).

Primary Theoretical Assumptions

Whereas each theoretical model of SRL uses a distinct set of terms to describe the learning process, they also maintain a number of assumptions about learning that are consistent across models. Particularly amenable to observation using trace methods, these assumptions include (1) the learning process is composed of discrete, observable events of a (2) cognitive, metacognitive, motivational, and affective nature, which (3) occur in a (loosely) sequenced and temporal order. In each SRL model, the learning process is organized into phases, and the assumption is made that (4) learners repeatedly progress through these phases in a cyclical and iterative fashion until task engagement concludes and, ideally, the learning goal is achieved. In addition to these common assumptions, each theoretical model proposes a distinct conceptualization of complex relations involving learning processes. These include contextual factors (Ben-Eliyahu & Bernacki, 2015) like contingencies where the implications of an event are contingent on prior conditions (e.g., a prior event, task feature present, or learner characteristic; Winne, 2011) and instances when differences in temporal positioning of events render different learning outcomes (Molenaar & Järvelä, 2014).

Zimmerman’s (2000) Social Cognitive Model of Self-Regulation is an example of a well-known and representative theoretical model and is composed of three main phases: forethought, performance, and self-reflection phases. Each phase further includes subprocesses that span the cognitive, affective, metacognitive, and motivational channels (e.g., task strategies, metacognitive monitoring, goal orientation, self-satisfaction) described by Azevedo and colleagues (Azevedo, Harley, Trevors, Duffy, Feyzi-Behnagh, Bouchet, & Landis, 2013). When SRL involves multiple cycles, the specific events that occur in a phase, such as forethought, may vary across cycles. For instance, a student who set a goal in a first cycle may refine it in the next. A student may also shift the strategies employed over cycles or revise outcome expectations. The diversity of proposed SRL processes in each phase and the variability with which they are proposed to occur across iterations underscore the complexity of the larger phenomenon (i.e., SRL) to be traced. To capture cognitive, metacognitive, motivational,

and affective processes in sufficient context to model assumptions requires that three defining features of SRL be considered when tracing its events: time, granularity, and context.

Time

SRL events are inherently temporal (Azevedo, 2005, Winne & Hadwin, 1998, 2008; Zimmerman, 2000, 2011). Events are thus to be understood in context of or combination with those that precede and follow them, meaning they must be captured in a continuous fashion. Log files that trace learning events are ideally equipped to capture temporally bound and embedded events, and SRL theory can then be used to label and organize them into individual occurrences, combinations, sequences, or patterns that reflect theoretically grounded processes to be investigated. This treatment of the raw log of learning events thus requires interpretation, and data often requiring restructuring, all under the supervision of a chosen SRL theory. For example, if the SRL process is to be observed at a general level as described in the Social Cognitive Theory posed by Zimmerman, attention should be paid to tracing forethought processes that precede performance processes that precede self-evaluative processes. This can be challenging to operationalize depending upon the kind of events that are logged, inferences about what they represent, and the need to make choices about aggregating across multiple traces (e.g., combining multiple forethought sub-processes) to represent a larger category (e.g., forethought). These decisions are influenced by the granularity with which learning technologies trace events.

Granularity

Depending on the learning environment in which SRL is being studied, SRL events can be observed at different grain sizes. In order to represent SRL appropriately, it is important to consider the time scale on which it occurs, and what individual events or combinations of events reflect an SRL process. Processes like help-seeking can be observed as they occur over the course of seconds or minutes in a log of attempts at solving a math problem (i.e., on the cognitive band; Ben-Ellyahu & Bernacki, 2015). Other SRL processes such as monitoring one's preparedness for an upcoming exam can be observed over a lengthier time scale and as comprised of numerous events that occur over an extended period of hours, days, or even weeks (i.e., the use of a study guide, periodic self-assessment of progress towards learning goals, and subsequent practice collectively demonstrate monitoring as it occurs on the social band). Single traced events are thus well-equipped to represent some SRL processes (e.g., a single act of rehearsal; Zimmerman, 2000, 2011), while extended logs of trace data can be restructured to represent times when multiple individual events can be observed over a longer period as a trace of a process like monitoring. Depending on the features of one's learning environment and conceptualization of SRL, it is possible to observe SRL processes entirely on a single band, or to restructure trace data into representative events that span multiple time bands (i.e., conceptualizing monitoring as individual events like self-assessment quizzes vs. a pattern of self-assessment and restudy). So long as log data provide a sufficiently fine-grained record of events, an SRL process can be represented and analyzed.

Contingencies Among Traces and Contextuality

The final feature of self-regulated learning events that poses a measurement challenge is their contextual nature (Ben-Ellyahu & Bernacki, 2015; Winne, 2011). Many conceptual models include a contextual assumption wherein an action can only be understood in the context of environmental factors, the learner who enacts it, or prior events. Winne (2011) described these contingencies using the logic of IF-THEN conditional statements, wherein a specific SRL event (i.e., the "THEN") is warranted only in the presence of a prior event or context (i.e., in the presence of the "IF"). This contingent interpretation of SRL processes can be informed by sequential logging of events. Next, I appraise the utility of trace data for testing hypotheses by considering the elements of an SRL event that are traced by learning technologies, the ways these data can be used to represent SRL processes, and the methods that must be adopted to test assumptions of SRL models.

Research Evidence

Trace Data in Self-Regulated Learning Research

The value of trace data for testing theoretical assumptions rests upon the ability of the technology to validly, comprehensively, and contextually represent learning events. To produce a trace, the technology must be designed in a way that it captures evidence of a learner's cognitive, affective, metacognitive, or motivational activity. These actions include instances when the learner initiates an interaction with a feature of the software through the use of hardware. Inputs of values into fields, selections of dropdown menus, clicks on buttons, or navigational moves can all be traced by logging each tap, click, touch, swipe, or keystroke made on a device. Once these interactions with the technology are logged, they are observable and can be enriched by adding important metadata that describe the SRL event. These metadata can include immediate details about the event itself: labels (e.g., chapter, unit, and name of a problem attempted), precise action (e.g., click of the "example" button), a timestamp, and the values entered by the learner provide important information about the context and content of the event. These metadata are often pulled from tables linked in a relational database and might include information about the location of the item within a curriculum (e.g., unit, section, and problem names), the correctness of an entry if it is scorable, or additional labels that categorize the event (e.g., application of the value "monitoring" to each event where a learner accesses a tool designed for self-assessment).

These design features determine whether a log of trace data is a sufficient source to test a hypothesis that derives from SRL theory. This can be best understood by examining a learning environment, its alignment to SRL theory, and the trace data that are recorded as students use it to learn. For instance, intelligent tutoring systems (ITSs) like Cognitive Tutors are equipped to support mastery of precisely understood skills through problem solving practice (Koedinger & Corbett, 2006). Because these ITSs support students as they learn well-defined concepts like mathematics concepts and language rules, the task is a constrained one where students' actions that can be traced include some task-specific cognitive strategies, and the decision to seek help. This ITS environment is ideal for examining assumptions about help-seeking. For instance, researchers have used trace data to observe instances where students request hints in lieu of attempting problems that the students appear capable of answering (Alevén, McLaren, Roll, & Koedinger, 2006). A more extensive review of SRL in ITS contexts can be found in [Chapter 17](#) (Azevedo, Taub, & Mudrick, 2018/this volume).

In contrast, other learning environments are designed to support students as they pursue much broader sets of learning objectives. For example, considerable research has examined how students pursue science learning using hypermedia environments (e.g., Azevedo, 2005). These laboratory studies often pose an open-ended learning objective like "learn as much as you can in the time allotted," and capture evidence of students' study activities using think-aloud protocols as learners interact with materials hosted in a computer-based learning environment. Through use of trace data to capture events that correspond to students' utterances in a think-aloud, similar research can be conducted in authentic learning contexts such as undergraduate courses where students use content hosted on a learning management system (LMS) to facilitate their learning.

Example: Tracing Self-Regulated Learning Events in Learning Management Systems

In authentic learning contexts like undergraduate life science courses, students pursue multiple instructor-provided objectives that include declarative knowledge about biology topics (e.g., state definitions, identify structures and functions of anatomical features of the circulatory system), as well as conceptual and procedural knowledge (e.g., describe the process of oxygenation). The learning task posed by the course includes attending lecture sessions, reading a textbook, and completing assignments, as well as a considerable portion of learning activities that are facilitated by resources the instructor posts on the LMS course site.

As students pursue one or more instructor-set learning objectives for a unit of a course over the days and weeks before an exam, they learn on- and off-line as they attend lectures, study with printed materials, and access materials on the LMS. Whereas the LMS can only log a subset of events within the larger task that can be labeled

“undergraduate science learning,” the logs the LMS produces can provide valuable insight about the ways that students utilize learning resources, and how this influences their outcomes. To understand and represent learning events in this ecologically valid environment, a careful approach to modeling SRL processes must be undertaken. First, the design of the LMS environment, the kinds of resources the instructor provides, and assumptions about how learners use content and LMS features must be considered. In an LMS that supports learning multiple objectives, students must be provided with appropriate resources that support commonly observed learning strategies like reading, viewing diagrams, and self-quizzing, as well as tools that help them plan their study and monitor their learning (Greene & Azevedo, 2007, 2009). In an example college anatomy course, such resources may be organized by function and include lecture notes, supporting diagrams, and other primary documents that contain the knowledge to be acquired (i.e., items supporting strategy use). Other resources contained in the LMS that can support planning might include a syllabus, schedule, and course calendar tool, as well as interactive tools that learners can use to monitor their progress on learning objectives, or their mastery of content using online quizzes.

SRL models generally assume that use of such resources affords superior learning outcomes, but the frequency, order, or combinations of SRL processes that best promote learning are not well articulated. For instance, the Social Cognitive Model (Zimmerman, 2000, 2011) poses very generally that SRL occurs in a cyclical fashion where forethought activities like planning occur before performance activities like studying, and that self-reflection activities like self-assessment of one’s knowledge follow the performance phase ([Table 24.1](#)). This assumption could be tested by examining the frequency with which students access planning, study, and self-assessment resources during a given period, and whether this temporal use of course resources yields superior outcomes to some other sequence or combination of activities. [Table 24.2](#) provides

[Table 24.1](#) Assumptions of the Social Cognitive Model from Zimmerman (2000) with samples of potential tracing and analytical approaches

Assumption	Traced events representing processes	Potential analytical approach to test assumption
“... self-regulatory processes and accompanying beliefs fall into three cyclical phases: forethought, performance or volitional control, and self-reflection processes” (p. 17).	Forethought: Access study guide performance: (re)visit content to be tested. Self-reflection: Access of test solution.	<i>Sequence mining or association mining:</i> Analysis to observe prevalence of co-occurrence across a unit of study.
“Self-regulation is ... cyclical because feedback from prior performance is used to make adjustments during current effort. Adjustments are necessary because ... factors are constantly changing during the course of learning and performance, and must be observed or monitored using three self-oriented feedback loops” (p. 14).	Monitoring based on performance feedback: Click to open itemized feedback from self-assessment quiz (with pointer to lecture topic). Adjustment (future cycle): Subsequent accesses of course content.	<i>Contingency analysis or state transition analysis:</i> Test whether students are more likely to next revisit resources pertaining to topics of items missed on a self-assessment quiz rather than other resources.

[Table 24.2](#) Sample tabular data extracted from an LMS server log

Event	User	Session ID	Time	Day	Course ID	Content_ID	Content name	Resource type
11359	82909	J248E170F5	2014-09-23_17:07:31	30	_784166_1	_1706_1	Exam 1 study guide	Planning/monitoring study
11360	82909	J248E170F5	2014-09-23_17:21:19	30	_784166_1	_1726_1	Ch1 notes	Lecture notes/content
11361	82909	J248E170F5	2014-09-23_17:21:23	30	_784166_1	_1733_1	Ch2 notes	Lecture notes/content
11362	82909	J248E170F5	2014-09-23_17:21:27	30	_784166_1	_1744_1	Ch3 notes	Lecture notes/content
11365	82909	J248E170F5	2014-09-23_18:39:36	30	_784166_1	_1727_1	Ch1 self-assessment quiz	Monitoring learning
11366	82909	J248E170F5	2014-09-23_18:49:17	30	_784166_1	1727_2	Ch1 self-assessment quiz—results	Monitoring learning
11367	82909	J248E170F5	2014-09-23_18:53:20	30	_784166_1	_1727_1	Ch1 self-assessment quiz	Monitoring learning
11368	82909	J248E170F5	2014-09-23_19:22:10	30	_784166_1	1727_2	Ch1 self-assessment quiz—results	Monitoring learning
11369	82909	J248E170F5	2014-09-23_19:23:01	30	_784166_1	1729_1	Ch1 learning objectives self-check	Monitoring progress
...	...	...	...	...	...	...	...	...
00043	83166	K320F903G7	2014-08-25_16:28:55	1	_784166_1	_1701_1	Syllabus	Policy document
00044	83166	K320F903G7	2014-08-25_16:29:01	1	_784166_1	1702_1	Course schedule	Policy document
00046	83166	K320F903G7	2014-08-25_16:30:17	1	_784166_1	_1706_1	Exam 1 study guide	Planning/monitoring study
00052	83166	K320F903G7	2014-08-25_16:33:55	1	_784166_1	_1726_1	Ch1 notes	Lecture notes/content
00054	83166	K320F903G7	2014-08-25_16:34:15	1	_784166_1	_1733_1	Ch2 notes	Lecture notes/content
00055	83166	K320F903G7	2014-08-25_16:34:22	1	_784166_1	_1744_1	Ch3 notes	Lecture notes/content
01094	83166	V477P370I1	2014-08-31_22:31:44	7	_784166_1	_1727_1	Ch1 self-assessment quiz	Monitoring learning
01097	83166	V477P370I1	2014-08-31_22:43:42	7	_784166_1	1727_2	Ch1 self-assessment quiz—results	Monitoring learning
01098	83166	V477P370I1	2014-08-31_22:12:31	7	_784166_1	1744_1	Ch1 table 1.2 directional terms	Lecture notes/content
08911	83166	A117F265W9	2014-09-14_22:05:51	21	_784166_1	_1727_1	Ch1 self-assessment quiz	Monitoring learning
08949	83166	A117F265W9	2014-09-14_22:19:52	21	_784166_1	1727_2	Ch1 self-assessment quiz—results	Monitoring learning
08954	83166	A117F265W9	2014-09-14_22:21:41	21	_784166_1	_1738_1	Ch2 self-assessment quiz	Monitoring learning
08961	83166	A117F265W9	2014-09-14_22:39:58	21	_784166_1	1738_2	Ch2 self-assessment quiz—results	Monitoring learning
08988	83166	A117F265W9	2014-09-14_22:42:25	21	_784166_1	_1756_1	Ch3 self-assessment quiz	Monitoring learning
08990	83166	A117F265W9	2014-09-14_22:59:52	21	_784166_1	_1756_2	Ch3 self-assessment quiz—results	Monitoring learning

a sample log of learning events that can occur within the LMS environment, and the extent to which they can be used to represent a forethought to performance to self-evaluation sequence. The specific content item that students accessed is listed under “Content name” and the variety of learning process that content is theorized to enable is

captured in the processes listed under “Resource type.” This specific table displays LMS-recorded events by a pair of students to illustrate relevant learning events that occurred within and across log-in sessions. Using these trace data, two different fore-thought to performance to self-evaluation sequences can be observed which occur over different time spans and can be used to represent the learning process that is hypothesized to occur within the Social Cognitive Model.

The first set of traced events occurs on the 30th day of the semester, immediately prior to the exam. During a single session (i.e., Session ID = J248E170F5), user 82909 downloaded a study guide and, after a 14-minute delay, all the lecture notes for the first unit of the course. After a delay of 78 minutes, the learner proceeded to complete a self-assessment quiz on [Chapter 1](#) content in about 10 minutes. The student spent 4 minutes reviewing the results of the self-assessment, repeated this testing + review process, then visited a tool designed to enable students to view learning objectives and rate mastery of each.

It can be inferred from the timing of this example that this session reflects a student’s studying on the day immediately preceding the first of five unit exams. Tight cycles of study can often be observed in this period of the semester, making it an ideal time to use learning logs to examine patterns of learning behaviors and their influence on exam performance. It can be hypothesized that students who demonstrate a seemingly thoughtful combination of forethought (i.e., access of a study guide to plan a session), performance (i.e., downloading notes, and perhaps practice-quiz completion), and self-evaluation (i.e., viewing of quiz results) might outperform students whose behavior does not correspond to the SRL cycle (e.g., evidence of download of learning materials, but no planning or self-evaluation). To test this hypothesis, one would simply need to download the log file, sort it by learner and timestamp, and then code the learner’s behavior pattern based on the presence vs. absence of a forethought to performance to self-evaluation sequence that these traced events are believed to reflect. Students can be grouped by their adherence to the sequenced SRL phases and compared, or a score can be applied to capture SRL-like metrics (e.g., number of each event type; number of sessions containing all three event types in sequential order) and these continuous metrics can be analyzed as predictors of achievement (Bernacki, Vosicka, & Utz, 2016). Thus, a short time period can be observed to examine the impact of SRL cycles immediately prior to an exam (i.e., “self-regulated cramming”), and a brief log of traced learning events provides evidence of this phenomenon.

What if instead the goal was to examine SRL behaviors on the social band (Ben-Eliyahu & Bernacki, 2015) with an aim to identify students who demonstrate a SRL cycle as it occurs over the many weeks of a unit? Trace data logged by the LMS can afford this level of analysis as well by adopting the same sort logic (i.e., select all events by a learner and sequence by time) and examining learning events across many sessions. By taking this approach to measuring the learning behaviors of user 83166, a similar pattern of events can be observed that reflect forethought then performance then self-evaluation phases. This student accessed the course syllabus and schedule as well as the first unit’s exam study guide on the very first day of the course ([Table 24.2](#), first row after ellipses). This student also accessed the notes for all three chapters in the unit. At weekly intervals (i.e., on Day 7, then on Days 14 and 21 thereafter), the student initiated a series of events that provide evidence of a learning strategy: spaced practice using self-testing (Karpicke & Roediger, 2007), or that can be classified as an ongoing metacognitive monitoring and control tactic (Winne & Hadwin, 1998) wherein the learner continually rehearses and gauges mastery of past content (i.e., [Chapter 1](#) on Day 14, [Chapter 2](#) on Day 21), while also developing and assessing mastery of new content ([Chapter 2](#) on Day 14, [Chapter 3](#) on Day 21). This data representation can be used to compare students who are adept at SRL from the outset of the semester (i.e., User 83166), to those who only demonstrate SRL behaviors during the cramming period (i.e. User 82909), to those whose study patterns appear to be erratic, or lacking key SRL processes like planning, monitoring, or evaluation.

Inherent Challenges to Tracing Learning Using Log Data

The log of events that accrue as learners use a technology provide tremendous potential for capturing critical learning processes. However, researchers who study learning using traced events must consider their data with

some skepticism. Does an event in the log actually represent a learning event, or some action induced by the design of the environment? Does each instance of that traced event consistently represent the same phenomenon, or are many different kinds of activities subsumed under a single trace? Does an event traced in this environment represent a sufficiently robust phenomenon that inferences can be made about the implications of the event as they would affect learning in another learning context? That is, any researcher who wishes to trace and understand learning must establish (1) the validity of inferences made about the learning events that are traced and (2) how well a learning process observed via trace data in a single technology represents a learning process that generalizes to other tasks and contexts.

The Validity of Traced Events

Researchers' ability to investigate SRL processes has long been limited by the methods available to represent them. For instance, self-report methods are particularly good at characterizing students' intentions for using cognitive and metacognitive strategies (e.g., Motivated Strategies for Learning Questionnaire; Pintrich, Smith, García, & McKeachie, 1993). However, self-reports have also been shown to provide an inaccurate report of the frequency and type of behaviors students conduct when questionnaire items prompt descriptions of typical use or aggregate estimates (Winne & Jamieson-Noel, 2003). Further, the aggregated nature of retrospective self-report measures flattens these data, rendering them incapable of describing students' actions or intentions on an event-by-event basis. Self-report data are thus less capable of validly testing research questions with temporal, sequential, or contextual features (Wolters & Won, 2018/this volume).

The paradox posed by self-report measures (i.e., information about learners' intentions without sufficient accuracy or granularity to represent the sequential, contextual, cyclical process of SRL) is inverted with trace data. A log can accurately trace individual events in sequence, but fails to provide any indication of why a learner chose to act in the ways observed. Researchers who employ trace data to represent learning processes do so at a time scale where it is generally unreasonable to ask a learner to describe the intentions associated with each learning event. Validation is thus necessary before inferences about learning can be drawn. Depending upon the duration of the task and its occurrence in lab or field settings, different strategies can be employed to increase the likelihood that traced events truly represent a particular learning process. These include a-priori design choices to label learner intentions within the traced data, concurrent verbal self-reporting on students' learning, and retrospective confirmation of the phenomenon that a traced event may reflect.

A-Priori Design Choices

When studying SRL in a sufficiently malleable learning technology, researchers can design learning tools that serve as both a resource to the student and as a source of information to researchers about students' intentions. For example, Zhou and Winne (2012) investigated how different achievement goals that individuals adopt influence their studying when using a web browser. Learners who studied using nStudy (Hadwin, Nesbit, Jamieson-Noel, Code, & Winne, 2007) navigated pages of content and used tools to highlight text, make notes, and label and categorize their annotations for future use. A standard version of nStudy allowed students to color code their highlights and freely label notes, thus capturing authentic annotation behaviors. Students' notebooks are often littered with highlights and scribbles in margins that are only decipherable by the author. In order to capture students' rationale for making annotations, Zhou and Winne adapted nStudy's annotation features by constraining the label feature to include only labels that represented students' intentions for making a highlight or a note. Limiting annotation options to tags indicating "this is important" or "know this for the test" makes transparent students' achievement goals: a desire to learn or a desire to perform well on an assessment, respectively. To the extent that such explicit labeling of intentions can be added to a learning tool and still allow learning to occur in an authentic fashion, learners' intentions can be described with some precision, and questions about the implications of intentions on behavior and subsequent achievement can be analyzed. However, the strategies a student can employ when learning are diverse, and incorporating a labeling process into these actions can detract from the authenticity of many events (e.g., asking learners to state why they accessed specific content

or initiated a self-assessment). In this case, a more flexible approach needs to be adopted to ensure that inferences about actions are valid.

Concurrent Self-Reporting

When SRL is observed in a laboratory, researchers can collect multiple channels of information about the learning process in addition to traces. These channels of data can include video recordings of students' actions outside of the technology (e.g., notes and drawings on scrap paper), video capture of students' facial expressions to identify affect, eye tracking to capture fixations on and saccades across content on the screen, and think-aloud protocols that prompt an ongoing self-report of the thought processes that accompany logs of events. This intensely rich, multichannel depiction of the learning process provides tremendous opportunity to cross-validate logged events with other channels and a full description of this approach is provided in [Chapter 17](#) (Azevedo et al., 2018/this volume). Of particular import for validating inferences about logged events is the concurrent narrative generated by a think-aloud protocol. This method, which is also explained in even greater detail by Greene and colleagues (Greene, Deekens, Copeland, & Yu, 2018/this volume), provides a fine-grained description of students' thought processes as they navigate through a learning task, employ learning strategies, and generate traces of these learning events. Using a taxonomy that describes these learning events at the level of macro- and microprocesses (Greene & Azevedo, 2007, 2009), the think-aloud protocol provides an opportunity to identify instances when the student's utterances reflect cognitive (e.g., strategy use), meta-cognitive (e.g., planning, metacognitive monitoring), and motivational events (e.g., acknowledgement of interest), as well as other events related to managing features of the learning environment.

To the degree that the timestamps associated with these utterances can be aligned to the timestamps associated with individual traced events in a log file, the think-aloud data can provide a self-report of a student's thought processes as an event, or a sequence of events, is traced. If a student's thought processes and the events that co-occur are consistent in their alignment (e.g., each time a student revisits the learning goals for the task, the student utters "Let's see how well I've mastered this topic" or "Let's see whether I've covered this topic in enough detail"), confidence that this traced event reflects a metacognitive monitoring process increases. Think-aloud protocols provide the most precise and fine-grained stream of data for validating inferences about events traced by a learning technology, but they are untenable to implement when learning tasks are long in duration, extend over many sessions, or occur in the educational "wild." In these instances, the resources available to validate inferences are less precise, but equally critical for ensuring inferences about learning events are accurate.

Retrospective Descriptions

When observing learning in ecologically valid contexts, trace data provide an automatic, unobtrusive log of data (Greene & Azevedo, 2010). Such data are quite authentic in the events that they describe, but this description lacks students' input that confirms why they engaged in each action. This is the persistent challenge for understanding SRL at scale: data from a sufficient number of individuals are needed in order to observe specific behaviors, and so that the statistical power is available to analyze such behaviors within and across contexts. Further, when such data can be obtained, it must then be confirmed that the behavior being traced accurately reflects the specific learning process under study.

To continue the running example from the prior section, consider the science learning task that students undertake when they use resources hosted on the LMS for their large biology lecture course. When playing the role of an instructional designer during course site creation, the instructor selected resources that convey information about topics at an appropriate level of depth, and in a format that encourages students to use the most appropriate learning strategies to master course objectives. Labels describing topical content items and the assumptions about the ways a student should use the various formats of resources provided can be applied to the log of events. For example, when students access a "learning objectives self-assessment tool," they have the opportunity to view the learning objectives the instructor uses to guide instruction for a unit, and can self-assess their progress toward

mastering each. This tool can also be used for a number of other purposes including planning how to prepare for an exam, and monitoring progress during study. Single accesses of this type of tool can be traced, and inferences about learning processes with only this piece of data could be made with some confidence that the trace reflects a metacognitive learning event indicative of either planning or monitoring. By incorporating some temporal metadata about the event (i.e., whether it occurred at the beginning of a log-in session, prior to other events inferred to reflect strategy use, or on one of the earliest days of a new unit), this inference can be refined to a specific type of metacognitive event: planning. If it occurs mid-session or mid-unit, or if it is not the first time students have accessed the tool and rated their mastery, the inference may be adjusted to reflect a metacognitive monitoring event. These examples demonstrate coarse (i.e., metacognition) and slightly finer (i.e., monitoring or planning) inferences can be made from trace data about events as they reflect learning processes.

Inferences in this LMS example have relied only on unobtrusively logged events to this point with no additional information solicited from the learner. Thus, log-based traces can be analyzed across many learners as they occur authentically during a semester. Such interpretations are reasonable given contextual data and their alignment to instructional design and SRL theory; they possess a fair amount of face validity. However, if these inferences are accepted without further cross-validation with other channels of information, there is a risk that events could be mislabeled; a student may have used a tool for something other than was anticipated when labeling took place. To allay such concerns, researchers can collect information about a students' typical use of each resource. While this type of information is of limited use for analysis of individual learning events, a summary statement about the singular or multiple learning processes a tool supported is critical for determining the precision of inference that can be drawn from the tool's appearance in the log.

Depending on the researchers' intentions, different assessment methods might be useful to refine inferences. If attempting to discriminate whether a student used a tool for two potential SRL processes that draw from SRL theory, researchers can probe using a closed response question such as a multiple-choice item. Learners can check boxes to indicate whether they used a quiz to self-assess their knowledge (i.e., monitoring), as a tool to train their retrieval capabilities and enhance their knowledge (i.e., strategy use), or both, or neither. Based on these responses from many students, the precision of an inference can be validated and refined. If the vast majority of students indicate they used this only as an assessment tool, then that inference can be drawn for the sample. If the majority indicate both types of use, then a less fine-grained inference must be accepted. If additional information about learners can be used to consistently discriminate which ones use the tool for self-assessment only, and which use it for retrieval practice, this inference may be accepted, but not without a fair bit of effort and another degree of inference (i.e., that learners' intentions for actions can be classified by prior characteristics, motivations, or actions). In the final case where more than a handful of learners fail to check either box, a new round of validation must be undertaken. By going back to the logs, it is possible to see if students who indicated "none" truly did not use the tool, or whether they used it but did not find the potential classifications sufficient to describe their reason for doing so. At this point, an open-ended item would be more appropriate to capture other learning processes that are reflected when an unobtrusive log traced events involving this learning resource.

The Generalizability of Traced Learning Events

With some effort to iteratively examine unobtrusive traces of events and students' self-reports on the nature of these traced events, an appropriate level of inference can be drawn about an event or sequence enacted by a specific type of learner or in a specific context. At this point, the learning process can be analyzed and understood as it occurs within the context of the learning technology, task type, and domain. However, the degree to which this specific traced learning process is indicative of how an individual would learn in another context remains in question. To the extent that a single learning technology can trace learning in a variety of domains (e.g., an ITS interface that logs math learning and language learning events), inferences can be made about learning that span domains. To the extent that a single domain can be investigated across learning environments (e.g., a science learning task involving the circulatory system that occurs in hypermedia, a massive open online course, and an LMS), parallel traces of learning processes can be used to abstract an understanding of this learning process that spans environments. To achieve the former, a learning environment needs to be sufficiently flexible that it can

support learning in a number of different domains or tasks. To achieve the latter, a fair bit of research must be conducted before general statements can be made about how students self-regulate their learning across technologies. In the next section, I survey emerging research across additional technologies that trace learning. I examine the affordances of technologies and the degree to which they capture temporal, sequential, and contextual aspects of learning before discussing the potential analytical approaches that can be employed to investigate SRL processes.

Future Research Directions

With the greater use of learning technologies, availability of learning analytics toolkits, and interest in the use of “big data” to drive decision making and provide opportunities for adaptive learning (Siemens, 2012), more and more technologies are making available the data they already collect on how students learn. Early research on self-regulated learning was limited to a few pioneering technologies like ITSs that mostly examined help-seeking (e.g., Koedinger & Aleven, 2007) and studying platforms like g- and nStudy (e.g., Zhou & Winne, 2012). Now, studies published in the last few years outpace what can be summarized in this chapter. A representation of ongoing and emerging research appears in [Table 24.3](#). Its contents demonstrate the breadth of learning technologies that now provide logs of learning events, the diversity of learning tasks and content domains they address, and the emerging set of sophisticated analytical methods currently being employed to understand self-regulated learning.

Whereas the sheer volume of relevant research precludes discussion of even individual representative studies, themes emerge from the contents of the table’s columns. First, the number of learning technologies that trace events have broadened to include teachable agents, open-learning environments, online and e-learning courses, massive open online courses (MOOCs), educational games, and platforms for computer-supported collaborative learning ([Table 24.3](#), Column 2). Note that other chapters in this handbook thoughtfully consider SRL with ITSs and teachable agents (Azevedo et al., 2018/this volume), digital educational games (Nietfeld, 2018/this volume), and computer-supported collaborative learning environments (CSCs; Reimann & Bannert, 2018/this volume). Second, these technologies afford study of SRL processes in multiple academic domains: SRL processes can be studied as domain-general vs. domain-specific and can be examined as they unfold differently across tasks and domain types. Third, as technologies allow observation of a greater variety of tasks that learners undertake with a greater diversity of tools (Column 3), an increasing number of SRL processes, some classified within established theories and taxonomies (e.g., Greene & Azevedo, 2007, 2009) and some yet to be mapped, can be studied. This broad representation of SRL events (Column 4) allows researchers to ask increasingly sophisticated questions about the occurrence of SRL events, and to examine complex and dynamic relations

Table 24.3 Representative studies by learning technology, task, SRL processes traced, and analytical approach applied to study SRL phenomena

Study	Learning environment	Learning task	Events traced	Analysis	Focus of inquiry
1. Järvelä, Malmberg, & Koivuniemi (2016)	nStudy	Cognitive, motivational, and emotional bases of learning	Task definition, planning, monitoring, evaluating	Sequence mining	Socially shared regulation
2. Segedy, Kinnebrew, & Biswas (2015)	Teachable agents—Betty’s Brain	Environmental science	Information seeking, editing, evaluation	Coherence analysis	Identifying SRL behaviors to be scaffolded
3. Biswas, Kinnebrew, & Segedy (2014)	Teachable agents—Betty’s Brain	Environmental science, concept mapping	Cognitive strategies, metacognitive strategies	Data-driven exploratory	Effect of scaffolding on learning strategy use
4. Barba, Kennedy, & Ainley (2016)	Massive open online course	Macroeconomics	Motivation video views, quiz attempts	Non-parametric	Dynamic relations between motivation and participation on task completion
5. Siadat, Gašević, & Hatala, (2016)	LearnB	Business case studies	Task analysis, goal setting, making plans, task strategies, appropriate strategy change, evaluation, reflection	Transition-based graph analysis	Effect of social awareness training on self-regulated workplace learning
6. Morgan, Keshkar, Duan, Nash, & Graesser (2012)	Serious games (“Urban Science”)	Collaborative science learning	Dialogue moves (question, response, feedback), scaffolding, task strategies	State transition networks	Effect of mentoring on strategy use

between them as they occur in combination, sequence, or patterns. Fourth, use of fine-grained, sequential, and temporal representation of events requires sophisticated analytical approaches to handle questions that assume temporal structuring, require the modeling of sequences of events, or examine contingent relations where a learning event must be understood within context of one or more prior events or conditions (Columns 5, 6; for a review see Biswas, Baker, & Paquette 2018/this volume).

Emerging Research Opportunities

Recent special issues of journals like *Educational Psychologist* and *Metacognition and Learning* have explored the ways that computer-based learning environments can provide the trace data needed to study SRL processes (Greene & Azevedo, 2010), and with added focus on temporal and sequential (Molenaar & Järvelä, 2014) as well as contextual and dynamic processes (Ben-Eliyahu & Bernacki, 2015). Studies within these special issues, and many others like them, highlight the importance of emerging technologies and methodological approaches that can enhance our understanding of SRL processes and their implications.

Data-Driven Analysis of Learning Behaviors

The immense size of the logs produced by learning technologies makes identifying meaningful individual events a challenge. It is often an open question whether an event is important only in a certain context or whether it should be understood to represent a learning event in isolation or as part of a combination, sequence, or pattern. Data-driven analyses like those described by Biswas et al. (2018/this volume) in [Chapter 25](#) can identify events of import and facilitate their collection, and maintenance of important metadata, so they can be analyzed in context and at an appropriate grain size.

New Analytical Approaches

Whereas the immensity of logs poses a focal challenge, the complexity of SRL assumptions poses a measurement and analysis challenge. Even when the events to be measured are known, the theoretical assumptions sometimes outstrip the methodological toolkit of the classically trained educational researcher. Emerging analytical methods can be combined with log data to answer challenging research questions about SRL.

Latent variable approaches (e.g., growth and mixture modeling) can be used to represent differences in learners' trajectories after a specific learning event takes place. Dynamic relationships between learning processes as they occur across multiple cycles of SRL may require path models that estimate reciprocal cross lags between events. Multilevel models may be necessary to examine the predicted effects of a learning strategy across different task conditions (e.g., differential effect of requesting help prior to attempting to solve a problem step across problems that differ in type, complexity, and prerequisite knowledge). These complex questions often require that researchers who wish to study SRL appraise the value of emerging methodologies and obtain additional training beyond traditional offerings of most doctoral programs. Adopting methods from other fields can also help with the investigation of theoretical assumptions. For instance, contingent relationships can be tested using state transitions, graph models, and non-parametric methods ([Table 24.3](#)). Socially shared processes can be understood if a system-level approach to modeling is applied, and if methods like social network analysis that account for complex interactions are employed.

Opportunities for Experimental Studies

Causal assumptions in SRL can be difficult to study in authentic settings because of the length of learning tasks and the complexity with which they must be modeled. To the extent that a learning task can be observed within a technology environment, the combination of trace data and experimentation can be a powerful tool for examinations of causality. For example, Koedinger, Aleven, Roll, and Baker (2009) describe a series of in-vivo experiments (i.e., true experiments where subjects are randomly assigned to conditions within a software

environment used in an ecologically valid educational setting) to examine how scaffolding metacognitive processes affects learning. New research programs are emerging where this kind of in-vivo approach can be implemented within other common learning environments that also log data. Online education courses are perhaps the most common setting where this type of approach can be employed. The LMS where online learning occurs provides adaptive release options which enable designers to assign content to groups (i.e., enabling assignment to experimental vs. control conditions), or to release content at specific times during a task to manipulate the temporal ordering of events learners in a group enact.

Implications for Educational Practice

There has been rapid development of trace data tools that can inform students, teachers, and the technology itself about students' learning and achievement. During the software design process, technologies log user events for troubleshooting purposes. Educators can now get access to these existing traces of student actions with minimal effort and can use them to inform their instruction (i.e., "academic troubleshooting"). For instance, the example LMS data in this chapter come from logs kept by the university's information technology (IT) office. Such data already exist on campus and can be provided to instructors in summary or tabular form using software and systems IT departments already use (e.g., Splunk to extract and display server logs; Dominguez, Bernacki, & Uesbeck, 2016; Hong & Bernacki, 2017; Zadrozny & Kodali, 2013). Likewise, trace data from cloud-hosted learning technologies can be obtained via application program interface (API) connections so educators can observe an individual's behaviors, or investigate whether groups or classes are behaving as anticipated in response to instruction.

The Promise and Pitfalls of Data Dashboards

The potential impact that immediate, fine-grained feedback can have on students' choice of learning behaviors and instructors' pedagogical decision making cannot be understated. This information can be a powerful tool for guiding learning and instruction or informing students for the purposes of self-regulation, so long as it is delivered in a way that the viewer, either teacher or student, can understand and use it. Feedback on discrete outcomes can be quite simple, as when students attempt problems and receive immediate feedback about the correctness of their attempt. This information is easy to interpret, and what should be done next is often quite clear. When data are less easily interpreted, they must be summarized coherently and presented parsimoniously with sufficient scaffolding that a viewer can determine how to make use of this more complex feedback. Research on the design and use of data dashboards is just now emerging (e.g., Verbert, Duval, Klerkx, Govaerts, & Santos, 2013). As more learning technologies provide complex feedback in the form of "open learner models" and data dashboards, these tools can be evaluated and principles can be derived about the best ways to represent data on learning, and how best to train students and teachers to use them to self-regulate their learning and instruction.

Adaptivity

Much like humans who have learned how to interpret and utilize feedback, learning technologies can make good use of trace data when they can provide evidence of a learning event and when an appropriate response to that event can be cued. This describes quite precisely the design of ITSs that map students' problem solving attempts to a cognitive model of the skill they are attempting to learn, and then use the correctness of the attempt to cue a similar problem, if the skill is not yet mastered, or a new problem type training a yet-to-be-mastered skill (Koedinger & Corbett, 2006). In this instance, trace data allows the software to adapt to individual learners. In addition, trace data can be used to improve a learning technology so it can more effectively trace and adapt to students' learning. In the ITS literature, "closing the loop" studies demonstrate that respecifying a skill, by merging two skills or splitting one into two, improves the accuracy of models (Koedinger, Stamper, McLaughlin, & Nixon, 2013). These new models are then programmed into software, and learners' skill mastery can be traced more accurately and supported more effectively via refined hints, which can lead to more efficient learning.

Conclusion

The SRL research toolkit is expanding both in terms of the raw data available that can be used to trace learning and the analytical methods that can make sense of such immense logs of detailed data. Enthusiasm for research with technologies that trace learning events is well warranted. Empirical studies can be conceptualized that test even the most complex of assumptions posed in SRL models. Given the diversity of assumptions across models and researchers' increasing ability to observe and model them, research in this area will continue to expand. However, researchers must temper their excitement with thoughtful consideration of the challenges posed by log data as a medium for validly representing SRL events.

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25 Data Mining Methods for Assessing Self-Regulated Learning

Gautam Biswas, Ryan S. Baker, and Luc Paquette

There has been considerable ongoing interest in developing a theoretical understanding of self-regulated learning (SRL), developing methods for monitoring such processes as students work on learning tasks in computer-based learning environments (CBLEs), and using learner modeling and scaffolding methods to promote its development among students. A key development that has the potential to improve theory of SRL is enhanced measurement of the behaviors and processes that occur when students self-regulate, or do not, when working in CBLEs (Winne & Baker, 2013). In this chapter, we discuss the recent advancements and potential for further advancement in leveraging data mining methods to study SRL behaviors and processes. Specifically, we review how educational data mining (EDM), conducted on fine-grained data from learner interactions, can produce an understanding of SRL and the phenomena which compose it.

In this chapter, we define SRL as the process by which people, when faced with complex learning tasks, perhaps beyond their current capabilities, are able to set goals, create plans for achieving those goals, and then continually monitor their approach and their performance to become better learners and problems solvers (Bransford, Brown, & Cocking, 2000). SRL is a multi-faceted construct. According to Grau and Whitebread (2012), metacognition refers specifically to the monitoring and control of cognition, whereas self-regulation encompasses monitoring and control of cognition plus additional factors that affect learning and problem solving abilities, such as engagement, motivation, and emotion. Veenman (2012) pointed to a number of cognitive processes that are important for successful learning and understanding, focusing on science domains. Phillips and Norris (2012) further elaborated on the monitoring and control processes that govern the acquisition of knowledge from texts and Pressley (2002) argued that metacognitively sophisticated readers self-regulate their learning using a variety of strategies, such as the self-questioning and self-explanation strategies identified by Chi (2000). Grau and Whitebread (2012) noted limited use of metacognitive knowledge in young children's science learning, but found more significant use of regulation strategies such as planning, monitoring, control, and reflection. Perels, Dignath, and Schmitz (2009) studied how teaching SRL processes, such as goal setting, motivation, strategy usage, and self-reflection, can contribute to improved mathematical achievement.

The ongoing interest in SRL has led to increasing effort to develop operational theories that describe how successful SRL manifests under different conditions and in different situations (Butler & Winne, 1995). Several prominent theories have emerged, describing the processes surrounding and composing SRL (Efklides Schwartz, & Brown, 2018/this volume; Hadwin, Järvelä, & Miller, 2018/this volume; Hoyle & Dent, 2018/this volume; Usher & Schunk, 2018/this volume). One theory with particular relevance to much of the work in EDM on SRL is the work by Winne and his colleagues (Winne, 2018/this volume). Starting from an information-processing perspective, Winne and Hadwin (1998, 2008) proposed an architecture for SRL processes called COPES (i.e., Conditions, Operations, Products, Evaluations, and Standards). Learning according to this model occurs in four weakly sequenced and recursive stages: (1) task definition, where the students develop their own understanding of the learning task; (2) goal setting and planning, which follow the task definition phase and represent the students' approach to working on the learning task; (3) enactment of tactics, which represents the phase where the students carry out their plans for learning; and (4) adaptations to metacognition, which are linked to both in-the-moment adjustments of one's tactics and post-hoc evaluation of one's approach based on successes and failures achieved during enactment. COPES provides a cognitive architecture model that outlines how learners implement these stages. In this model, environmental factors and cognitive information constitute conditions within which cognitive activities occur. Single cognitive actions or ordered sequences, also called tactics and strategies, create internal products that are driven by the students' goal orientations. Winne and colleagues (Winne & Hadwin, 1998; Zhou & Winne, 2012) discussed further how a student's goal orientation (Elliot & McGregor, 2001) influences their internal states (i.e., cognitive, metacognitive, and affect) as well as their external learning behaviors (e.g., a focus on memorization of concept definitions while reading versus a focus on understanding by trying to establish relations between concepts). The four stages of learning create different products: starting from

a perception of the learning task and how to tackle it, developing study goals and study tactics, applying these tactics to generate and organize learned knowledge, and finally, reflection and evaluation of the effectiveness of the tactics employed and making adjustments as needed for the next recursive application stages.

Azevedo and colleagues (Azevedo, Moos, Johnson, & Chauncey, 2010) built on Winne and Hadwin's (2008) information-processing model of SRL, emphasizing the notion of SRL as an event, and used this notion to develop a framework for measuring cognitive, metacognitive, and affective processes during complex, hypermedia learning. They posited that such learning involves the use of numerous self-regulatory processes, such as goal setting and planning, knowledge activation, metacognitive monitoring and regulation, and reflection (Azevedo, 2008; Greene & Azevedo, 2009; Winne & Nesbit, 2009; Zimmerman, 2008). In their work, they have studied how students regulate key cognitive and metacognitive processes in order to learn about complex and challenging science topics. Their use of self-report and think-aloud constructs, such as Content Evaluation, Judgment of Learning, and Feeling of Knowing (Azevedo et al., 2010) serves as a complement to the work discussed below, which uses EDM to measure SRL.

Giving a full recounting of all the open questions raised by these frameworks is outside the scope of this chapter, but it is worth noting that one of the major contributions of these frameworks is in eliciting what is known by the field, and what areas need more focused research. For example, Efklides (2011) noted that metacognition interacts with affect in SRL, and discussed the role that metacognitive processes play in development of affect, but her discussion was largely focused on the valence of affect, rather than the complex cognitive-affective states such as frustration, boredom, and flow that D'Mello and Graesser (2012) identified as playing a key role during learning. It is still unclear, for instance, whether behaviors like gaming the system are ultimately expressions of poor SRL skill (e.g., Aleven, McLaren, Roll, & Koedinger, 2006), motivation (e.g., Martinez-Miron, du Boulay, & Luckin, 2004), or responses to affective states such as boredom and confusion (e.g., Baker, D'Mello, Rodrigo, & Graesser, 2010). Of course, it is also likely that a combination of factors contributes to the emergence of specific learner behaviors.

One core step towards improving theory of SRL is to improve our measurement of the behaviors and processes that occur during SRL (Winne & Baker, 2013). There has been a considerable amount of research on SRL that uses think-aloud protocols (Greene, Deekens, Copeland, & Yu, 2018/this volume) and surveys (Wolters & Won, 2018/this volume), but these methods have key limitations. Think-aloud protocols are expensive to study across large numbers of students or longitudinally; surveys cannot easily capture SRL as it is happening, without disrupting some of the key SRL processes.

An alternate data source for use in studying SRL is the fine-grained data that comes from online learning and CBLEs. The increased availability of fine-grained learning data (cf. Baker & Siemens, 2014) makes it feasible to study students' SRL processes more intensively than surveys and facilitating greater depth of analysis than think-aloud protocols. Researchers have long recognized the potential benefits of using CBLEs to study students' SRL (e.g., Derry & Lajoie, 1993; Rieber, 1996). However, much of this research has had a history of being conducted as small, heavily-instrumented laboratory studies, as opposed to the more natural learning occurring in authentic classroom settings, where data collection is noisy and often difficult, and where key inflection points in learning are often rare, and hard to detect. However, in recent years the number of high-quality CBLEs in classrooms has grown, they have scaled across students to a greater degree, and the log data that can be collected has increased in quality and quantity. These developments have come together to produce data sets that can include hundreds of thousands of students performing millions of interactions with one or more learning environments (see, for instance, the Pittsburgh Science of Learning Center DataShop—Koedinger, Stamper, Leber, & Skogsholm, 2013). This new era of big data in education provides opportunities to study multiple aspects of student behaviors and SRL, which, otherwise, would have been difficult to measure and validate.

However, despite considerable recent progress (Aleven et al., 2006; Azevedo et al., 2010; Baker, Gowda, & Corbett, 2011; Bondavera et al., 2013; Cleary, Callan, & Zimmerman, 2012; Kinnebrew, Segedy, & Biswas, 2014; Sabourin, Mott, & Lester, 2013; Zhou & Winne, 2012), tracking and measuring students' self-regulation

behaviors from their overt actions in a CBLE remains a difficult task. To capture the full range of SRL behaviors, researchers require techniques for detecting key aspects of cognition, metacognition, affect, and motivation in the context of the learning task and the environment. Such analyses often rely upon first identifying and assessing learners' cognitive skill proficiency (cf. Aleven et al., 2006; Baker et al., 2011), interpreting their action sequences in terms of learning strategies (Azevedo et al., 2010; Kinnebrew, Loretz, & Biswas, 2013; Zhou & Winne, 2012), detecting relevant aspects of their affect and engagement (Baker & Ocumpaugh, 2014; Jacques, Conati, Harley, & Azevedo, 2014; Paquette, de Carvalho, & Baker, 2014), and evaluating the students' success in accomplishing their current tasks. The crux of the problem lies in the inaccessibility of students' mental processes and structures, and establishing the link between observed activities and the students' underlying reason and motivation for doing them is difficult (Winne, 2010; Veenman, 2013).

CBLEs allow researchers to track many details of students' learning interactions, activities, and task performance. The learning activities logged by a CBLE result from internal cognitive and metacognitive states, strategies, and processes used by the student. In some cases, the behaviors can be directly linked to these constructs through other data sources, and these links can be used to produce models that can be utilized at greater scale. Prediction modeling and other techniques developed in EDM have accelerated progress in this area, as we discuss in the following section.

Educational Data Mining

In recent years, there has been a shift from collecting data specifically tailored to a planned analysis to using the voluminous quantities of data generated by interactions with online systems. This trend has been accompanied by increasing awareness that statistical methods oriented at falsifying hypotheses in small data sets can be complemented by data mining and machine learning methods oriented at producing models validated to generalize across data sets. Then the resulting models can be applied at scale to longitudinal data sets collected across large populations. These methods have had substantial impact in a range of fields (Collins, Morgan, & Patrinos, 2004; Summers et al., 1992). Over the last decade, there has been increasing interest in these methods in education (Baker & Siemens, 2014), and there have been increasing calls for applying these methods more broadly in cognitive psychology as well (Yarkoni & Westfall, 2016).

There are a wide range of methods in EDM. Several taxonomies of methods have been proposed, including taxonomies by Romero and Ventura (2007), Baker and Yacef (2009), and Scheuer and McLaren (2012). Within the broad range of data mining methods used in educational domains, five stand out in their use to detect and study SRL: (1) feature engineering, (2) prediction modeling, (3) sequence mining, (4) cluster analysis, and (5) correlation mining. We will briefly define each of these here and then discuss their use in research projects further below.

Feature Engineering

Feature engineering uses rational processes to develop meaningful variables for describing the studied data so that these variables can be used for further analyses, particularly prediction modeling and correlation mining. Although this method can be applied in a rapid fashion, better results are typically obtained through more intensive processes that connect to theory and qualitative understanding of the data (e.g., Sao Pedro, Baker, & Gobert, 2012). Feature engineering is a special case of the broader method of knowledge engineering. For example, Paquette et al. (2014) reported using a cycle of interviewing expert coders of student strategic behavior, developing models of the behavior of interest, presenting those models to the experts in the context of actual data in order to obtain feedback, and then iterating between interviews and model development until both the experts and the modeler were satisfied that the cognitive process has been fully represented. The variables produced by this process—various behaviors potentially indicative of gaming the system such as whether the student entered the same answer in multiple places—were then input into a prediction model. Examples of knowledge engineering

and feature engineering are seen below in the discussion of Aleven et al.'s (2006) help-seeking model, and the models that followed it.

Prediction Modeling

Prediction modeling, also referred to as supervised learning, consists of developing models to infer a variable which is available for a small subset of data, but is not naturally available in broader data sets of interest. The task of prediction modeling is usually divided into two subcategories: (1) classification, the prediction of categorical variables; and (2) regression, the prediction of numerical variables.

Prediction modeling can be used in situations where it may be expensive to label data by hand, e.g., with regards to SRL strategies, or infeasible to obtain for all of the 10,000+ students using an online learning environment in a given year. In such situations, labels can be collected for a subset of the data and the remaining labels inferred using a prediction model. To achieve this, a set of predictor variables is used to develop a model that accurately predicts the label (also called predicted variable). This model is then validated in terms of how successful it is at inferring the labels on held-out (unseen) additional data. The variables used in prediction modeling are generated using feature engineering, discussed above. Then, automated algorithms are used to find the combination of features that best matches the cases where data for the predicted variables is available. An example of this work is seen in Sabourin, Mott, and Lester's (2013) work on predicting student self-reports of their SRL strategies.

Sequence Mining

Sequence mining attempts to discover patterns in time-series data (e.g., the sequence of actions students perform in a learning environment). A search process is employed to find common patterns (e.g., frequently occurring subsequences of actions) over time. One of the challenges in sequence mining is finding patterns that are both common and yet interesting or surprising as well. The common patterns can then be interpreted in terms of students' learning behaviors, and when analyzed in context may provide information about student SRL strategies, for instance. Köck and Paramythis (2011) and Vaessen, Prins, and Jeuring (2014) provide examples of sequential pattern mining methods. Recent extensions to frequent sequence mining include the work on Differential Sequence Mining (DSM) to find patterns that differentiate two groups of students (e.g., students in an experimental condition who receive specific scaffolds, versus those in the control condition who do not; Kinnebrew et al., 2013).

Cluster Analysis

Cluster analysis consists of searching for groups of data points that are similar to one another, in terms of a set of data features (i.e., variables). Clustering, an entirely bottom-up or unsupervised method, can be very useful for gaining a quick understanding of completely unknown data, but it is sometimes prone to obtaining findings that are already known, particularly when used in well-known domains. Clusters are validated by examining whether data points in a cluster are more similar to each other than to data points outside that cluster. Segedy, Kinnebrew, and Biswas (2015) have used clustering to characterize students who have similar learning behaviors when working in CBLEs. As for sequence mining, the work by Köck and Paramythis (2011), described below (p. 394–395), as well as the work by Vaessen and colleagues (2014) and Bouchet, Harley, Trevors, and Azevedo (2013), represent the use of cluster analysis to study sequential pattern mining.

Correlation Mining

Correlation mining consists of searching for correlational relationships between large numbers of variables, sometimes looking at all pairwise correlations in a table, and sometimes looking at correlations between one variable and a set of other variables. It is distinguished from prediction in that it looks at many relationships between just two variables, rather than attempting to derive a combination of predictor variables to infer a single

predicted variable. Prediction models can be hard to understand, as they build off of the interactions between many variables; correlation mining produces results that are more easily interpreted. When correlating large numbers of variables, it is important to use appropriate methods for post-hoc control of Type I error, such as the Benjamini and Hochberg (2003) post-hoc correction. Examples of correlation mining given below include work by Bernacki et al. (2014) and Ogan et al. (2015).

Research Evidence on the Use of Educational Data Mining Methods to Detect and Study SRL

There have been a range of methods from the broad space of EDM that have been used to detect and study SRL. One of the best-known threads in this work starts with a model by Aleven et al. (2006) of the strategies associated with help-seeking in Cognitive Tutor Geometry, a type of intelligent tutor. Aleven's model was represented through 57 production rules associated with help-seeking. Beyond a prescriptive model for how help should be used appropriately, Aleven's model included 11 buggy rules (i.e., definitions of inappropriate behaviors) such as help avoidance, defined by Aleven et al. (2006) as "situations in which the student could benefit from asking for a hint or inspecting the glossary but chose to try the step instead," and hint abuse, defined by Aleven et al. (2006) as "situations in which the student misuses the help facilities provided by the Cognitive Tutor" (p. 113). Many of these rules had parameters; for example, the rule identifying when a student was avoiding help was based on an estimate of the probability that the student knew the skill, and used a cutoff to identify when the student's knowledge was sufficiently low that the student should have sought help (Aleven et al., 2006). Roll, Baker, Aleven, McLaren, and Koedinger (2005) showed that this model (initially published in a 2004 conference publication) could be made more accurate by empirically searching for different parameter values, a method considered data mining by some researchers (Scheuer & McLaren, 2012). Aleven et al. (2006) found evidence that several of the strategies they identified were correlated with differences in learning gains, with help avoidance and hint abuse both associated with poorer learning outcomes. However, Roll et al. (2014) found that in some cases apparent hint avoidance could be associated with positive learning outcomes, if students with low prior knowledge attempted problems before seeking hints. Both of these papers found that using help in the fashion recommended in Aleven et al. (2006) was associated with better learning outcomes.

Aleven et al.'s model was used as the basis for an automated intervention that identified student SRL errors and provided automated feedback on them. This automated intervention led students' behaviors to be more in-line with Aleven's prescriptive model of appropriate help-seeking behavior (Roll, Aleven, McLaren, & Koedinger, 2011), but did not lead to improved domain learning (Roll, Aleven, McLaren, & Koedinger, 2007).

Several other research groups built on the work by Aleven and colleagues. Working in the same system as Aleven and his colleagues, Shih, Koedinger, and Scheines (2008) used feature engineering to develop additional indicators of metacognitive behavior, using correlation mining to find evidence that apparent hint abuse was associated with positive learning outcomes, if the student paused after reading the hint. Shih and colleagues interpreted this behavior as self-explanation. Working in a Cognitive Tutor on genetics, Baker et al. (2011) used prediction modeling to build a regression model able to assess a student's preparation for future learning (Bransford & Schwartz, 1999), specifically whether a student was more successful at learning a future topic outside the learning software. They found that the same pausing behavior, in this case after receiving a message telling students why their answer was wrong, was associated with preparation for future learning. They also replicated Aleven et al.'s earlier result, finding a negative correlation between help-seeking and learning.

Otieno, Schwonke, Salden, and Renkl (2013) used feature engineering to extend the model in Aleven et al. (2006), analyzing the use of glossaries in the same intelligent tutoring system as Aleven and colleagues, and used correlation mining to determine that use of glossaries to review or learn terms and geometric rules was associated with better learning outcomes. Ogan et al. (2015) used correlation mining to study a set of help-seeking behaviors within a Cognitive Tutor for scatterplots, including the behaviors examined in Aleven et al. (2006) and Baker et al. (2011), and compared their correlation to learning in three different countries. They found that the behaviors that were associated with better learning differed between countries. For example, hint abuse was found to have

a negative correlation with learning in the USA, replicating Aleven et al. (2006), and the Philippines, but not in Costa Rica, whereas help avoidance in the USA was more strongly negatively correlated with outcomes than in the Philippines and Costa Rica.

Bernacki et al. (2014) used correlation mining to study the relationship between goal orientation and hint-seeking behaviors in the same system studied by Aleven et al. (2006), comparing repeated measures of three goals students could have towards learning (i.e., performance-approach, performance-avoidance, and mastery goals; respectively, whether a student had the goal of performing well, avoiding performing poorly, or developing mastery of the knowledge) to measures of behavior within an intelligent tutor for geometry. They found that students' overall goal orientation was not correlated with hint-seeking behaviors, but that students whose degree of performance-approach goals varied considerably over time were more likely to seek help.

In further work, researchers have attempted to exploit the temporal nature of SRL over time. Köck and Paramythis (2011) used a combination of Discrete Markov Models (DMMs), a form of sequential analysis, and clustering to discover help-seeking strategies within the Andes intelligent tutor for physics. In their work, DMMs were used to discover the probabilities that an action, such as asking for a hint for the next step, asking for a strategic hint, or requesting to see the solution would be executed by the student immediately following any of those same actions. For any attempt to solve an exercise, the set of all probabilities was used to describe the student's help-seeking behavior during this attempt. Clustering analysis was conducted on all the collected help-seeking behavior to group similar behavior into common strategies. Köck and Paramythis's (2011) more bottom-up approach (i.e., looking for common patterns in help usage over time) nonetheless found results relatively similar to those in Aleven et al. (2006). They found four patterns of help-seeking usage over time, two corresponding to hint abuse, one corresponding to help avoidance, and one corresponding to appropriate help usage. Their findings provided corroborating evidence for the relevance of the categories identified by Aleven and his colleagues.

Vaessen, Prins, and Jeuring (2014) used the same combination of DMMs and clustering as Köck and Paramythis (2011) to discover help-seeking strategies used by students in an intelligent tutor for computer programming. Vaessen et al. (2014) analysis resulted in the discovery of five main strategies: "little help," in which the student rarely asked for help; "click through help," in which the student started with the most general form of help and continued by asking for more specific help, sometimes asking for the solution; "direct solution," in which the student immediately asked for the solution; "step by step," in which the student often used the help button to ask what the next step should be and then copied that next step into their solution; and "quick solution," in which the student used some of the help functionalities, but ended by asking to see the solution.

In addition to using EDM techniques to discover common help-seeking strategies, Vaessen et al. (2014) also used prediction modeling to study the relationship between the usage of those strategies and the students' achievement goals. They created models for the prediction of the students' usage of the five help-seeking strategies using their goal orientation scores as predictors. They found a positive relationship between mastery avoidance goals and the click through help strategy, a negative relationship between mastery avoidance goals and the direct solution strategy, a positive relationship between performance-avoidance goals and the direct solution strategy, and a negative relationship between performance-approach goals and the quick solution strategy. However, they did not explicitly analyze the relationship between the strategies they identified and student learning outcomes or performance beyond the sequences of behavior themselves.

Clustering was also used by Bouchet and colleagues (2013) in the context of MetaTutor, a hypermedia learning environment about human body systems, such as the circulatory, digestive, and nervous systems (Azevedo & Witherspoon, 2009). They used EM (i.e., Expectation Maximization) based clustering, a form of clustering that can discover relatively complex patterns, to discover multiple classes of learners among college students using the MetaTutor system (Bouchet et al., 2013). The clusters differentiated students both by performance as well as learning behaviors and the amount of SRL processes they were prompted to enact. Specifically, they found that one cluster of students spent less time reading and taking notes but more time re-reading their notes; another

cluster of students spent more time taking notes and more time re-reading them; and a third cluster of students spent time neither taking notes nor re-reading them.

Sabourin et al. (2013) used prediction modeling techniques to generate early predictions of students' use of SRL strategies in Crystal Island, a self-guided game-based learning environment for the domain of microbiology. In this work, they studied how a range of indicators correlated to expert ratings of the degree to which students' status reports reflected SRL. In their model, they predicted SRL using both behaviors within Crystal Island and variables such as demographic information, pre-test scores, and scores on personality, goal orientation, and emotion regulation questionnaires. Their model incorporated the students' usage of each of the curricular resources, the number of in-game goals completed, and evidence of off-task behaviors. Their model achieved high predictive accuracy, but did not provide detail on which behaviors were especially predictive.

More complex temporal patterns were seen in the work by Biswas and his colleagues. This work was conducted in the open-ended learning environment Betty's Brain (Kinnebrew et al., 2013; Kinnebrew, Segedy, & Biswas, 2014), a system designed to help middle school students (i.e., grades 5–8) develop and practice SRL skills, including metacognition, as they learned about science topics. The focus of their research was on relating sequences of student activities in the learning environment to cognitive skills and metacognitive strategies that students can employ to achieve their learning tasks. In early work, Biswas, Jeong, Kinnebrew, Sulcer, and Roscoe (2010) used hidden Markov models (HMMs), a simple algorithm for analyzing changes over time, to identify and interpret student learning behaviors at an aggregate level (Biswas et al. 2010; Kinnebrew et al. 2013). They built on this work by using more complex sequential pattern mining algorithms to identify sequences of actions performed by different groups of students (Kinnebrew et al., 2013; Sabourin et al., 2013) or by the same students in different contexts (Kinnebrew et al., 2014), identifying interesting and meaningful patterns of behavior post-hoc from sequences of students' learning behaviors. Biswas and colleagues used this approach to identify SRL-related behaviors that differentiated: (1) more and less successful students (Kinnebrew et al., 2013); and (2) how students' approaches to learning change across the course of interventions that extended over multiple days (Kinnebrew et al., 2014). By studying these behavior patterns and the contexts in which they occur, Biswas and colleagues linked specific behavior patterns to students' learning behaviors and metacognitive strategies, such as guessing and checking, coordinating learning resources, keeping track of progress, and investigating the effects of system feedback (Kinnebrew et al., 2014). These models have been built into automated detectors that have been used to offer support linked to the inferred strategies. For example, when students demonstrate poor understanding in identifying critical information in the learning resources, a pedagogical agent (i.e., a character within the software) can guide them through practice problems and explain effective strategies for identifying and extracting relevant information for building models (Segedy et al., 2013). As with work by Roll et al. (2007, 2011), the resultant system led to more appropriate behavior but did not lead to a difference in domain learning (Segedy et al., 2013).

In further work, Segedy et al. (2015) developed a methodology called coherence analysis (CA), a more automated form of feature engineering, for analyzing and interpreting students' behaviors in open-ended CBLEs. Within CA, student actions are labeled in terms of whether they result in the student receiving information that can help them improve their current solution. As a result, they are said to have generated potential (i.e., value) for improving their models that should support future actions. If students do not act on this information, this approach assumes that they did not recognize or understand the relevance of the information. This may stem from incomplete or incorrect domain knowledge (i.e., science) understanding, incomplete task understanding, and/or incomplete or incorrect metacognitive knowledge. In addition, when students take actions without encountering any information that justifies that action, CA assumes that they are guessing or applying trial-and-error methods. Results of applying CA to data from a recent classroom study found that CA-derived metrics predicted students' task performance and learning gains and provided the basis for grouping students based on their learning behaviors and problem solving approaches (Segedy et al., 2015). Recent work has applied sequential pattern mining on top of data annotated according to CA, as well as annotations according to a hierarchical task model which supports interpretation of students' learning and problem solving strategies in terms of their coherence (leads to a successful use of the strategy) or a lack of coherence (ineffective use of the strategy) (Kinnebrew,

Segedy, & Biswas, 2017). For example, this approach yielded evidence for previously unknown learning strategies, such as an informed-guess-and-check strategy and a systematic reading and note-taking approach.

Future Research Directions

Despite the considerable work already done to measure and study SRL using EDM methods, there are several directions that remain open for future research. In this section, we briefly discuss a few directions that we believe to be of particular importance and interest.

Investigating Interactions of Cognition, Motivation, Metacognition, and Affect in SRL Models

The first direction is more thoroughly and conclusively studying the links in models such as Winne's model. The existing models situate SRL as a process that interacts with and is influenced by several other processes and phenomena. For example, take the role of affect (i.e., emotion in context). Theoretical models (e.g., Winne & Hadwin, 2008; Efklides, 2011) highlight the key role that affect plays in SRL. But we still do not know enough about exactly how this influence manifests.

With recent advances in measuring affect (see review in Baker & Ocumpaugh, 2014), it is now possible to automatically detect a variety of affective states in a range of online learning environments. When we combine automated measures of affect with automated measures of SRL, we create an opportunity to better study the interplay between these constructs. We can study the onset of SRL behaviors and examine the affective states that students appear to manifest at the beginning of the SRL, and during and afterwards as well. This will allow us to more closely investigate hypotheses about how these classes of construct relate (e.g., Efklides, 2011), and will allow us to investigate in closer detail findings from field observations, such as the temporal relationship observed between boredom and hint abuse/systematic guessing (Baker et al., 2010).

Using Automated Detectors to Drive Research

Another promising area is the use of automated detectors as a contributor to mixed-methods research. Thus far, automated detectors have largely benefitted from mixed-methods research rather than contributing back to it. For instance, field observations, survey data, and think-aloud protocols have been used to generate data on affect and engagement that can be used to create automated detectors (Baker & Ocumpaugh, 2014). We anticipate the future development of research that uses automated detectors to alert researchers about interesting and/or important events occurring. For example, envision a researcher standing by in a school, being automatically notified when a theoretically interesting event occurs in some student's SRL processes; perhaps a student shifts from struggling and trying to answer on his/her own to attempting to self-explain hint messages. This could be an ideal time for the researcher to conduct field observations or even a brief interview with the student.

Trace Data: A New Opportunity

Another opportunity for future research in measuring SRL using data mining comes from an emerging form of data: trace data (Perry & Winne, 2006; Bernacki, 2018/this volume). Trace data consist of data automatically collected through activity, which is designed to indicate what the student is doing, for example by choosing an SRL-related activity explicitly in an interface (Nesbit, Zhou, Xu, & Winne, 2007). It is differentiated from more general log data by the direct interpretability of the actions. Although data mining can also be conducted on simple interaction log data rather than trace data, particularly with the use of feature engineering, trace data can facilitate the analysis of log data.

Winne and his colleagues have collected trace data within the context of their gStudy software environment (Nesbit et al., 2007). gStudy provides: (1) a browser for learners to retrieve and study documents, and (2) tools that allow learners to highlight, categorize, and structure selected content. They can create hyperlinks between

their selected content, defined as objects, to create notes, glossaries, and concept maps. As students use gStudy, they not only complete activities but report directly on their SRL through their actions, including goal setting and planning, selection of text for further study and analysis, tactics and strategies used, and reflection methods employed. Nesbit et al. (2007) used this data in combination with graph-theoretic methods and transition matrices to perform a fine-grained analysis of study events. This approach helped them differentiate between learners who quickly fell into a regular studying pattern versus those who experimented with studying to gradually improve their learning tactics and processes. One of their interesting findings was that student actions and action patterns often differed from their responses to more traditional self-report instruments such as the MSLQ, the Motivated Strategies for Learning Questionnaire (Pintrich, 1991). Additionally, the trace data provided accurate information on students' frequency, pattern, and durations of learning activities, which allowed for much more precise studies of how students regulated their learning over time. Trace data has also been built into MetaTutor (Azevedo & Witherspoon, 2009). MetaTutor extends the paradigm in gStudy to also give real-time brief questionnaires on fine-grained constructs such as Judgment of Learning and Feeling of Knowing.

Trace data creates several research opportunities. Though only applied in a limited set of contexts thus far, developing generalized representations of the log data, e.g., as a sequence of actions with a description of the context in which the actions were performed, provides opportunities for developing generalized measures and mining algorithms for detecting and analyzing SRL behaviors across a wide range of learning environments (e.g., Segedy et al., 2015; Kinnebrew et al., 2017). Also relevant to this chapter, trace data can be triangulated with the data obtained from other log analysis methods. For example, traces of goal setting could be correlated with data on student affect to more deeply study the role that different manifestations of affect have on goal setting, helping us build on models of the role that affect plays in the emergence of SRL processes (Efklides, 2011). Alternatively, the type of purely behavioral analysis applied by Aleven et al. (2006) or Köck and Paramythis (2011) could be connected to trace data to see whether the behaviors that students intend and plan to engage in are the behaviors which they actually engage in.

Implications for Educational Practice

The recent advances in using EDM to measure SRL, and the behaviors associated with it, have several potential uses. In this chapter, we have primarily discussed potentials for research. But the potential implications for practice are, if anything, even greater. It is well-known that there are several reasons to support students in developing better SRL skills (see other chapters in this volume such as Efklides et al., 2018/this volume; Hadwin et al., 2018/this volume; Usher & Schunk, 2018/this volume; Winne, 2018/this volume). Models that can infer if a student has SRL skills, and what he or she lacks, in real time have several uses.

One use that has been proposed is identifying behaviors in real time that are associated with poor self-regulation, such as the metacognitive bugs in Aleven et al. (2006). These bugs can then be used to generate real-time feedback. As discussed above (p. XX), Aleven et al.'s model was used as the basis for an automated intervention that identified student SRL errors and provided automated feedback on them; but it did not lead to better learning of domain content (Roll et al., 2007). It remains to be seen why this was. One possibility is that the feedback messages promoted surface change in behavior but not changes in deeper cognition. Another possibility, stemming from evidence connecting the metacognitive behaviors studied by Aleven and his colleagues to preparation for future learning (Baker et al., 2011), is that the intervention studied in Roll et al. (2007) was actually effective, but that the wrong measure was used to test its effectiveness. Other research by Arroyo et al. (2007) gave metacognitive messages based on automated measures of SRL between problems rather than in real time. They found that students who received their interventions had better learning gains than students in a control condition.

Another way to use evidence of poor self-regulation is to use it to drive automated adaptation by the system that compensates for poor self-regulation. This approach may not improve student learning in future situations, but may avoid the student failing to learn what he or she is studying at the moment. Baker et al. (2006) used

measurement of gaming the system (i.e., inappropriate use of help and/or systematic guessing) to drive which content students received further practice on, giving the students additional opportunities to learn material they had bypassed by gaming. They found that this approach led to better learning for gaming students.

An alternate use is the use of SRL measurements to inform instructors about students who are not displaying effective SRL, and then letting the instructors take action. Simple reports to instructors about students who are not participating actively in their online courses have been found to lead to higher levels of student retention and success (Arnold & Pistilli, 2012). Products along these lines are becoming common in higher education settings, although typically involving simpler behaviors than those studied in SRL research. Empowering teachers with meaningful reports on student SRL may create the potential for improved outcomes as well.

Overall, through the use of accurate data on student SRL, we may be able to improve student behavior, enrich their metacognition, and ultimately improve their outcomes. Improving SRL has the potential to have a long-lasting effect on learners; if we can go beyond helping them learn today, and help learners learn how to learn, the impacts may be broad-ranging indeed.

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Section V

Individual and Group Differences in Self-Regulation of Learning and Performance

26 Calibration of Performance and Academic Delay of Gratification

Individual and Group Differences in Self-Regulation of Learning

Peggy P. Chen and Héfer Bembenutty

Educators who are interested in providing interventions for all learners, regardless of their diverse backgrounds and cognitive abilities, need to assess individual and group differences in the self-regulation of learning (see McInerney & King, 2018/this volume). Research with young children through adults has consistently demonstrated that learners who self-regulate by being proactive, selecting strategies, planning tasks, monitoring progress, adapting to changes, and sustaining efforts are more successful in their learning and academic performance than those who do not (see Usher & Schunk, 2018/this volume). In this regard, the cognitive processes of goal setting and planning, strategy use, monitoring, and reflection are pivotal to successful self-regulation of learning.

This chapter focuses on two internal self-regulatory processes that learners engage in while monitoring their learning progress and reflecting on their performance outcomes: calibration of performance and academic delay of gratification. Specifically, this chapter provides an understanding of individual and group differences in learners' calibration of performance as well as the significance of delaying gratification for attaining academic goals (Bembenutty & Karabenick, 2004, 2013; Chen & Rossi, 2013; Chen & Zimmerman, 2007). Self-regulation of learning requires students to actively self-assess their learning progress; and calibration of performance and delayed gratification involve students' initiation of judgments that are fundamental to self-regulation as they monitor, exert control, and make adaptive changes while engaging in complex learning endeavors. Research suggests that students who are well calibrated in their academic performance (Hacker, Bol, & Keener, 2008), and who delay gratification in various learning undertakings, effectively engage in self-monitoring, self-control, and self-adapting learning strategies (Bembenutty & White, 2013).

Although a large body of research on calibration and delay of gratification already exists, there is a need to articulate how these two concepts intersect, as well as how they uniquely contribute to learners' successful self-regulation of learning. It is particularly important to examine how these two concepts manifest in students' use of self-regulatory learning strategies, such as self-monitoring, self-reflection, and self-adaptation. This chapter addresses the roles that calibration and willingness to delay gratification play in the self-regulation of learning and provides a synthesis of the empirical evidence on the impact of self-regulation on students' learning and performance. The chapter begins with a discussion of the self-regulation of learning, with a focus on academic contexts and the relationship of self-regulation to metacognition, including individual and group differences. To show the breadth and depth of the literature on calibration and delay of gratification, research from both the United States and other countries is presented. The chapter concludes with recommendations for future research and educational implications.

Relevant Theoretical Ideas

According to social-cognitive theorists, self-regulation of learning is a multidimensional process that learners initiate to direct their behaviors, cognitions, emotions, and environment to achieve desired goals (Zimmerman & Schunk, 2011). Highly self-regulated learners use many complex strategies, exhibit heightened metacognitive awareness, engage in iterative modification of their learning, and integrate self-feedback and information from external feedback (Zimmerman, 2013). Based on the widespread interest in the self-regulation of learning and its application to educational contexts, theorists have generated various models to depict self-regulatory processes.

Although these models have similarities, each provides a unique contribution to the field of self-regulated learning (Bembenutty, Cleary, & Kitsantas, 2013; Efklides, Schwartz, & Brown, 2018/this volume; Usher & Schunk, 2018/this volume; Vohs & Baumeister, 2016; Winne, 2018/this volume; Zimmerman & Schunk, 2011).

Although some researchers have studied self-regulated learning and metacognition separately, others have considered them to be concepts closely related to each other. From the information-processing and cognitive-psychology frameworks, self-regulatory processes have been considered under the umbrella of metacognition (Dunlosky & Metcalfe, 2009), whereas other research has conceptualized metacognition as a subcomponent of self-regulated learning (Dinsmore, Alexander, & Loughlin, 2008; Schunk, 2008; Veenman & Alexander, 2011; Zimmerman, 1995).

Metacognition, first made known by Flavell (1979), was originally described as knowledge and understanding of one's own cognitive processes, and he later expanded the concept to include anything psychological, such as knowing one's motives, emotions, and motor skills as well as perceiving them in others. Major theorists have conceptualized metacognition similarly and refer to metacognitive monitoring, knowledge, and control (Dunlosky & Metcalfe, 2009; Nelson & Narens, 1990). Metacognitive monitoring refers to how individuals judge and assess their understanding of an ongoing cognitive activity (Dunlosky & Metcalfe, 2009). Metacognitive knowledge refers to people's conscious declarative knowledge about cognition, including facts, beliefs, and sets of procedures, which can be general or specific. Metacognitive control refers to one's regulation of cognitive processes or activities (Dunlosky & Metcalfe, 2009). In educational contexts, students engage in cognitive monitoring processes, such as judging whether they are solving problems correctly, assessing the progress of completion of the task at hand, estimating how well they have learned the material, and modifying aspects of learning tasks and experiences.

The theoretical frameworks of self-regulated learning and metacognition both share many processes and mechanisms such as monitoring progress, self-assessment, reflection, and use of feedback. Brown and Harris (2013) posited that student self-assessment in educational situations involves monitoring one's learning processes and performance outcomes. In this regard, Panadero, Brown, and Strijbos (2015) noted that accuracy, or "realism" of student self-assessment, which supports appropriate inferences, warrants further attention. Comparing students' performances to their internal standards, or to externally imposed standards, provides a more accurate picture of their actual skill levels and corroborates if their perceived learning/understanding is accurate. The underlying processes of student self-assessment can be considered broadly as the student's execution of metacognitive knowledge and monitoring while engaging in target tasks. Thus, we consider measurement of the accuracy or realism of student self-assessment as parallel to the measurement or calibration of performance. Further, student self-assessment is considered a critical sub-process of self-regulation that occurs during the self-reflection phase of the self-regulated learning cycle (Panadero et al., 2015; Zimmerman & Moylan, 2009).

Accurate student self-assessment serves learners not only by providing a measurement of performance but also by providing them with a "truthful" signal by which to make sound educational decisions (Panadero et al., 2015). In self-assessment, the particular concern is that students may falsely believe that their work is good enough when they lack an understanding of their performance in relation to external standards. Poor calibration of one's performance, particularly overconfidence, may create a false sense of mastery that can lead students to stop learning prematurely, refuse help, and become oblivious to acquiring the additional skills and knowledge they need. Brown, Andrade, and Chen (2015) emphasized the need to address issues of accuracy in self-assessment by drawing attention to the degree to which students' self-reflection of their work is truthful and contains the least amount of error.

Similar to calibration of performance, academic delay of gratification involves meta-cognitive and self-regulated processes. Delay of gratification depends largely on individuals' capability to make decisions, while taking into consideration such concerns as timing, subjective values of the rewards, and available information for uncertain outcomes or rewards. Further, like calibration of performance, people who are successful at self-imposing delay of gratification or exhibiting high self-control are better at calibration between temporary and future rewards

(McGuire & Kable, 2016). There is substantial theoretical evidence to support the notion that both calibration of performance and academic delay of gratification should provide a significant prediction of learners' motivation and use of cognitive and metacognitive processes, as well as shed light on group and individual differences in academic performance. Thus, the next two sections concern the roles and functions of performance calibration and academic delay of gratification in relation to self-regulated learning.

Calibration of Performance

Calibration has been defined as the correspondence between a person's confidence judgments and his or her actual performance on a particular task (Hacker, Bol, & Keener, 2008). Research has shown a mainly positive relationship between calibration accuracy and performance (Bol, Riggs, Hacker, Dickerson, & Nunnery, 2010; Hadwin & Webster, 2013; Pajares & Graham, 1999). Learners who calibrate well are more likely to attain desired goals. Further, when learners are poorly calibrated in their performance, they tend to overstate their confidence levels; simply stated, they are overconfident. When students overestimate their capabilities or are overconfident in their skill sets they may not engage in self-regulated learning behaviors or implement the strategies needed to succeed academically (McGuire & Kable, 2016). If students erroneously believe that they know precisely what to do on a task, they may not carefully check their work or monitor their progress. When learners are overly confident, and then find themselves unable to demonstrate certain skills, their motivation could be damaged.

Confidence judgments can be measured prior or post learners' performance (i.e., prediction and postdiction), and then the confidence judgment can be compared to the actual performance outcome. Further, both of these judgments have been utilized to measure calibration (Chen, 2003; Nietfeld, Cao, & Osborne, 2005). As Hacker, Bol, and Keener (2008) posited, a prediction judgment is a prospective monitoring process that occurs during acquisition and retention, but before retrieval of knowledge or performing a task. A postdiction judgment is a retrospective monitoring, or a self-reflective process in models of self-regulated learning, that occurs after retrieval or performing a task. Understanding differences in learner calibration involves understanding how students make various prediction and/or postdiction judgments in high-stake or testing situations (Bol, Hacker, O'Shea, & Allen, 2005; Hacker, Bol, & Bahbahani, 2008; Nietfeld et al., 2005). Learners estimate their overall test scores or the number of questions they believe they answered correctly, and compare those judgments to their actual obtained scores. Other research has focused on learners' calibration by comparing their self-efficacy beliefs and their actual performance. Thus, calibration of self-efficacy beliefs is analogous to prediction judgments or prospective monitoring (Brannick, Miles, & Kisamore, 2005; Chen & Zimmerman, 2007; Klassen, 2007).

Schraw (2009) discussed frequently used measures to ascertain the accuracy of metacognitive judgments or judgments made about individuals' learning and performance. Measures of judgments can be presented as two categories: absolute or relative accuracy. Absolute accuracy measures the discrepancies between a confidence judgment and a performance. For example, accuracy index measures the amount of this discrepancy, while bias index measures the direction of the discrepancy (such as over-or under-confidence). The Hamann coefficient is used to measure the amount of discrepancy with category data (yes/no; true/false), while relative accuracy measures the strengths of "association" between confidence judgments and performance outcomes (such as correlation and Gamma coefficients). The discrimination index is another relative measure that measures individuals' ability to distinguish between correct and incorrect items or events in relation to confidence. In addition to absolute and relative measures of calibration, researchers have used a calibration curve (i.e., hybrid scores), which visually represent the difference between the ideal and the deviation of calibration scores (Schraw, 2009).

Academic Delay of Gratification

Delay of gratification has been conceptualized as individuals' competence to defer immediate impulses while waiting for a reward that is temporarily distant, and is associated with a host of positive outcomes, such as academic achievement, positive health outlook, high self-esteem, and impulse control (Mischel, 2014). In

academic contexts, willingness to delay gratification is construed as a state of intention and readiness to defer immediate rewards for the sake of pursuing long-term goals—and is contrasted with the concept of ability per se, which is commonly associated with individuals' talents, skills, expertise, traits, or aptitudes. Like calibration of performance, delay of gratification involves learners' activation of self-regulated and metacognitive processes that involve making judgments and decisions about tasks, time, and strategies; monitoring progress; modifying environment and behaviors; and exhibiting self-control.

Research on delay of gratification began with Mischel's (2014) now-classic marshmallow test, in which children were asked to choose between a less valuable reward (e.g., a marshmallow) and a larger reward (e.g., two marshmallows), the latter of which involved a 15-minute wait. Children were left alone in an experimental room while they were observed through a glass. If they did not wait and ate the marshmallow before the experimenter returned to the room, they were unable to get the second marshmallow. Individual differences were observed among the children, some of whom waited and received both marshmallows, while others ate the marshmallow shortly after the experimenter left the room.

Mischel's (1966, 2014; Mischel & Ebbesen, 1970) studies showed children's use of behavioral, cognitive, and metacognitive skills to cope during the waiting time. Among other strategies, some children played with their hands, sang, slept, invented games, moved away from the tempting reward, verbalized positive thoughts, and imagined rewards. These findings supported a generalized, cross-situational competence that some children possessed more than others. The successful children used metacognitive strategies (i.e., planning, controlling, and monitoring their intention) to wait for the larger reward (Mischel, 2014). Follow-up research on those children indicated that those who were able to wait longer were more academically and socially competent than were those who were unable to wait. Now in their forties, those who were able to wait have been found to have high academic and professional successes, fewer encounters with the law, and less use of illegal drugs than those who could not wait (Casey et al., 2011; Mischel, 2014; Mischel et al., 2011).

Consistent with Flavell (1986), Mischel (2014) also argued that children who successfully complete tasks that require delay of gratification engage in metacognitive processes in order to remain task-focused, even when more attractive activities compete for their attention. An important discovery made through the marshmallow test was that delay of gratification can be learned by mastering self-control and by teaching cognitive and metacognitive skills to regulate individuals' emotions, feelings, temptations, and future behaviors (Mischel, 2014). Individuals are able to engage in the metacognitive process of inhibiting their impulses, controlling their attention, and monitoring their progress in order to pursue valuable goals by transforming challenging situations through self-distraction, which are skills that children learn in school (Mischel, 2014). Having strategic plans and self-directed goals for how to deal with challenging situations have proved to be effective metacognitive skills that sustain long-term delay of gratification. In essence, Mischel posited that cognitive and metacognitive skills can be acquired that make individuals able to persist under difficult situations and could result in developing self-efficacy beliefs about their competence to perform designated tasks. Like engaging in appropriate metacognitive skills and calibration of performance, sustaining delay of gratification over time is an important component of self-regulation of learning (Bembenutty, 2009).

Applying the seminal work of Mischel to academic learning contexts, Bembenutty and Karabenick (1998, 2004, 2013) conceptualized academic delay of gratification as a competence that individuals develop through their social and environmental interactions from parents, teachers, peers, society, and media outlets. During the last few decades, academic delay of gratification has attracted the attention of educational psychologists, who considered it an important individual competence essential for academic success (Chua & Kang, 2012; Ganotice & King, 2014; Zhang, Karabenick, Maruno, & Lauermann, 2011). Bembenutty and Karabenick (1998, 2004, 2013) developed the Academic Delay of Gratification Scale (ADOGS) and found evidence that suggested that students' use of cognitive and metacognitive learning strategies is associated with academic delay of gratification. ADOGS has been translated into Chinese, Korean, Dutch, Filipino, and Turkish, and has been used internationally to study academic delay of gratification (e.g., Avci, 2013; Chua & Kang, 2012; Zhang, Karabenick, Maruno, & Lauermann, 2011).

Research Evidence

Calibration of Performance: Individual and Group Differences

Studies on individual and group differences in calibration of performance have been conducted with various age groups (i.e., from children to adults), abilities (i.e., average, gifted, students with learning disabilities), and content areas (i.e., math, reading, writing). The research consistently shows that higher-achieving students are better at calibrating their performance; however, gender differences in calibration were not consistently observed. Ewers and Wood (1993) conducted one of the first studies on calibration that included gender. They investigated gender and ability differences between gifted and average-ability fifth graders in relation to their self-efficacy and prediction accuracy for mathematics. They found ability and gender differences in math self-efficacy among fifth graders, but no gender differences in math performance. In regard to prediction accuracy, gifted students made fewer overestimations than did regular students, and girls made fewer overestimations than did boys. Chen (2003) and Pajares and Graham (1999) studied middle-school students' math self-efficacy calibration and performance and, in contrast to the research of Ewers and Wood, found no gender differences in calibration of performance. In regard to ability differences in calibration, the findings are more consistent, as all three studies showed that high-performing students were better calibrated, had higher math performance scores, and were less biased toward overconfidence than were lower performing students (Chen, 2003; Ewers & Wood, 1993; Pajares & Graham, 1999).

Bol, Riggs, Hacker, Dickerson, and Nunnery (2010) compared students in sixth-grade regular math classes to those in honors math classes and found that students in both types of classes reported overconfidence in their predictions and postdictions of performance, but this finding was true to a lesser extent for students in the honors classes. The researchers also asked students to explain their calibration accuracy and found that the most frequent explanation they gave for their prediction was their belief about the effort and time they had spent studying. Students' most frequent explanation for postdiction (i.e., why their postdiction was accurate or inaccurate) was that they knew how many questions they had answered correctly or incorrectly. Overall, students were overconfident in their judgments, but gifted and higher-performing students demonstrated less overconfidence than did regular students.

Klassen (2007) examined the calibration of self-efficacy among adolescents with and without learning disabilities (LD) in spelling and writing. The results showed that students with LD overestimated their writing and spelling performance. Compared to students with LD, non-LD students were more accurate or better calibrated in their spelling and writing performance. In an effort to understand whether a group's calibration would differ from an individual's, Bol, Hacker, Walck, and Nunnery (2012) examined calibration of performance in high-school biology classes. They provided only some of the students with calibration guidelines, and found that those who were given these guidelines were more accurate and had higher test scores than did those who had not received the guidelines. Further, students who made calibration judgments were, as a group, more accurate and achieved higher scores than did those who made calibration judgments individually. This study showed that calibrating as a group and providing calibration guidelines positively influence students' calibration and performance (Bol, Hacker, Walck, & Nunnery, 2012).

According to Bandura (1997), more accurate self-assessment of one's competency demonstrates one's self-regulated learning processes, but slight overconfidence can help sustain motivation. The key to improving students' calibration is to help them to better understand what they know and do not know in a way that they can use the information to effectively implement appropriate strategies. In this regard, Pajares (as cited in Madewell & Shaughnessy, 2003) stated, "The issue of 'accuracy' of one's self-efficacy cannot easily be divorced from issues of [one's] well-being, optimism, resilience, and optimal functioning" (p. 397). The critical issue in calibration of performance is false processing fluency: students who are overconfident about their performance tend to stop studying sooner, allocate less learning time than needed, or are reluctant to use alternative strategies (Finn & Tauber, 2015).

Using the ADOGS, Bembenutty and Karabenick (1998, 2004, 2013) found that U.S. college students with a high willingness to delay gratification also reported using meta-cognitive learning strategies, such as planning, monitoring, and self-regulation. The same students also reported high self-efficacy beliefs and frequent use of resource-management strategies, such as time management, peer learning, help seeking, and effort regulation. Students with a low willingness to delay gratification, in contrast, reported metacognitive deficiencies, such as an inability to properly set learning goals, poor self-monitoring of goals, low organizational skills, and problems with time management.

The ADOGS has been used to identify individual differences among learners in a number of countries. Chua and Kang (2012) examined the relations among academic self-concept and maternal parenting behaviors on the ability of Korean and Malaysian third graders to delay gratification. The results indicated that Korean children reported more willingness to delay gratification and a higher academic self-concept than did Malaysian children, and that academic self-concept had a significant positive effect on delay in both the Korean and the Malaysian samples. No gender difference was found for willingness in either sample.

Avci (2013) examined the relationship between self-regulation, future-time perspective, and academic delay of gratification among Turkish teacher-candidates. The results showed that participants who set distant goals and connected them with current actions reported a higher willingness to delay gratification and greater future-time perspective, and were more successful at avoiding environmental distractions. Most importantly, Avci found a significant positive association between participants' delay of gratification and their metacognitive self-regulation.

Bembenutty (2007) examined gender and ethnic differences among college students in relation to the relationships between academic performance, self-regulation, motivation, and delay of gratification. He found gender and ethnic differences in relation to motivation, use of cognitive strategies, delay of gratification, and use of self-regulation in learning. In addition, there were significant ethnic differences, with Caucasian students earning higher course grades than minority students. There was no gender difference within each group; Caucasian males did not differ from Caucasian females, and minority males did not differ from minority females. Overall, minorities obtained lower grades than did Caucasian students. Minority male students reported significantly lower self-confidence than Caucasian males in their ability to perform academic tasks, while minority female students reported higher delay gratification than minority male students. Students with a high willingness to delay gratification also reported engaging in self-generated actions and thoughts while pursuing academic goals, using appropriate learning strategies, and maintaining high levels of motivation (Bembenutty, 2007).

Willingness to delay gratification also has been studied among adolescents who were required by authorities (e.g., court, school, parents) to enroll in disciplinary alternative-education programs. Herndon, Bembenutty, and Gill (2015) examined individual differences in academic performance, violence, willingness to delay gratification, and substance abuse among students who were required by authorities to enroll in a disciplinary alternative middle-school program. Using correlational analysis, the researchers found that students who reported a high willingness to delay gratification, coupled with a low tendency toward violent behavior and substance abuse, also obtained higher on their standardized math test scores. Herndon et al. (2015) also found that race and ethnicity had a weak association with math performance as well as with reported violent behavior.

While King and Du (2011) found that the factor structure of the ADOGS was invariant across gender among university students from mainland China, Kim, Chung, Lee, and Kwon (2001) examined eighth-grade Korean students' use of learning strategies, planning ability, and academic delay of gratification. Students were classified as having either a high or low level of volitional skills. Students with high-level volitional skills and delay of gratification used more learning strategies than did their low-level counterparts.

In a study conducted in Chinese elementary schools, Zhang et al. (2011) examined the relation between willingness to delay gratification and behavior indicative of academic delay of gratification. The researchers assessed students' time devoted to non-school activities and playtime prior to taking a high-stakes final exam. The results revealed that students who reported high willingness to delay gratification spent less time playing long before the examination date than those who reported low willingness to delay gratification. The researchers also found that students who reported a high willingness to delay gratification increased their study time and decreased the time they spent in play, while the opposite was reported among their counterparts. This finding is important because delaying gratification when no major assessments are pressing reflects planning, controlling, and monitoring of metacognitive processes. When an important examination was temporarily remote, students high in academic delay of gratification also reported higher tendencies to engage in metacognitive processes than did those with low willingness to delay gratification.

Arabzadeh, Kadivar, and Dlavar (2012) examined the effects of teaching self-regulated learning strategies on Iranian high-school students' academic delay of gratification, using the ADOGS. Students were randomly assigned to the experimental or control group. The experimental group received training in self-regulated learning strategies for fifteen sessions, and the ADOGS was administered to both groups at both pre- and post-test. The findings revealed that the teaching of self-regulated learning strategies had a significant effect on students' academic delay of gratification. The results also indicated that students' willingness to delay is a function of how proximal important tasks were.

Bembenuddy (2016) examined teacher candidates' self-reported willingness to delay gratification, self-handicapping, teacher self-efficacy beliefs, academic performance, and gender differences among undergraduates and graduate teacher candidates seeking initial teaching certifications, and graduates seeking professional teaching certification in the United States. The results revealed that delay of gratification was positively associated with academic performance and teacher self-efficacy, but it was inversely related to reported self-handicapping behavior. Self-handicapping was inversely related to academic performance. Undergraduate teacher candidates reported higher willingness to delay gratification than did male graduate teacher candidates and males at the master's level. Teachers and teacher candidates reported willingness to delay gratification depended on their gender and also on their educational level. This finding is consistent with a previous study that found gender differences in delay of gratification (Bembenuddy & Karabenick, 1998).

Future Research Directions

Despite the important findings of the body of research presented in this chapter, future research on the calibration of performance and academic delay of gratification is warranted. One recommendation for future research is to improve the validity or interpretations and use of student self-assessment information. Because classroom learning is interactive among students and their teachers, accuracy of student self-assessment as a part of formative assessment is influenced by multiple factors (Brown et al., 2015). Most important, researchers need to closely examine how students interpret and use their calibration of performance information to guide future studying or to modify their self-regulatory processes. Thus, the extension of calibration research in classroom settings, particularly as a crucial part of formative classroom assessment, warrants further research, in consideration of its many moving parts.

Another recommendation for future research is to focus more on training in calibrating performance, as prior studies have shown that such training has not consistently resulted in a positive effect on student performance. For example, Bol et al. (2005) found that using a number of practice tests during the course of one semester did not result in undergraduate students' improvement in calibration accuracy. Similarly, Nietfeld et al. (2005) monitored students' accuracy over a number of tests during a semester and found that it remained unchanged. Notably, such research did not include the training of students in how to reflect on or use their accuracy information to improve calibration. Huff and Nietfeld (2009), who included monitoring training exercises in their studies, found that such training improved student calibration accuracy. Bol et al. (2012) found that including

guidelines and having students work in groups also improved learners' calibration accuracy. Merely presenting feedback on calibration accuracy is not informative enough to guide learners in proceeding to the next step in the learning process. In addition to researching learners' calibration, Hattie (2013) suggested examining teachers, specifically proposing to have new directions of future calibration research examine teachers' use of students' calibration information in their instruction, as well as teachers' own calibration of their instructional impact on student learning.

Despite the important knowledge gained from correlational studies of academic delay of gratification, such studies have limitations, such as self-assessment biases and the inability to infer causation. These limitations point to the need for experimental studies, such as ones that enable the manipulation between the assessments of delay and demonstrate how it affects academic tasks and decisions. Although it was not an experimental study, Zhang et al. (2011) found that students high in academic delay of gratification studied significantly more at the beginning of the reporting interval before a test than did students low in delay. Thus, future research on academic delay of gratification might consider interventions in which learners are trained in the use of metacognitive, cognitive, motivation, and behavioral strategies to delay gratification at an early stage of a learning endeavor.

Another area of future research is a re-examination of constructs and research methodologies. The concept of calibrating performance is not sharply defined because some researchers view it as metacognitive monitoring, whereas others see it as a measure of discrepancy between one's confidence judgments and the actual performance outcome. These conceptual definitions dissociate calibration from other psychological and environmental factors, which, in combination, may influence the person's calibration of performance. To better understand the calibration mechanism, future research should focus on the development of a succinct model of calibration, including the mechanisms or cognitive processes involved, and the motivational processes that support the construct. Because measures of calibration of performance may have been too general, future research should provide better operationalization of measures of calibration.

Although evidence supports the importance of willingness to delay gratification in multiple academic outcomes, measured by the ADOGS, it is unclear whether students behave accordingly. Further, it is unclear whether students are able to transfer willingness to delay gratification from an academic setting to others kinds of settings. Thus, future observation and longitudinal research designs are needed to examine the nature of this calibration and its consistency with students' reported willingness to delay gratification and their actual behavior.

Questionnaires have been the primary source of data gathering to date in regard to these issues by research methodologies, and they have some limitations. Brown et al. (2015) questioned whether students' interpretations of items were consistent with their intended meaning and whether their response choices were congruent with those interpretations. Although researchers cannot avoid using questionnaires in studying constructs related to personal agency, employing other research methodologies, such as qualitative approaches with grounded theoretical frameworks, is needed to provide a clearer understanding of the sources of individuals' calibrations and the reasons behind their willingness to delay gratification. Researchers may wish to consider alternative data collection formats, such as online and trace approaches (Winne & Jamieson-Noel, 2002), think-alouds, logs, journals, and diaries (Zimmerman, 2008).

Another potential research direction would be the use of longitudinal or cross-sectional studies to understand developmental changes in relation to calibration of performance and delay of gratification, particularly in school settings. Although Mischel (2014) has demonstrated the profound advantages experienced by children who showed a general delay of gratification in academic learning, developmental studies are nevertheless needed. Moreover, in relation to developmental studies about students' calibration of performance, research remains unclear vis-a-vis the pattern of their development, particularly with regard to authentic school tasks and learning situations. These recommendations are central to the validity and clarity of these constructs.

Educational Implications

Calibration of performance and delay of gratification within academic settings are important to enhancing learning and performance. Research on both has mostly shown evidence of associations with positive educational outcomes, including enhanced motivation, self-regulation, academic performance, and cognitive processes (Bembenutty & Karabenick, 2004; Hacker et al., 2008; Hadwin & Webster, 2013; Zimmerman & Moylan, 2009). Thus, one implication for educational practice is for teachers to consider integrating self-regulatory processes in their classroom practices, with a focus on calibration accuracy and learners' willingness to delay gratification. For instance, teachers could first demonstrate how to set realistic yet challenging goals for completing tasks and assessing related self-efficacy beliefs. In addition, teachers could model self-reflection of one's understanding of a task and process of completing it. As students become more reflective and more self-aware, they can set their own goals and make plans for how they will complete the task. In addition, teachers could demonstrate the use of such tools as homework logs, rubrics, dairies, and self-monitoring forms to manage students' learning progress and outcomes. To make self-monitoring transparent, Chen and Rossi (2013) provided feedback forms to at-risk high-school students to help them to monitor their performance in regard to certain topics. Similarly, Bembenutty (2010), who provided students with homework logs, found that the students who reported use of the logs had a greater willingness to delay gratification.

Another implication for educational practice is the critical examination of the meta-cognitive monitoring processes that students frequently utilize while engaging in learning or completing tasks. Students are often unaware of how effective their own learning processes are and often lack knowledge of how to use, manage, and control information that they receive during instruction. Simply providing feedback to students is not enough to prompt them to modify their learning behaviors or use of strategies. As Butler and Winne (1995) noted, outcome-based feedback derives from a student's performance results on a criterion task, whereas process-based feedback is concerned with how a student performs that task. The implication for educational practice is that teachers should provide quality feedback and model for students how to use that information to modify their current knowledge and skill levels. Feedback is critical to effective self-regulation (Hattie & Timperley, 2007), and information gathered through students' calibration of performance and the reasoning involved in their academic delay of gratification could be utilized by both students and their teachers as feedback for formative purposes. As Shute (2008) stated, formative feedback is "information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning" (p. 154). According to Hattie and Timperley (2007), feedback for formative purposes is intended to close the gap between learners' current knowledge and skill levels, as reflected in their performance, and a future performance goal. To be effective, feedback must target the appropriate skill level of learners. Calibration of performance could provide outcome-based feedback, while information about how students delay gratification may provide process-based feedback. In a pre- and post-experimental study, Wollenschlager, Hattie, Machts, Moller, and Harms (2016) found that middle-school students who received teacher-giving rubric as feedback, in addition to explicit information for improvement in their learning, showed significantly better performance, high motivation (i.e., perceived competency), and higher calibration accuracy than did students who received teacher-given rubric as learning goals.

This chapter presented the interconnections between self-regulated learning and metacognition models: specifically, calibration of performance and academic delay of gratification. Research provides evidence that both calibration performance and delay of gratification are associated with many motivational, cognitive, and, especially, self-regulatory processes that influence learning outcomes. Further, the research indicates that calibration of performance and delay of gratification should be implemented together to produce effective academic learning and outcomes in multiple learning contexts.

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27 Academic Help Seeking as a Self-Regulated Learning Strategy

Current Issues, Future Directions

Stuart A. Karabenick and Eleftheria N. Gonida

No longer viewed as evidence of dependency, seeking help when needed is now considered an important self-regulated learning (SRL) strategy (e.g., Butler, 2006; Karabenick, 1998, 2004; Karabenick & Berger, 2013; Karabenick & Newman, 2006; Ryan & Pintrich, 1997). The conceptual shift can be attributed to Nelson-Le Gall's (1981) identification of instrumental help seeking, designed to promote learning and understanding in contrast to executive help seeking that is work avoidant, such as asking for solutions and answers. Help seeking has much in common with other regulation strategies employed in response to the lack of comprehension or progress toward desired academic goals. This conclusion was an explicit consequence of the Zimmerman and Martinez-Pons (1990) study in which help seeking was among the SRL strategies more frequently employed by more than less advanced students and consistent with the Zimmerman self-regulation model (e.g., Zimmerman, 1989; 2000). It is decidedly unique, however, in two notable respects: (a) in contrast to cognitive strategies (e.g., memorization or organization), and except for studying with peers, it often involves some form of social interaction, for instance, between students and teachers either in person or increasingly technology mediated; and (b) it is the only strategy that is potentially stigmatizing due to its implications of inadequacy and one that may incur such other personal costs as the need to reciprocate the helper (e.g., Nadler, 1998). Moreover, it may take place at all three phases of the Zimmerman model (see Usher & Schunk, 2018/this volume). For example, in the forethought phase, help seeking may occur as a result of task analysis; in the performance phase as a result of self-observation and error identification; and in the self-reflection phase as a consequence of self-evaluation that suggests the need for further assistance.

Theoretical Approaches to Academic Help Seeking

Help-Seeking Process: Need, Personal Competencies, and Contextual Resources

Although differing in some respects, various help-seeking process models (e.g., Nelson-Le Gall, 1981) include a series of steps or stages, where learners: (1) determine whether they have a problem; (2) determine that help is needed or wanted; (3) decide whether to seek help; (4) select the type of help seeking (i.e., its goal: instrumental or executive help seeking); (5) select the source of help; (6) solicit help; (7) obtain help; and (8) process the help received. It is important to note that although logically sequential, in practice the order of these steps may vary; for example, when the decision to seek help is influenced by the motivation-related characteristics of available help sources (e.g., whether a knowledgeable close friend versus a judgmental performance-oriented teacher).

Theory and research have indicated that adaptive help seeking is facilitated when learners possess a series of cognitive/metacognitive, emotional, and social competencies at each stage of the help-seeking process (see Karabenick & Berger, 2013; Karabenick & Dembo, 2011). Specifically, cognitive/metacognitive competencies are related to the awareness of the existence of a problem, understanding that help is needed in order to overcome it, and knowing how to seek help (e.g., to ask questions). Affective-emotional competencies and/or resources are needed to regulate learners' beliefs and emotions when coping with difficulty and threats to self-esteem that include the embarrassment that may accompany appearing incompetent. Social competencies include selecting the appropriate sources of help under different conditions, and if help is sought from another individual, the skills to approach those sources in a socially acceptable manner. In addition to the above personal competencies, contextual resources such as supportive characteristics of the learning environment and knowing situational norms (e.g., classroom rules) or obtaining help also play an important role in the help-seeking process.

The process model described above implies that help seeking should be directly related to the learners' perceived need for help. Need becomes obvious to participants in experimental studies in which learners are made to fail at a series of tasks (e.g., Butler, 1998), but learners may not always be aware they need help in many circumstances. Failure at this micro-level of SRL (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Efklides, 2011; Greene & Azevedo, 2009) is primarily attributed to metacognitive deficits due to the lack of awareness of the task situation and the relationship between the task and the learner (Efklides, 2011; Tobias & Everson, 2009). The observed relation between need and help seeking may also be non-monotonic due to the influence of factors other than need. For example, poorly performing students, who objectively need help the most, may not seek help due to feeling hopeless or threatened, or due to the lack of adequate help-seeking skills such as the inability to formulate questions (Karabenick & Knapp, 1988a; Renkl, 2002).

Understanding the relation between need and help seeking was advanced by research that focused on statistically controlling for need levels or the use of conditional likelihood estimates (i.e., intentions). For example, in a study testing the proposition that better students, those who more frequently use other learning strategies, are more likely to seek help, reported strategy use was not directly related to help seeking (Karabenick & Knapp, 1991), in part because students using more strategies were less likely to need help. They were more likely to seek help, however, when need levels were taken into consideration, or when using conditional statements that asked students the likelihood they would seek help if needed.

Whether help is solicited, obtained, and processed (see Karabenick & Berger, 2013; Karabenick & Dembo, 2011) also depends on whether learners possess the cognitive and social competencies described above. How to start a conversation, address a question, ask for help, obtain the help needed, and process the help, accordingly, are important skills that facilitate learners' help seeking. Moreover, being the only self-regulatory strategy, other than peer learning, that is potentially social in nature, in many instances learners need to possess appropriate social skills for seeking help from a variety of sources. For example, asking for help from teachers required different competencies compared to doing so from friends or more knowledgeable classmates (Makara & Karabenick, 2013).

Contextual Resources in Educational Settings

Contextual resources in schools determine the rate and effectiveness of help seeking. For instance, Newman (2000) described the role teachers play in the socialization of students' help seeking that includes both teacher instrumental and emotional support: (a) a personal relationship with students that may facilitate student-teacher communication, (b) academic goals that are supportive of SRL, and (c) daily learning experiences that help children develop questioning skills and promote academic competence. In the same vein, Butler (2000, 2006) described the formal and informal messages conveyed about the benefits and costs of help seeking when coping with difficulty, and variations both in the degree to which teachers support student questioning and the ways they respond to students' bids for help that facilitate adaptive help seeking in the classroom. For example, teachers' ability to know or infer students' need levels is essential when responding appropriately to requests for help, especially for those less familiar with learners such as new teachers in a class or those who only teach a few hours per week in several different classes. Fortunately, teachers, especially those in elementary grades, are generally capable of inferring need given their frequent interactions with students and access to other information, such as test scores (Ryan, Patrick, & Shim, 2005).

Technological Advances and Academic Help Seeking

Described initially by Keefer and Karabenick (1998) and more recently by Karabenick and colleagues (Karabenick & Berger, 2013; Karabenick & Puustinen, 2013; Mäkitalo-Siegel & Fischer, 2011), the rapid expansion of Information and Communication Technologies and Intelligent Learning Environments (ILEs) that

Kitsantas and Dabbagh (2010) have designated Integrative Learning Technologies have markedly changed the help-seeking environment. Many instructional ILEs include help-related features that are integrated into tutoring systems. Among the most pervasive is the Cognitive Tutor and its Help Tutor companion (e.g., Roll, Aleven, McLaren, & Koedinger, 2007) that deliver context-sensitive help based on models of the adaptive help-seeking process. A key feature consists of learners' options to select help that ranges from general information that is considered adaptive (e.g., glossaries) to all too-frequently selected complete solutions which is considered maladaptive (i.e., executive help or "bottoming out"). An additional purpose of the Help Tutor involves training adaptive help-seeking skills that are generalizable to other instructional contexts (Roll et al., 2007), and features of the Tutor led to the discovery that greater learning benefits can result when students with low prior knowledge persist at tasks and avoid rather than seek help (Roll, Baker, Aleven, & Koedinger, 2014). Similarly, Ecolab (Luckin, 2013), based on Vygotsky's zone of proximal development (ZPD), scaffolds learners by providing assistance that is just beyond a student's ability to progress independently.

One of the major consequences of such technologies is the availability of archived information in ILEs that can be mined to track learners' interactions with each other, with instructors, and with other ILEs (Winne et al., 2006; Mäkitalo-Siegl, Kohnle, & Fischer, 2011). Synchronous and asynchronous communication systems used in classes, as well as during non-class times, can expand opportunities to track the student learning process to more completely understand help seeking and other forms of SRL. The growth of Learning Analytics has also taken advantage of such information to design quasi-metacognitive early warning systems that alert learners of their need for assistance and suggest forms of remediation (Bernacki, 2018/this volume).

Technology also raises the important issue of whether help seeking is necessarily a social form of SRL. It is clearly non-social when help is sought from artificial intelligent systems or "private" devices that are not networked (Karabenick & Knapp, 1988b) or various online sources such as Google or Wikipedia. More generally, whether help seeking can be considered social requires a more nuanced perspective. One approach borrowed from research on social influence (Allport, 1985) is whether presence of "others" is real (e.g., a teacher in a classroom), imagined (e.g., "What would your mother think?"), or implied (e.g., someone will know that I sought help). Whether ILEs and information sources influence help seeking would depend, therefore, on the social characteristics of the learning contexts and motivational consequences in which such artificial systems are embedded (Howley, 2015; Karabenick, 2011; Karabenick & Knapp, 1988b). Application of social influence theory expands the category of situations in which help seeking can be considered social self-regulation, especially those when social is implied (Karabenick, 2011; Keefer & Karabenick, 1998). Nevertheless, instances where seeking help is clearly private (e.g., Karabenick & Knapp, 1988b) preclude categorically classifying help seeking as necessarily social SRL. A more appropriate classification would, therefore, designate help seeking as a resource management strategy, or more accurately as an external resource management strategy (Karabenick, 2014), that is, an SRL strategy applicable in any goal-driven learning and performance context.

Advances in the Construal of Help-Seeking Sources

As noted at the outset, source considerations can play an important role in the decision to seek help. Early studies of academic help seeking, as well as more contemporary research (e.g., Reeves & Sperling, 2015; Ryan & Pintrich, 1997; Ryan & Shim, 2012), focused on the distinction between informal (e.g., peers) and formal sources (e.g., teachers) and their impact on learners' perceived benefits and costs of seeking help (Newman, 2008). Alternatives have become both more varied and more complex in part due to technology's provision of increasing access to potential help resources. Makara and Karabenick (2013) have proposed a framework designed to bring greater conceptual clarity to the help resource landscape. The framework specifies four ways to characterize sources: formal vs. informal, personal vs. impersonal, mediated vs. face-to-face, and dynamic vs. static. Importantly, these are understood as learners' subjective appraisals or construals rather than how the characteristics are specified a priori. For instance, teachers may be viewed as relatively formal depending on how friendly they are perceived. In addition, although presented as dichotomous, in many cases the appraisals fall

along a continuum, such as a college teaching assistant who may be viewed somewhere between a formal and informal source.

Peers are generally classified as informal sources by younger as well as college students, and considered more approachable than formal sources (Ryan & Shim, 2012). Informal sources are generally viewed as less authoritative, especially when compared to formal sources (e.g., teachers). Although potentially more available, informal sources may also be less likely to provide requested help compared to formal sources that provide help due to their role obligations. Sources can also be differentiated into those considered more personal versus more impersonal. Impersonal sources are those in which the relationship between the helper and help seeker is perceived to be distant, formal, or indifferent. Personal sources are usually viewed as close, although they need not be face-to-face relationships. Learners can feel a personal connection to friends, online strangers, and even avatars. Instructors and peers are generally viewed as personal sources, compared to such impersonal sources as textbooks, course websites, and search engines. A chat room could be positioned somewhere in between since it is personal in the sense that there are other individuals contributing, but impersonal to the extent that learners may be unaware of with whom they have a limited personal relationship. Personal help may be perceived as of higher quality when it can be tailored to the help seekers' needs. Technology can also alter how personal a help source is perceived to be, such as whether the source is someone who has been "friended" on a social networking site.

As noted above, communication with sources can be mediated via some form of technology or face-to-face. Mediated sources of help include discussion boards, emails, phone conversations, course sites, search engines, and textbooks. Mediated sources may be more accessible than sources that require face-to-face interaction and potentially more threatening compared to, as discussed previously, mediated sources that can be relatively private (Karabenick & Knapp, 1988b). Whether access to a source is face-to-face or mediated may even influence whether the act is interpreted as "searching for information" or "seeking help" (see Tricot & Boubée, 2013). Finally, sources may differ in whether they accommodate to learners' help-seeking needs, and thus be categorized as dynamic versus static (Schworm & Nistor, 2013) or capable of adapting to the learner help-seeking needs. Cognitive tutors, discussed earlier (Aleven, McLaren, & Koedinger, 2006), are typically dynamic compared to static web pages given their ability to offer context and performance-contingent help.

This may not be a complete list of dimensions, however; for example, Huet et al. (2013) has also proposed distinguishing between systems of help that are user created compared to those formally established. To reiterate, regardless of what frameworks are used, it is important to keep in mind that the impact of the source depends on learners' source construals. Research is needed to understand how learners distinguish between sources and how their own cognitive map of resources contributes to their likelihood of seeking help.

Academic Help Seeking: Research Evidence

Initial studies of motivational influences on help seeking examined elementary and middle school students' perceived benefits, and the threat-related costs that appear to begin in middle school (e.g., Butler, 1998; Newman, 1990; Newman & Schwager, 1993). Early studies also found that low achievement was associated with the reluctance to seek help, indicating that those students who are more in need for help are often less likely to ask for it although they are aware they need it, and continue to experience poor achievement and failures (Newman & Goldin, 1990).

Help-Seeking Orientations

Butler (1998) identified three reasons or orientations to seek or avoid seeking help: (a) autonomous (i.e., focused on learning and understanding when seeking for help or on independent accomplishment when being reluctant to seek help), (b) ability-focused (i.e., wanting to be successful or highly concerned with perceived threat to competence), and (c) an expedient orientation (i.e., focused on expediting task completion and work avoidance or on perceptions that asking for assistance will not expedite task completion). The above orientations were

associated with different patterns of help seeking or its avoidance. An autonomous orientation was associated with instrumental help seeking, such as asking for facilitating hints when really needed or after working on a task alone longer than other students, whereas an expedient orientation was related to executive help seeking, such as asking for answers instead of hints after spending little time on the problem alone. Those with ability-focused orientations perceived a threat to their competence and were more reluctant to seek help and more likely to cheat. An alternative classification proposed by Ryan et al. (2005) designated help-seeking orientations as appropriate, avoidant, and dependent. Students with an appropriate help-seeking orientation sought help when needed compared to those with an avoidant orientation, which was considered most maladaptive. Those with a dependent orientation tended to ask for help the minute they faced difficulty, with a mixed motivational profile that shared adaptive and avoidant characteristics.

Motivational Approaches

Most research on motivation and help seeking has adopted achievement goal theory, although recent research has begun to focus on expectancy-value theory (Karabenick, 2016). At the individual level, achievement goal orientations have been consistently associated with student help seeking (Butler & Neuman, 1995; Karabenick, 2004; Ryan, Hicks, & Midgley, 1997). Mastery-oriented students (i.e., those focused on understanding and improvement) are more likely to seek instrumental help, less threatened by help seeking, less likely to avoid seeking help, and less likely to seek expedient or executive help. By contrast, those with higher levels of performance-approach (i.e., focused on performing better than others) and performance-avoidance orientations (i.e., concerned about performing worse than others) are more threatened by help seeking, more likely to avoid seeking help, and more likely to seek help for expedient reasons (Karabenick, 2003; Ryan & Pintrich, 1997). Substantial research has also studied the social analogues of achievement goals, which in their most recent versions have been conceptualized as social development goals (i.e., improving social relationships and social skills), social demonstration-approach goals (i.e., desiring positive feedback from others and gaining social prestige), and social demonstration-avoid goals (i.e., avoiding negative judgments from others as being socially undesirable). Similar to results with achievement goals, having a social demonstration-approach goal is negatively related to adaptive help seeking but, surprisingly, having a social demonstration-avoid goal is sometimes not related to avoidant help seeking (Ryan & Shin, 2011).

The Role of Context

An extensive body of research has also studied motivation and help seeking in relation to contextual factors. With the class as the unit of analysis, assessed by aggregating students' perceptions, often designated as achievement goal structure, a number of studies have indicated that students in U.S. elementary and middle school classes that are more mastery-focused are less likely to avoid seeking needed help (Ryan, Gheen, & Midgley, 1998; Turner, Midgley, Meyer, Gheen, Anderman, Kang, & Patrick, 2002). The classroom influence of perceived performance goals appears to begin in U.S. middle schools and continues into high school (Karabenick, Zusho, & Kempler, 2005; Ryan et al., 1998). Recent evidence involving aggregated student perceptions of their middle and high school math classes found effects for both mastery and performance goal structure (Schenke, Lam, Conley, & Karabenick, 2015). Specifically, students in classrooms collectively perceived to be more mastery-oriented at the beginning of the school year increased their instrumental help-seeking intentions and seeking help from peers at the end of the year, whereas performance-approach goal structure at the beginning of the year predicted decreases in reported intentions to seek help from teachers and positively predicted expedient help-seeking intentions at the end of the year. The influence of class-level mastery goal structure apparently diminishes by the time students reach college, however, where only class aggregated estimates of performance goals have predicted class differences in help-seeking intentions (Karabenick, 2004).

In addition to research on aggregated achievement goals, classes in which middle and high school students perceived higher levels of support (i.e., composite measure that combined perceived teacher support for student collaboration and student questioning, teacher fairness, and respect and caring) were more likely to seek adaptive

help (Karabenick et al., 2005). Consistently, college students in classes with teachers they perceive as more supportive to their questions are more likely to have questions, less inhibited to ask them, and are thus more likely to ask questions when necessary. By contrast, students with teachers they perceive as less supportive are more likely to report being confused and to feel more threatened by having to ask the questions that could assist in alleviating that confusion (Karabenick & Sharma, 1994; see also Kozanitis, Desbiens, & Chouinard, 2007). In the same vein, both perceived teacher instructional support (e.g., questioning, clarifying, feedback provision), the strongest predictor of help seeking, and emotional support (e.g., encouragement, empathy, friendliness) have predicted academic help seeking in adolescents; in addition, emotional support was related to lower levels of perceived threat from perceptions of inadequacy (Federici & Skaalvik, 2014).

Future Research Directions

Help seeking has been acknowledged as an important adaptive SRL strategy for more than three decades. And since the 1980s, an extensive body of theoretical and empirical work has shed light on many aspects of this critical learning strategy, including the different types of help, the help-seeking process, the competencies required, the sources of help, and the person and situation factors related to seeking help. However, there are at least three critical issues in the field of help seeking that need further investigation: (a) consequences of advances in self-regulation of learning in ILEs (e.g., Azevedo, Taub, & Mudrick, 2018/this volume; Reimann & Bannert, 2018/this volume), (b) the need to test the effectiveness of help-seeking-focused intervention programs for students with a vulnerable help-seeking profile, and (c) the need for more developmental research on help seeking (see Hoyle & Dent, 2018/this volume).

As discussed above, technology-supported learning and communication environments have resulted in major changes in help-seeking theory and research (see Karabenick & Puustinen, 2013; Mäkitalo-Siegel & Fischer, 2011). Vitally important, the rapid growth of information technology has made myriad resources accessible almost instantly. Although an apparent blessing, as in other areas of functioning, the challenge many face is learning to manage these resources which frequently may require mastering new skills, and the prospect of whether and how this abundance has and will increasingly result in more executive help seeking (e.g., students find ready-made schoolwork on the Internet) as it has in help-assisted tutoring systems (Aleven et al., 2006). This resource management strategy (Karabenick, 2014) requires further conceptual and empirical examination. And more research is needed taking into consideration the earlier discussion that included the criteria defining the nature of social interactions, since technology can be used both as a mediator for access to help from other people and as a direct source of help (Karabenick, 2011).

Second, a major challenge is improving the effectiveness of intervention programs designed to facilitate adaptive help seeking, especially for those with vulnerable help-seeking cognitive/metacognitive and/or motivational profiles. Recommendations to instructors for creating help-seeking-friendly learning environments that would promote all learners' help-seeking adaptive beliefs, attitudes, competencies, and behaviors in school classrooms have been suggested in the literature (e.g., Karabenick & Berger, 2013). However, further studies are needed to verify evidence-based systematic interventions designed to promote adaptive help seeking either at a primary or a secondary prevention level (i.e., aiming to address the whole class before help-avoidance behaviors occur or aiming to meet the needs of help-seeking avoidant students to reduce help-seeking vulnerability). Moreover, it would be important to know whether such interventions would function better as part of a broader training program on SRL or as a distinct intervention program. A further advance in the field would be a focus on teachers' help-seeking beliefs, attitudes, and behaviors and their relation to support for student help seeking (Butler, 2007).

Third, despite the number of studies on help seeking among elementary, secondary, and college students, with the exception of Newman's (2000) pivotal contribution, few studies have adopted a developmental perspective (e.g., Butler & Neuman, 1995; Gonida, Karabenick, Makara, & Hatzikyriakou, 2014; Nelson-Le Gall, Gumerman, & Scott-Jones, 1983). Clearly, more developmental research on seeking or not seeking help is needed, particularly in regard to variables that might support or undermine adaptive help seeking at different ages. Help seeking has

been conceptualized as a developmental skill (e.g., Butler, 2006; Nelson-Le Gall, 1985; Newman, 1990); a developmental approach is therefore relevant when examining such critical issues referred to previously as the recognition of the need for help, the personal and social competencies required for help seeking, the selection of help-seeking sources and how contextual resources are perceived. Independent of their age and grade level, learners will inevitably be in challenging situations, and help from other sources would be significant for overcoming difficulties. However, it is clear that help-seeking interventions need to be tailored to accommodate different age groups and class levels.

In summary, a constellation of factors points to the increasing importance of research on the role that help seeking plays in the learning process. As long as learning environments change and scientific theories about learning and learners change as well, the strategy of seeking needed help will always be an important part of learners' toolkits. Failure to provide such tools is not an option given the increasing complexities of negotiating the process of knowing if learners have a problem, whether help will alleviate the problem, whether to seek help, the type of help, and the optimal resources from which to select.

Implications for Educational Practice

All the above theory and research has significant implications for promoting help seeking as an adaptive SRL strategy in educational settings. Our previous discussion on the role of context has indicated that most of the relevant literature has approached seeking or not seeking help along two axes in regard to learning environments: classroom goal structures (i.e., mastery or performance) and teacher support (i.e., instructional and/or emotional). These two axes may represent different lines of theory and research (i.e., achievement goal theory and classroom social climate research, respectively), which are complementary, and both emphasize the role of teachers in creating learning environments friendly to help seeking (see Butler & Shibaz, 2008; Schenke et al., 2015).

Help-Seeking-Friendly Learning Environments

As discussed earlier, accumulated evidence that includes elementary school to college students indicates that mastery-focused learning environments constitute a favorable academic context that promotes help seeking for all learners in everyday school/academic life (e.g., Butler, 2000; Du, Xu, & Fan, 2016; Karabenick, 2004; Karabenick & Sharma, 1994; Karabenick et al., 2005; Kozanitis et al., 2007; Schenke et al., 2015; Skaalvik & Skaalvik, 2013; Turner et al., 2002). In a mastery, but certainly not in a performance environment, teachers may foster instrumental help seeking as an adaptive SRL strategy by inviting students to discuss and exchange their beliefs about help seeking, by using role playing with peers, or by modeling the help-seeking process themselves. In other words, teachers need to purposefully devote instructional time to learning experiences that provide students, first, with opportunities to change mal-adaptive help-seeking beliefs and, second, to develop the required instrumental help-seeking competencies while working on specific tasks (Karabenick & Berger, 2013). This can be further facilitated in cooperative classrooms with or without technological resources, where classmates work in collaborative learning groups and have frequent opportunities to experience beneficial social aspects of learning such as socially shared regulation of learning (Järvelä, 2011; see also Hadwin, Järvelä, & Miller, 2018/this volume).

Despite the different labels that have been used in the literature to describe teacher support, in general, instructional or instrumental and emotional types of support are the prevalent categories. Instrumental support is that which teachers may provide to students in their attempt to contribute to better understanding, improvement, and school success, whereas emotional support is primarily related to student-teacher relationships and teachers' caring for students. Both types have been found conducive to help seeking but via different paths. Instrumental or instructional support contributes to the enhancement of students' cognitive and metacognitive competencies, and emotional support primarily contributes to the motivational and social competencies required for adaptive help seeking. Thus, in their everyday instruction, teachers need to adopt, on the one hand, behaviors such as questioning, clarifying, feedback provision, and modeling and, on the other hand, provide their students with

positive emotional support such as encouragement and respect for their needs. More specifically, teachers should encourage students to seek needed help, limit their hesitation to address questions, and support their questioning by complimenting students who ask questions and by devoting sufficient time to respond to their questions. Further, teachers should design challenging assignments for their students that create opportunities in class or in homework to experience difficulty as part of their learning and personal development. It would also be important for them to publically acknowledge to their students that seeking needed help is an adaptive way to alleviate difficulty. They should avoid encouraging students to persist alone indefinitely or praise them only for independent strivings, and of course should never ignore student requests for help (e.g., Butler, 2006; Du et al., 2016; Karabenick & Sharma, 1994; Federici & Skaalvik, 2014; Strati, Schmidt, & Maier, 2017).

Unfortunately, many classrooms may constrain the application of these practices due to such practical limitations as time, the need to cover the material, or having to contend with a large number of students. Moreover, teachers themselves may hold maladaptive beliefs and attitudes toward help seeking by themselves as well as their students (see Butler, 2007). In addition, even some teachers who hold adaptive beliefs about help seeking need to be mindful of how they respond to students, because positive behaviors on their part may not be perceived as such, especially by students with a vulnerable motivational profile characterized by self-threatening concerns or by students with poor self-regulating strategic tendencies that are less likely to result in academic success (Butler, 2006; Karabenick & Sharma, 1994). Teachers and other instructional staff can also help students contend with the array of helping resources that are increasingly available, especially at higher grade levels and in post-secondary contexts. Finally, it is important to recognize that these suggestions extend beyond the classroom, in view of evidence that perceived parent beliefs, achievement-related messages, and behaviors are related to help seeking (Bong, 2008; Gonida et al., 2014; Newman, 2000; Puustinen, Lyyra, Metsapelto, & Pulkkinen, 2008).

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28 The Three Facets of Epistemic Thinking in Self-Regulated Learning

Krista R. Muis and Cara Singh¹

Are vaccines safe? What are the health implications of eating genetically modified foods? Are humans the major cause of climate change? Answers to these questions have become hotly debated issues of global concern that have taken the Internet and social media by storm. For example, a quick online search of the vaccine question results in over 30 million hits. Only 45% of these sites contain scientifically accurate information (Kortum, Edwards, & Richard-Kortum, 2008). What sites do parents turn to when making decisions about whether they should vaccinate their child? Do they evaluate the source of the information? Do they critically evaluate the content? As access to self-authored, unregulated Web 2.0 online content continues to grow exponentially (Kata, 2012), it is imperative that individuals today have the skills necessary to identify reliable sources of information and to grapple with complex and often contradictory content. Even in formal educational contexts, research has shown that students rely heavily on Web content for general and academic information (Metzger, Flanagin, & Zwarun, 2003). For individuals to make informed decisions regarding these socio-scientific issues, and for students to select high-quality content from which to learn, it is critical that they develop appropriate learning skills and the ability to evaluate the epistemic aspects of new information. That is, individuals must become highly self-regulated learners and engage in high-quality epistemic thinking.

Self-regulated learning (SRL) is defined as an event that unfolds during learning that is goal directed and includes cognitive, metacognitive, motivational, affective, and social components. Following Barzilai and Zohar (2014), we define epistemic thinking as a multifaceted view of personal epistemology that, in basic terms, is the study of individuals' thinking about knowledge and knowing (Hofer & Pintrich, 1997). What lies at the intersection of these two theoretical constructs is the potential to develop a citizenry capable of making informed decisions about issues of global importance and how to navigate the complexities of knowledge today. Why these two constructs? As theoretical and empirical work in SRL began to flourish in the 1980s and '90s (Dinsmore, Alexander, & Loughlin, 2008) alongside theoretical and empirical work in personal epistemology (Schommer, 1990), theorists began to realize that one influential learner characteristic that plays an important role in SRL includes individuals' beliefs about knowledge and knowing, or learners' epistemic beliefs (Hofer & Pintrich, 1997; Winne & Hadwin, 1998). Early research that explored relations between epistemic beliefs and SRL found that epistemic beliefs predict: how individuals approach mathematics problems (Schoenfeld, 1985); reading comprehension standards (Ryan, 1984); and self-reported use of learning strategies during learning (Schommer, 1998), to name a few.

Since then, researchers have explored relations between epistemic beliefs and SRL and, based on their studies, Muis (2007) developed a theoretical model that delineates how and why epistemic beliefs relate to various facets of SRL. Since 2007, over 200 empirical studies have been published that explore relations between some form of epistemic thinking and SRL. Additionally, conceptualizations of beliefs about knowledge and knowing have also evolved, as has our own thinking about epistemic thinking. Accordingly, what we present in this chapter is an integrated conceptualization of epistemic thinking, which is informed by current theories of epistemic cognition (Chinn, Buckland, & Samarapungavan, 2011) and epistemic metacognition (Barzilai & Zohar, 2014). Inherent in each of the components of SRL are aspects that focus specifically on the nature of knowledge and knowing. As such, the various facets of epistemic thinking are central mechanisms that drive SRL but are also a regulated aspect during learning. The chapter begins with a description of the three facets of epistemic thinking followed by an integrated theoretical model of epistemic thinking within SRL. Empirical work is presented that supports hypothesized relations between epistemic thinking and SRL, with a specific focus on epistemic beliefs. Future directions for research that tap into areas that have yet to be explored are then delineated. The chapter ends with implications for educational practice.

Theoretical Frameworks

Epistemic Thinking

In a very fruitful line of research, developmental and educational psychologists have explored individuals' thinking about knowledge and knowing. Various topics within this line of research include beliefs about knowledge, what the sources of knowledge entail, how knowledge is justified, what constitutes truth and evidence, and the domain specificity of beliefs, among many others. Since Perry's (1970) seminal work with Harvard undergraduate students, several theoretical frameworks have been established that can be delineated along two lines of research: developmental frameworks (e.g., Baxter Magolda, 2004; King & Kitchener, 1994; Kuhn, 1991), and multidimensional frameworks (e.g., Greene, Azevedo, & Torney-Purta, 2008; Hammer & Elby, 2002; Hofer & Pintrich, 1997; Muis, Bendixen, & Haerle, 2006; Schommer, 1990). Different researchers have also used numerous labels to describe the various facets of epistemic thinking, including epistemological beliefs (Schommer, 1990), epistemic beliefs (Mason, 2003), epistemic cognition (Chinn et al., 2011; Kitchener, 2002), epistemological reflection (Baxter Magolda, 2004), epistemological resources (Hammer & Elby, 2002), and reflective judgment (King & Kitchener, 1994). Developmental models have examined how individuals move through a patterned sequence of development, whereas multidimensional frameworks have considered thinking about knowledge and knowing to include multiple dimensions that are relatively independent (Schommer, 1990) or more theory-like (Hofer & Pintrich, 1997). Due to space constraints, the various frameworks are not delineated here, as they have been fully elaborated elsewhere (see Greene, Sandoval, & Bråten, 2016; Hofer & Pintrich, 1997; Muis, 2004; Muis et al., 2006). Rather, an overview of the two general frameworks is presented, followed by our integrated framework.

Developmental Frameworks

Researchers within the various developmental frameworks view epistemological development as a progression through different qualitative levels of epistemological thought. Although different labels have been used, each level or stage can be similarly described based on Kuhn's framework (Kuhn & Weinstock, 2002). At the first stage, young children are considered direct realists wherein they view knowledge as a direct copy of reality. In the second stage, the absolutist stage, individuals view knowledge as definitively right or wrong. They believe that knowledge is objective, reflects the true state of the world, and that authority figures have all the answers. After being exposed to more conflicting paradigms, individuals move into the multiplist stage wherein different and conflicting views are considered equally valid, that one point of view is as good as another, and all points of view are mere opinion. Finally, at the last level, individuals begin to realize that there are multiple possibilities for knowledge and knowledge claims must be evaluated for the quality of the argument and its supporting evidence. Knowledge is considered as uncertain, but tentative conclusions are possible given a general consensus.

Multidimensional Approaches

In contrast to the developmental views, multidimensional frameworks view thinking about knowledge and knowing as a set of multiple dimensions that are relatively independent (Schommer, 1990), more theory-like (Hofer & Pintrich, 1997), or contextually specific epistemological resources that entail fine-grained cognitive resources that individuals use to understand and reflect on knowledge, its forms, and their stances (Louca, Elby, Hammer, & Kagey, 2004). The most prominent multidimensional framework is Hofer and Pintrich's (1997), which generally captures the multiple dimensions across the varying perspectives. According to Hofer and Pintrich (1997), multidimensional frameworks can be combined to reflect four belief dimensions about knowledge (i.e., the first two dimensions) and knowing (i.e., the last two dimensions): (1) the certainty of knowledge, which ranges from a belief that knowledge is unchanging to knowledge is evolving; (2) the simplicity of knowledge, ranging from a belief that knowledge is isolated bits and pieces of information, to knowledge is organized as highly related concepts; (3) the source of knowledge, ranging from knowledge as handed down by authority to knowledge is acquired through logic and reason; and (4) justification for knowing, ranging from

authority figures being unquestionably correct to a critical evaluation of knowledge claims and the use of evidence to justify those claims through logic and reason.

These beliefs are typically described as ranging from a less constructivist view of knowledge (i.e., knowledge is simple, certain, handed down by authority, and blindly accepted as true) to a more constructivist view of knowledge (i.e., knowledge is complex, tentative, derived through logic and reason, and critically evaluated). More recently, theorists have expanded the dimensions to take into consideration multiple subcomponents of justification (Greene et al., 2008), the domain-specificity and developmental nature of epistemic beliefs (Muis et al., 2006), or more broadly articulated philosophical perspectives that include epistemic aims and values, epistemic achievements, epistemic virtues and vices, and reliable and unreliable processes for achieving epistemic aims (Chinn et al., 2011).

The Three Facets of Epistemic Thinking: An Integrated Perspective

Given the multiple components that researchers have explored, following Barzilai and Zohar (2014), we adopt the term epistemic thinking, as it implies a multifaceted view of the broader literature and includes all aspects that researchers have explored over the past several decades, including more recent conceptualizations (Chinn et al., 2011). Specifically, like Barzilai and Zohar (2014), we argue that epistemic thinking includes three facets: (1) epistemic cognition, (2) epistemic metacognition, and (3) epistemic experiences.² Epistemic cognition is defined as thinking about the epistemic characteristics of particular information, including knowledge claims and their sources, as well as the enactment of epistemic strategies and processes for reasoning about that information, its sources, and knowledge claims (Barzilai & Zohar, 2014), which are all directed at epistemic aims (Chinn et al., 2011). Epistemic aims are goals that individuals set that focus specifically on acquiring true, justified beliefs; beliefs that accurately reflect the state of world, which are supported by sufficient reasons. Individuals may also set an epistemic aim of understanding by forming complex, explanatory connections across various information (Kvanvig, 2003), or set the epistemic aim of merely “knowing” something by being able to recite the information. As such, three products that result from epistemic aims being achieved include knowledge, understanding, and beliefs (Chinn et al., 2011). One additional component of epistemic cognition related to achieving epistemic aims includes reliable and unreliable processes (Chinn et al., 2011). This component focuses on the causal processes by which one can achieve knowledge, understanding, or other epistemic aims, through various epistemic strategies.

Epistemic strategies include, for example, evaluating the accuracy of incoming information against one’s own prior knowledge (i.e., knowledge-based validation [Richter & Schmid, 2010]) or with what one has already processed from a current text or learning situation (i.e., consistency checking [Richter & Schmid, 2010]), both of which are considered epistemic validation strategies. Epistemic strategies may also include an evaluation of the incoming information against one’s epistemic beliefs. Justification strategies include providing reasons in support of a claim or in support of an answer to a complex mathematics problem (Muis, 2008; Muis & Franco, 2010), providing reasons for evidence, and evaluating the quality of the reasons and evidence put forward by others (Barzilai & Zohar, 2012), to name a few. Sourcing strategies include evaluation of the trustworthiness, credibility, and reliability of sources (Bråten, Strømsø, & Britt, 2009), and integrating multiple viewpoints, which requires evaluating multiple sources, comparing and contrasting claims made, evaluating the quality of evidence provided for each claim, and providing explanations to account for differences between the various perspectives (Barzilai & Zohar, 2012; Bråten, Britt, Strømsø, & Rouet, 2011). In addition, it is important to note that from a more traditional philosophical perspective, the sources of knowledge are far more diverse than what educational psychologists have typically explored (cf. Chinn et al., 2011; Murphy, Alexander, & Muis, 2012). More contemporary perspectives on philosophical epistemology suggest there are six sources of knowledge: perception (i.e., extraction of information through the five senses), introspection (i.e., the attention the mind gives to itself and its own operations), memory, testimony (e.g., authority or experts), inference (through valid induction or deduction), and reason (Bernecker & Dretske, 2007). These entail just some of the epistemic strategies that individuals may use during knowledge construction.

The metacognitive facets of epistemic thinking are similar to the more classic definitions of metacognition, which include knowledge of one's own cognitive processes and the regulation of those processes (Brown, 1978; Flavell, 1976). As such, epistemic metacognition entails both epistemic metacognitive skills and epistemic metacognitive knowledge regarding the nature of knowledge and of knowing strategies and processes. Epistemic metacognitive skills include processes of regulation and control of epistemic cognition that include planning, monitoring, control, and evaluation of one's knowledge and of one's epistemic cognitions. Epistemic metacognitive knowledge entails knowledge, beliefs, ideas, and theories regarding the nature of knowledge and knowing, which have typically been labeled as epistemic beliefs.³ The four dimensions described by Hofer and Pintrich (1997) fall within this category, but have recently been expanded to include multiple sub-dimensions within each. For example, Chinn et al. (2011) proposed that beliefs about the structure of knowledge should also include beliefs about the universality of knowledge (i.e., universal laws) versus its particularity (i.e., context specific), and the deterministic nature of knowledge (i.e., one determined outcome) versus stochastic knowledge (i.e., probabilistic outcomes, not fully predictable). For justification for knowing, in addition to logical coherence or justification by authority in more traditional conceptualizations, Chinn et al. (2011) have also called for inclusion of more fine-grained analyses, which may include beliefs about the precision of the evidence, its elegance, or fruitfulness.

Epistemic metacognitive knowledge can be divided into two more subcomponents: knowledge about the individual and others as knowers, which Barzilai and Zohar (2014) call epistemic metacognitive knowledge about persons, and epistemic metacognitive knowledge about strategies and tasks. This second subcomponent entails knowledge about how to carry out an activity that will lead to knowing, what epistemic strategies to use under what conditions to achieve epistemic aims, and whether those epistemic strategies are reliable or unreliable as a function of the specific context under which they are employed.

The last facet of epistemic thinking in our integrated model is epistemic experiences, which include both epistemic affect and epistemic motivation. For both epistemic affect and epistemic motivation, the object focus of the affective or motivational experience is on the nature of knowledge and knowing. As such, affect or motivation is evoked by processes of knowledge construction and justification (Barzilai & Zohar, 2014; Efklides, 2011) or perceptions of those processes. Affective experiences may arise out of information-oriented appraisals (i.e., the cognitive component) when the incoming information aligns with existing beliefs or knowledge structures, but also arise when there are inconsistencies or other discrepancies in processing the information that cause cognitive disequilibrium (D'Mello, Lehman, Pekrun, & Graesser, 2014). Although other theorists have labeled the emotions that arise from these experiences as knowledge emotions (Silvia, 2010), or cognitive states (Clore & Huntsinger, 2007), we call them epistemic emotions due to their object focus (Pekrun & Stephens, 2012). For example, when an individual sets the epistemic aim to understand something and achieves that goal, he or she may experience enjoyment in achieving that aim. In contrast, if incoming information is inconsistent with prior knowledge, an individual may first experience surprise, followed by confusion due to the discrepancy. Other experiences, such as feelings of uncertainty, an epistemic metacognitive experience, may trigger curiosity to resolve that uncertainty. Finally, motivational experiences that entail a specific epistemic component include, for example, epistemic self-efficacy, which Trevors, Feyzi-Behnagh, Azevedo, and Bouchet (2016) defined as individuals' confidence in their ability to evaluate knowledge claims conveyed by external sources and themselves as sources of knowledge. We suggest a broadening of the term epistemic self-efficacy to include confidence in being able to carry out any epistemic cognitive process.

Taken together, the three facets of epistemic thinking include epistemic cognition, epistemic metacognition, and epistemic experiences. Like Hofer (2004) and Barzilai and Zohar (2014), we consider epistemic thinking as inherently part of existing cognitive structures rather than a separate entity. Key to epistemic thinking is its object focus and, given that it is part of an existing cognitive structure, its various facets are also an inherent part of SRL. As such, epistemic thinking plays a key role in SRL but is also regulated during learning. In the sections that follow, an updated version of Muis's (2007) original model of SRL is delineated, which is followed by detailed propositions that specify how and why epistemic thinking influences various facets of SRL.

Epistemic Thinking in Self-Regulated Learning

Drawing on goal oriented (Pintrich, 2000) and metacognitively driven (Winne, 2018/this volume) models of SRL, we propose an integrated model to establish the role that epistemic thinking plays in SRL. Like most models of SRL, there are four phases of learning and five areas for regulation.⁴ The four phases include: (1) task definition, (2) planning and goal setting, (3) enactment, and (4) evaluation. The five areas for regulation include cognition (e.g., knowledge activation, epistemic cognition, epistemic aims), motivation (e.g., achievement goals, self-efficacy, epistemic self-efficacy, task value, epistemic value), affect (e.g., epistemic emotions, achievement emotions), behavior (e.g., time on task, effort expenditure, removal of distractions, help seeking), and context (e.g., resources, instructional cues, time available to complete task, assessment methods, quality of to-be-learned content, social context). Where appropriate, we describe how context plays an important role under various conditions, but focus primarily on how each of the components within the internal system may influence other components directly or indirectly.

Phase 1: Task Definition

In Phase 1, a learner generates a perception about the context, task, and the self in relation to the task. The resulting perception of the task is what defines it, and this perception is influenced by the external conditions, such as context and behavior (i.e., two of the five areas for regulation), and the cognitive, motivational, and affective conditions (i.e., the other three areas for regulation). In contrast, the cognitive, motivational, and affective conditions are derived from information the learner activates or retrieves from long-term memory. Information activated or retrieved includes learners' beliefs, motivational and affective factors related to the specific task (e.g., self-efficacy, achievement goals, task interest/value, trait emotions about the task, topic emotions), and other cognitive factors including prior knowledge and metacognitive knowledge about strategies and tasks. Once all information about the task, context, and self in relation to the task is activated or retrieved from long-term memory and enters working memory, the learner constructs a specific definition of the task. Once the task is defined, if a learner decides to proceed with the task, a shift to Phase 2 occurs and information activated during Phase 1 interacts and then influences the plans and goals that are set during Phase 2.

Phase 2: Planning and Goal Setting

During Phase 2, the learner begins to devise a plan to carry out the task using specific strategies that automatically come to mind or are recalled from long-term memory (Winne & Hadwin, 1998). Given that knowledge of strategies may have been activated during the task definition phase and brought into working memory, this information may influence the plans and goals the learner sets for learning. Goals are modeled as multifaceted profiles of information (Butler & Winne, 1995) and each standard in each profile is used as a basis against which to compare the products created during learning. When a learner begins to carry out the plans and goals, a transition to Phase 3 occurs.

Phase 3: Enactment

In Phase 3, enactment occurs when the learner begins to work on the task by applying the strategies chosen to carry out the task. When the learner engages in the task by applying the strategies and a step is completed, information (i.e., products) is generated or copied to working memory, and can serve as feedback (Butler & Winne, 1995). If a learner monitors the profile of products created at each step in relation to the goal profile, internal feedback is generated. Additionally, if the product is observable (e.g., the learner engages in a particular behavior or has produced a tangible product like an essay), external feedback may be available if an external source, like a teacher or peer, responds to the learner's behavior. This feedback can be used to assess whether the set goals have been achieved. If any goal in the profile has not been achieved, the information produced from monitoring may be used to adjust or redefine facets of the previous phases. Once the task is complete and products are judged to meet the standards, a learner may engage in Phase 4.

Phase 4: Evaluation

In Phase 4, several types of reactions and reflections are conducted to evaluate the successes or failures of each phase or products created for the task, or perceptions about the self or context. Reactions and reflections also include judgments and evaluations about performance on the task as well as attributions for success or failure. For example, self-judgments are self-evaluations of the effectiveness of one's performance and attributions of causality regarding the outcomes (Zimmerman & Labuhn, 2012). These attributions reflect whether the cause of success or failure is due to effort or ability. Self-reactions can include achievement emotions, specifically outcome emotions (Pekrun, 2006) that arise from the judgments an individual makes about the product, such as pride, relief, shame, guilt, et cetera. Products created during learning are compared to the standards set during Phase 2 via metacognitive monitoring. As such, key to Phase 4 is metacognition, but metacognitive processes can occur during any phase of learning. Additionally, any products created within each phase can feed into other phases, which reflects the cyclical nature of SRL common among most models (Zimmerman & Labuhn, 2012). As such, a learning outcome can be as simple as completing a step in a larger series of steps to take to complete a task (i.e., achieving a specific goal or subset of goals), deriving an answer to one aspect of a problem, or assimilating or accommodating new information into existing knowledge structures.

Based on the description above, the model can be elaborated. The cognitive and affective conditions of a task, which are activated during Phase 1 of SRL, directly and indirectly affect the standards that are set in Phase 2. Each of the components in Phase 1 may also directly influence each other or interact to predict the standards set in Phase 2, resulting in indirect effects of some components from Phase 1 on Phase 2. From Phase 2, the various goals that learners set for the task directly predict the types of strategies that learners will implement during learning in Phase 3. Strategies implemented during Phase 3 directly influence the products created during learning. The central component of SRL is metacognition, which includes processes of monitoring, evaluation, and control of all components of SRL. Although Phase 4 is considered the evaluation phase of learning wherein metacognition is key, metacognitive processes can occur during each phase of SRL, and information elicited during metacognitive processing can feed back into the various phases. Finally, all components from within the internal system in addition to information from the external system (e.g., feedback from a teacher or peer) interact to influence learning achievement.

Next, we elaborate how epistemic thinking influences and interacts with other components within our model of SRL to affect the various processes and products. Due to space constraints, how each facet within epistemic thinking plays a role is not detailed. Rather, the focus is primarily on epistemic beliefs, though others are briefly mentioned. The propositions presented below are based on Muis's (2007) original four propositions, which are updated based on new conceptualizations of epistemic thinking and more recent research. That is, over 200 studies were identified that explored relations between the various facets of epistemic thinking and SRL since 2008. Due to space constraints, not all studies are reviewed here. We do, however, highlight important trends noted across these studies.

Proposition 1: Epistemic Metacognitive Knowledge and Epistemic Experiences Are Components of the Cognitive, Motivational, and Affective Conditions of the Task

Consistent with more global models of memory (Gillund & Shiffrin, 1984; McKoon & Ratcliff, 1992), information in long-term memory is activated when a learner begins to develop a perception of the task. External information about the task, whether instructions from a teacher, peer, or information processed from reading, enters working memory. Any newly encoded information, in combination with the contents from working memory, serves as a signal to all contents in long-term memory, including prior knowledge, and memories of experiences with previous similar tasks. Through spreading activation due to an overlap in semantic features, activation continues and information that has sufficient levels of activation enters working memory (McKoon & Ratcliff, 1998). As such, during Phase 1, perceptions of the task, context, beliefs about the self, and knowledge of the task are activated. Other SRL theorists (Pintrich, 2000; Schunk, 2001; Zimmerman & Labuhn, 2012) also

describe the first phase of learning as one in which these various processes and beliefs are activated prior to behavioral engagement with the task (see also Winne, 2018/this volume). They argue that motivational and affective components are activated, including self-efficacy beliefs, task value, achievement goals, outcome expectations, and intrinsic interest (Zimmerman & Labuhn, 2012).

Building from this, when learners' schemas for domain knowledge or knowledge of a task are activated, learners' beliefs about knowledge and knowing are also activated during the first phase of learning. The activation of epistemic beliefs provides the opportunity for these beliefs to exert an influence over other facets of SRL. However, given their epistemic focus, epistemic beliefs may be more influential over other epistemic components, like planning of epistemic strategies during the second phase of learning, and epistemic aims. Epistemic beliefs still play an influential role in the planning and goal setting of other non-epistemic components, but given the weaker correlations typically found between epistemic beliefs and other non-epistemic facets of SRL (see Schraw, 2013), predictive relations may be stronger with other epistemic components.

Other epistemic facets are also activated during the task definition phase of learning. These include epistemic metacognitive knowledge about epistemic strategies, epistemic self-efficacy, epistemic value, and epistemic emotions. Once activated, these components may also interact with each other, and epistemic beliefs, to influence Phase 2 of SRL, especially planning of epistemic strategies and epistemic aims, in addition to planning of other learning strategies and goal setting, but to a weaker extent.

Empirical Support

At the time of Muis's (2007) original publication, few studies had explicitly examined whether epistemic beliefs were activated during the task definition phase of SRL (Hofer, 2004). Since then, several studies have tested this proposition (e.g., Bromme, Pieschl, & Stahl, 2010; Pieschl, Stallman, & Bromme, 2014) and have also explored whether other aspects of epistemic thinking, including epistemic aims (Greene, Yu, & Copeland, 2014), epistemic emotions (Muis et al., 2015a; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015b), epistemic self-efficacy (Trevors et al., 2016), and epistemic metacognitive knowledge about persons and strategies (Barzilai & Zohar, 2012) are also activated. For example, Muis and Franco (2009) examined whether epistemic beliefs are activated during the task definition phase through retrospective recollections of students' task definitions for assignments and exams completed for an introductory undergraduate educational psychology course. Through coding of students' recollections, Muis and Franco found that all students had at least one epistemic belief dimension that was activated during task definition, and that 83% demonstrated evidence of at least two epistemic beliefs dimensions being activated. In another study, Pieschl et al. (2014) examined whether upper secondary students adjust their task definitions, and plans and goals as a function of task complexity and epistemic beliefs. Results revealed that students adapted their task definitions to task complexity as a function of their epistemic beliefs. Taken together, studies that have examined whether epistemic beliefs are activated during the task definition phase of SRL have shown that not only are they activated during Phase 1, but that they subsequently predict processes that occur during Phase 2. This proposition is elaborated next.

Proposition 2: Epistemic Metacognitive Knowledge Predicts the Standards That Are Set When Epistemic Aims and Other Goals Are Produced, Which Serve as Inputs to Metacognitive Regulation

Once epistemic beliefs have been activated during Phase 1, they predict the epistemic standards or other goals that learners set for the task. These goals can include epistemic aims, such as understanding, weighing multiple perspectives, critically evaluating knowledge claims, and other goals such as achievement goals. Additionally, if one belief or set of beliefs is more activated than others during task definition, then this belief or set of beliefs may be more predictive than others. Consistent with this notion, Schunk (2001) and Zimmerman and Labuhn (2012) proposed that during the forethought phase, individuals set goals for learning. Once products are created, individuals evaluate the products against some standard, such as their own previous performance, another person's performance, or internal standards individuals set for their current performance. In Muis's (2007)

original model, she further posited that epistemic beliefs translate into epistemic standards that serve as inputs to metacognition. As such, products created during learning are compared against the epistemic standards derived from epistemic aims as well as other standards set for the task. This is accomplished through metacognitive monitoring (Barzilai & Zohar, 2014; Hofer, 2004).

Empirical Support

A number of studies support these claims. For example, studies have shown that epistemic beliefs predict the types of achievement goals (Mason, Boscolo, Tornatora, & Ronconi, 2013; Muis & Franco, 2009; Xie & Huang, 2014), learning goals (Bromme et al., 2010; Chiu, Liang, & Tsai, 2013; Pieschl et al., 2014), and epistemic aims (Greene et al., 2014) that students set for learning. For achievement goals, Mason et al. (2013) examined relations between domain-specific epistemic beliefs regarding the development and justification of science knowledge, and achievement goals, science knowledge, self-concept, self-efficacy, and science achievement with a sample of students from the fifth, eighth, and eleventh grades. Results revealed that beliefs about the justification of science knowledge positively predicted mastery goals and performance-approach goals, and negatively predicted performance-avoidance goals.

For learning goals, Richter and Schmid (2010) investigated relations between epistemic beliefs, text characteristics, learning goals, and use of epistemic strategies across two studies with university students from various disciplines. Results revealed that separate knowing had a large indirect effect on epistemic strategy use, which was mediated by the learning goal of developing one's own point of view. Additionally, learners adapted their learning goals and epistemic strategies depending on the perceived familiarity of the texts they read. In Study 2, beliefs about the uncertainty of knowledge predicted increased use of epistemic strategies, but only when study motivation was low. Interestingly, this last result was mediated by epistemic curiosity. For epistemic aims, Greene et al. (2014) examined relations between epistemic cognition, SRL, and learning outcomes in the context of learning about vitamins in an online learning environment with university students. Results revealed significant, strong correlations between beliefs about the justification for knowing and epistemic aims, and weaker relations between beliefs about the nature of knowledge and epistemic aims.

Results from these studies, among others, suggest that epistemic beliefs play a role in setting the standards for learning, either directly through epistemic aims or via other goals that learners set. Typically, results across the majority of studies reveal that learners who espouse more constructivist epistemic beliefs are more likely to set approach goals and less likely to set avoidance goals, are more likely to set higher standards for comprehension, and are more likely to set higher source evaluation and justification standards than students who espouse less constructivist epistemic beliefs. Recall that a goal is modeled as a multifaceted profile of information (Butler & Winne, 1995) and standards are part of the multifaceted profile about a goal. These standards serve as a basis against which products are compared via metacognitive monitoring (Barzilai & Zohar, 2014; Winne & Hadwin, 1998).

Accordingly, epistemic beliefs play a role in both epistemic metacognitive regulation as well as more general metacognitive regulation. The distinction between the two concerns the object focus. That is, from the traditional view of metacognitive regulation, questions such as "Do I know this?" can be distinguished from questions that reflect an epistemic perspective, "How do I know this?" and "Do I believe this?" (Hofer, 2004). Given that epistemic aims may also include understanding (Chinn et al., 2011), questions such as "Do I understand this?" may also be considered epistemic metacognitive monitoring. If the products created during learning do not match the epistemic standards set, then learners may revisit another phase of SRL or quit (Winne & Hadwin, 1998). In contrast, if the products created match the standards set, the learner may believe the task is complete. As such, epistemic beliefs seem to relate to metacognitive processes.

Indeed, a number of studies have explored relations between epistemic beliefs and some form of metacognitive regulation (Barzilai & Zohar, 2012; Franco et al., 2012; Koksal & Yaman, 2012; Sandoval & Çam, 2011; Trevors et al., 2016). For example, Muis and Franco (2010) examined relations between epistemic beliefs, metacognition,

problem solving, and achievement in the context of learning in an educational psychology course. Results revealed that students who believed that knowledge is derived and justified through logic, reason, and empirical evidence engaged in more metacognitive regulation compared to students who believed that knowledge is derived and justified predominantly via logic and reason, or via empirical evidence. Based on these results, Muis and Franco argued that when an individual sets several standards for knowing, there is more information to evaluate, such as logical consistency of arguments as well as the reliability and validity of the knowledge claims, compared to when fewer standards are set. As such, they concluded that epistemic beliefs influence the types of information that learners monitor and evaluate during learning.

In a more recent study, Trevors and Muis (2015) investigated relations between epistemic beliefs about science knowledge (i.e., absolutist, multiplist, or evaluativist), cognitive and metacognitive processes, and conceptual change regarding misconceptions about evolution. Undergraduate university students were randomly assigned to receive a refutation text (i.e., explicitly identifies the misconception, refutes it, and then presents the correct conception) or an expository text about evolution, and were given a general comprehension goal or an elaborative interrogation reading goal. Results revealed that learners with evaluativist beliefs engaged in fewer comprehension monitoring processes (i.e., direct acknowledgement of understanding of the text without critically evaluating the claim made) compared to non-evaluativists, and were more likely to adapt their coherence-building processes as a function of reading goals compared to non-evaluativist learners.

Taken together, evidence of relations between epistemic beliefs and metacognitive processing has been well established in the literature, through self-reports, think-alouds, retrospective interviews, and other methods. However, the vast majority of research that has examined the role of epistemic thinking in SRL has explored relations between epistemic beliefs and use of cognitive strategies during the enactment phase. As Muis (2007) originally proposed, the link between epistemic beliefs and learning strategies lies in the standards that students set for learning once goals are produced. This proposition is elaborated next.

Proposition 3: Epistemic Metacognitive Knowledge and Epistemic Aims Predict Epistemic Strategies That Are Used During Learning

As previously noted, theorists have suggested that epistemic beliefs predict the standards individuals set for learning (Hofer & Pintrich, 1997; Schommer, 1998; Muis, 2007; Winne, 1995). These standards, in turn, serve as guides for self-regulatory cognition through choice of strategies. Choice of strategies then directly predicts learning outcomes. For example, when studying for an exam, if an individual believes that knowledge in a particular domain consists of isolated bits of unrelated facts, and that knowledge is certain, then he or she may set the standard of “knowing” or “understanding” as being able to recall those facts. This may lead the individual to use memorization as a learning strategy and, once the individual is able to recite those facts, he or she may judge that understanding has been achieved. In contrast, if the individual believes that knowledge in that domain is highly complex, and that experts have multiple perspectives on certain topics within that domain, then this individual may set the standard of understanding as considering relationships among the various knowledge claims and having a coherent understanding by critically evaluating the various perspectives.

Empirical Evidence

Several studies have demonstrated that learners with more constructivist beliefs typically employ deeper processing strategies, like elaboration and critical thinking, compared to students with less constructivist beliefs, who are more likely to employ more shallow processing strategies such as maintenance rehearsal (Franco et al., 2012; Hsu, Tsai, Hou, & Tsai, 2014; Kammerer, Bråten, Gerjets, & Strømsø, 2013; Strømsø & Bråten, 2010). Several studies have also explored mediated relations between epistemic beliefs and learning strategies via epistemic emotions (Muis et al., 2015a), achievement goals (Mason et al., 2013; Muis & Franco, 2009; Xie & Huang, 2014), and learning goals (Chiu et al., 2013; Richter & Schmid, 2010; Ryu & Sandoval, 2012), which

further supports our second proposition. As such, as Schommer (1998) originally proposed, epistemic beliefs predict learning strategies directly and indirectly via the goals that learners set for learning.

For direct effects of epistemic beliefs on learning strategies, Chan, Ho, and Ku (2011) examined relations between epistemic beliefs and critical thinking across two studies. Results demonstrated that the more students believed that knowledge is simple, the worse they performed on the critical thinking task. Results also revealed that students who believed that knowledge was certain exhibited poorer two-sided thinking and a stronger tendency to devalue or ignore counterarguments. For mediated relations, Xie and Huang (2014) explored relations between epistemic and learning beliefs, achievement goals, self-efficacy, and perceived usefulness and actual participation in asynchronous online discussions in a college-level online course. Results revealed that individuals who believed that authorities are the source of knowledge were more likely to set mastery goals, which subsequently predicted perceived usefulness of the online forum as well as non-posting and posting participation.

Other studies have also examined direct relations between epistemic beliefs and learning outcomes (e.g., Bråten & Strømsø, 2009) as well as between use of epistemic strategies and learning outcomes (e.g., Bråten, Ferguson, Strømsø, & Anmarkrud, 2014). For example, Bråten and Strømsø (2010) examined the effects of epistemic beliefs on learning about multiple conflicting documents on climate change. Results showed that a belief in critical inquiry for justification significantly predicted recall of facts from sentences and ability to judge valid within-text inferences. Additionally, a belief in the complexity of knowledge predicted ability to judge valid inferences within and between texts, both of which reflect a deeper understanding of the texts.

Taken together, the majority of studies reviewed demonstrate that more constructivist beliefs result in better learning outcomes. However, one caveat must be taken into consideration: the complexity of the task itself. For example, in an exam context where learners were asked to recall facts, performance did not differ as a function of individuals' epistemic beliefs given that more shallow processing strategies were effective for this task; maintenance rehearsal led to higher performance outcomes (Chevrier, Muis, & Di Leo, 2015). In contrast, when given more complex tasks or contradictory content (e.g., refutation text) that required use of deeper processing strategies, individuals with more constructivist beliefs performed better as they were capable of calibrating their learning as a function of the complexity of the task (Kendeou, Muis, & Fulton, 2011; Pieschl, Stahl, Murray, & Bromme, 2012; Pieschl et al., 2014). What is also important to note is that the majority of studies that did explore relations typically assessed use of cognitive strategies. Only a few studies examined use of epistemic strategies. Moreover, when epistemic strategies were measured through think-aloud methods, researchers reported that, in comparison to cognitive strategies, epistemic strategies occurred much less frequently (Chevrier et al., 2015; Greene et al., 2014). This suggests that students may not have the requisite knowledge to use or implement epistemic strategies, or that epistemic strategies may not play a prominent role in more mundane learning tasks. Fortunately, learners can be taught these strategies, among others (Muis & Duffy, 2013; Zimmerman, 2000).

In summary, the various facets of epistemic thinking are one component of the cognitive, motivational, and affective conditions of a task that are activated during the task definition phase of SRL. Although we focus primarily on epistemic beliefs in this chapter, other epistemic facets play a key role in SRL as well (see Muis, Chevrier, & Singh, forthcoming). To recap, epistemic beliefs, activated during Phase 1, predict the standards that are set when epistemic aims and other goals are produced in Phase 2. This, in turn, predicts the types of epistemic and cognitive strategies students use during Phase 3. When various products are created, the standards set during Phase 2 serve as inputs to metacognition. Given that metacognition is the hub of SRL, and is the primary mechanism by which information feeds back into each phase, at any point information may be updated across the various phases, which can affect subsequent action. This is elaborated next.

Proposition 4: Self-Regulated Learning May Play a Role in the Development of Epistemic Thinking

Most theorists view SRL as a cyclical process (see Efklides, Schwartz, & Brown 2018/this volume; Usher & Schunk, 2018/this volume; Winne, 2018/this volume). Information generated in any phase can feed into the same

phase or other phases given that memory can automatically activate conditional knowledge (McKoon & Ratcliff, 1992). For example, when a learner carries out a task, he or she may implement a particular epistemic or cognitive strategy that may not be effective for that particular task. Once feedback is generated through metacognitive monitoring, the learner may judge that the product does not meet a particular standard set for the task. Under this condition, the learner may then automatically or purposefully activate metacognitive knowledge about strategies and update that knowledge that the particular strategy is not effective under these learning conditions. Additionally, during enactment, the learner may encounter an obstacle that he or she may not know how to overcome and may realize he or she lacks knowledge of how to carry out the task. Under this condition, the learner's self-efficacy may be redefined (lowered), and he or she may decide to quit, engage in help seeking, or lower the standards set.

As such, the relationship between epistemic thinking and SRL is reciprocal and, by its very cognitive and metacognitive nature, epistemic thinking is also inherently regulated. The three facets of epistemic thinking feed important information into the SRL process, but SRL processes also feed information back into the various components of epistemic thinking. As learners engage in epistemic metacognitive processes, or more general metacognitive processes, products are compared to the epistemic standards and other standards that are set and feedback is generated. Information from this process can feed into any phase of learning, and epistemic metacognitive knowledge, epistemic experiences, epistemic aims, or epistemic cognition may be updated through assimilation of the new information into existing structures, or those components may be altered through accommodation.

Focusing solely on epistemic beliefs, Bendixen and Rule (2004) and Muis (Muis et al., 2015a; Muis, Trevors, & Chevrier, 2016) have argued epistemic change is likely to occur when individuals are confronted with information that conflicts with their existing beliefs. Epistemic change may not occur the first time that conflicting information is encountered but, through repeated exposure, epistemic change may occur over time. Individuals may also need to be explicitly aware of their beliefs in order for change to occur (Muis, 2004), similar to the requirement that misconceptions need to be activated in working memory prior to knowledge revision. In their Knowledge Revision Components (KReC) framework, Kendeou and O'Brien (2014) proposed that co-activation is a necessary condition for knowledge revision as it is the only way that old information can come into contact with and be integrated into new information. For example, with repeated exposure to complex, contradictory information about a topic, a learner may begin to realize that knowledge about this topic may be more complex and less certain than originally believed. Coupled with direct strategy instruction to develop learners' self-regulatory skills, epistemic change may also occur (Muis & Duffy, 2013). Of course, change may also occur immediately upon first exposure to contradictory information (Ferguson, Bråten, & Strømsø, 2012), or through refutation text of less constructivist epistemic beliefs (Porsch & Bromme, 2011) (for a complete discussion of epistemic change, see Muis et al., 2016).

For example, Ferguson and Bråten (2013) examined change in secondary school students' epistemic beliefs after reading multiple conflicting documents in science. The authors focused on beliefs about justification, and delineated three subcomponents: personal justification, justification by authority, and justification by multiple sources. Ferguson and Bråten found that after reading, half of the students who initially reported a moderate belief in personal justification subsequently reported a low belief on this dimension and reported stronger beliefs in either justification by authority or multiple sources. In another study, Muis and Duffy (2013) developed an intervention designed for epistemic change through direct instruction of learning strategies and constructivist pedagogy. Results showed that university students in the constructivist intervention reported more constructivist epistemic beliefs beginning around the eighth week of the course, and change continued until the fifteenth week. Additionally, students in the intervention reported increased use of critical thinking and elaboration strategies, as well as higher self-efficacy for learning midway through the semester. In contrast, in the control group, students' epistemic beliefs did not change over the course of the semester, nor did they report a change in strategy use or self-efficacy for learning.

Taken together, across the several studies reviewed, results revealed that training learners to engage in more metacognitive activity, to use deeper approaches to learning, and to critically evaluate source information and multiple competing claims not only fostered the development of better SRL, but also fostered change in epistemic beliefs. Accordingly, learners benefit from the development of SRL, which can also foster better epistemic thinking. Instruction that targets both aspects will foster a better citizenry, one that can critically evaluate not only what they are learning but also how they are learning it. Of course, there are several avenues for future research, which are described next.

Future Directions for Research

Trends in Previous Research

Since Muis's (2007) publication, there have been some interesting trends in research, but there are also gaps in the current literature that should be addressed in future work. Prior to delineating what will be fruitful avenues for future research, we highlight the trends across the various studies. First, with regard to methodologies, given that research in epistemic thinking and SRL has identified issues with regard to self-reports of both constructs (e.g., DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008; see Greene, Deekens, Copeland, & Yu, 2018/this volume; Wolters & Won, 2018/this volume), researchers are moving away from a sole reliance on self-reports. Of the articles reviewed, 20% used methods other than self-reports for both epistemic thinking and SRL processes, including think-alouds, eye tracking, interviews, retrospective recollections, computer log files, analyses of essays and argumentation structures, and case studies. Twenty-nine percent used self-reports to measure one of the constructs, but another method for the other construct. Not surprisingly, however, the vast majority of studies relied solely on self-reports to measure both constructs (51%). Despite this, researchers are moving in the right direction, with nearly half of the studies avoiding self-reports or using mixed methods.

A second trend identified included an increased focus on topic specificity with regard to the measurement of epistemic beliefs, and more task specificity with regard to the measurement of SRL. Although researchers within the multidimensional and developmental literatures previously perceived beliefs to be relatively domain-general (cf. Hammer & Elby, 2002; see Muis et al., 2006 for a review), the trend over the past decade has been one in which there has been an increase in measuring domain-specific and topic-specific epistemic beliefs. That is, 40% of the studies reviewed examined the topic-specificity of epistemic beliefs, and 26% examined the domain-specificity of epistemic beliefs. Only 28% examined relations in a domain-general context.

The final trend involves level of education. A consistent trend across both literatures, separately and in combination, reveals a shortage of research with elementary, middle, and high school students. Based on the studies reviewed, only 14% were conducted with elementary or middle school students, with the same percentage for secondary school students. The vast majority of studies (68%) that have explored relations between facets of epistemic thinking and SRL have been carried out with undergraduate or graduate students.

Building From Previous Research

Given these trends in recent research in conjunction with our proposed theoretical framework, several directions for future research can be identified. First, in creating a more inclusive epistemic framework and by expanding on current constructs, future research must progress beyond the singular study of relations between epistemic beliefs and SRL. Researchers should consider the more fine-grained components of epistemic thinking (e.g., epistemic self-efficacy, epistemic strategies, epistemic value, epistemic aims, epistemic emotions) and their dynamic relationship with SRL. This requires a move away from a sole reliance on self-reports of these constructs.

Second, following Barzilai and Zohar (2014), epistemic metacognitive knowledge about epistemic strategies, and when to use those strategies, may be more predictive of other facets of SRL than epistemic beliefs. Epistemic self-efficacy may also be a more powerful predictor of subsequent SRL processes and learning outcomes than epistemic beliefs. For example, Trevors et al. (2016) found that learners with less constructivist epistemic beliefs

reported lower epistemic self-efficacy for questioning the perceived expertise of the text when content included discrepant information. Results from their study suggest that individuals may know what epistemic strategies they need to employ, but do not feel confident enough to carry them out due to lack of prior knowledge. Investigations that explore specific epistemic aspects may provide greater insight into the ways in which epistemic thinking and SRL interact to predict learning outcomes.

Third, it is also plausible that epistemic thinking does not play a significant role in every aspect of learning. That is, depending on the nature of the task, epistemic thinking may not be required, or only certain aspects may be evoked. In some cases, more advanced epistemic thinking may even hinder learning. For example, in an upcoming mathematics exam, students may be required to memorize formulas needed to carry out the problems. Under this condition, the epistemic aim of understanding does not need to be evoked, and strategies to evaluate sources and methods of justification are not necessary. If, however, a learner sets the epistemic aim of understanding the formulas, he or she may spend more time attempting to achieve that epistemic aim, but fail to memorize the formulas, which would hinder performance on the exam. As such, future research must take the epistemic climate into consideration (Muis et al., 2016) and continue to focus on topic and task specificity.

In a similar vein, it is not always detrimental for students to employ more shallow processing strategies under certain contexts. For example, Muis and Duffy (2013) found that despite the fact that students in the intervention group reported an increase in critical thinking and elaboration strategies, both groups still relied heavily on rote memorization as a learning strategy. Further research into why and how epistemic thinking leads to changes in some areas of self-regulation and/or use of regulatory strategies but not others is worthy of investigation to better understand not only how epistemic thinking is related to learning, but specifically under what learning conditions it is used and why. It may be that under complex learning conditions (e.g., multiple perspectives, contradictory information), epistemic thinking will be evoked and will be more predictive of learning outcomes than with simpler tasks.

Fourth, the vast majority of studies reviewed focused primarily on university students. More research is needed with younger students to examine the development of epistemic thinking and SRL. In our province of Quebec, Digital Citizenship begins in kindergarten, and students as young as six begin to use the Internet as a source of information for learning. As such, it is absolutely critical that more research is carried out with younger populations to examine topics such as epistemic understanding (Ryu & Sandoval, 2012), judgments of the epistemic status of sources of justification (Sandoval & Çam, 2011), and use of evidence (Sandoval, 2005), among others. An important line of work with this population will include an examination of the co-development of SRL (see Perry, Hutchinson, Yee, & Määttä, 2018/this volume) with epistemic thinking. Not only is research needed to examine the role that epistemic thinking plays in SRL with younger learners, it is absolutely critical that learners are taught the skills necessary to navigate the complexities of content in general, and of content on the Internet in particular.

Finally, one significant gap in the literature was the lack of consideration of the role that collaborative learning and social epistemology play in learning more broadly. Collaborative learning is now a promoted staple of the classroom environment (Slavin, 2015). The benefits of collaborative success abound; emotionally, Jones and Isroff (2005) noted that collaboration and conversation have the potential to generate positive emotions and foster motivation. This in turn helps to support progressive communication and collaboration, and reinforces commitment to the co-construction of understanding (Jones & Isroff, 2005). Collaborative learning also necessarily promotes co-regulated learning (Järvelä & Hadwin, 2013; see also Hadwin, Järvelä, & Miller, 2018/this volume). In our review of the literature, we found only one study that took epistemic beliefs, collaboration, and co-regulated learning simultaneously into consideration (Zhao & Zheng, 2014). Future research should investigate the reciprocity between collaboration, social epistemology, and self- and co-regulated learning.

Indeed, much of the work in the field of epistemology has focused on knowledge and justified belief as individual constructs (Haddock, Millar, & Pritchard, 2010). Over the past two decades, however, social epistemology has grown substantially and has become one of the mainstays of contemporary views. Social epistemology recognizes

inquiry and argumentation as central to epistemic practices, and places testimony and advocacy in the spotlight (Code, 2010). As such, it stands to reason that educational psychology's focus on epistemic thinking as individualistic is too narrow (see also Chinn et al., 2011). An egocentric perspective distorts the picture of epistemic thinking given that social relationships and institutions shape learning and problem solving. During collaborative learning, social interactions shape individuals' thinking via other people's assertions and opinions. How learners negotiate the complexities of others' beliefs, epistemic aims, and epistemic strategies is a question that will be a fruitful and important line of inquiry.

Even in solo learning, individuals may interact with others and, through that interaction, may change the course of their epistemic thinking. Some questions that drive our curiosity include: What happens when individuals working together disagree (Sosa, 2010)? What epistemic emotions are triggered during disagreement? What co-regulatory processes are implemented to resolve that disagreement? How do learners negotiate the epistemic aims of the group? What are the norms of trust in collaborative learning? What are the processes of determining truth-telling among members of a group, and how is justification determined (Faulkner, 2010)? How do social epistemic emotions (e.g., curiosity about what someone else thinks) alter the trajectory of individual and group learning processes and outcomes? Taken together, the future directions presented here can readily be translated into educational implications, which are described next.

Educational Implications

At the beginning of this chapter, we discussed how learners' ability to make informed decisions along with their capacity to select and distinguish high-quality from low-quality information are key learning skills in the world of Web 2.0. Ultimately, learners must develop proficiency in SRL and engage in a sophisticated level of epistemic thinking. It is therefore appropriate that the chapter concludes with some pedagogical suggestions that will help teachers construct learning environments within an epistemic climate that promotes critical and reflective thinking.

In line with Muis et al. (2016), the epistemic climate should reflect a social constructivist paradigm. Social constructivist paradigms advocate that the learning environment fosters the construction of knowledge and encourages learners to be active participants in the learning process within a social and collaborative milieu (Windschitl & Andre, 1998). Pedagogically, the collaborative nature of the constructivist environment allows for the externalization of epistemic thinking through modeled behavior on behalf of the teacher (Muis & Duffy, 2013). Indeed, given that use of epistemic strategies and knowledge of those strategies are likely far more powerful predictors of learning outcomes than epistemic beliefs, teachers must teach students these skills directly. Not only can teachers help students develop SRL through modeling and scaffolding of the learning process (Muis & Duffy, 2013; Zimmerman, 2000), teachers also need to teach students epistemic strategies through the same mechanisms.

Additionally, while social constructivist pedagogical practices such as modeling and scaffolding are imperative to bring about and support epistemic thinking and SRL, attention to the motivational strategies that teachers use are also worthy of mention. For example, Dignath, Buettner, and Langfeldt (2008) conducted a meta-analysis on treatments aimed at improving SRL skills of early elementary students and found that motivational strategies play an important role in the induction and continuation of learning behavior. They considered various motivational strategies employed by educators, such as causal attribution, action control, and feedback. Coupled with consideration of the epistemic motivational components of epistemic thinking, like epistemic self-efficacy and epistemic value, activities should be varied, flexible, and dynamic to afford students autonomy in the evaluation of materials, and to require justification where appropriate. Students also need opportunities that allow for the demonstration of understanding. Within this consideration, we advise a high level of transparency on assessment criteria in that students are fully aware of the conditions and objectives on which they are being graded. Rubrics that reflect both the activity's criteria and gradations of quality (see Andrade, 2000) allow students to simultaneously interpret the understandings they have mastered and provides them with information on where to

focus their efforts on subsequent activities. Such transparent and explicit techniques in assessment may encourage appropriate setting of epistemic aims.

Perhaps the practice that ties the aforementioned climate, activity, and assessment practices together is the opportunity for reflection. The reflective practice should become a major part of all classroom activities and anticipations (“What do I expect to learn?”), and monitoring (“What am I learning?”) and subsequent reflection (“What did I learn?”) should become an integral part of every educational activity. Anticipating, monitoring, and reflecting allows learners opportunities to contemplate where their learning currently rests along the continuum of gradations. This type of self-analysis is key in the promotion of epistemic thinking in the creation of goals (epistemic aims), understanding strategies at the learner’s disposal (epistemic strategies), and in considering how able one is to achieve these successive approximations to mastery (epistemic self-efficacy). This awareness and contemplation of such fine-grained epistemic thinking, coupled with advanced SRL, will ultimately develop the educated and skilled citizenry capable of making informed decisions in the world of Web 2.0.

Notes

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[2](#) The first two facets are similar to those proposed by Barzilai and Zohar, whereas the last component differs. Specifically, Barzilai and Zohar (2014) call the third category epistemic metacognitive experiences (Efklides, 2011). We focus on emotions and motivation as opposed to the metacognitive component of these experiences.

[3](#) Though see variations in labeling as noted above.

[4](#) Typically, four areas are proposed for regulation, but we believe that motivation and affect should be separated out as they are psychologically distinct constructs (see Pekrun, 2006).

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29 Advances in Understanding Young Children's Self-Regulation of Learning

Nancy E. Perry, Lynda R. Hutchinson, Nikki Yee, and Elina Määttä

Kelsey Keller's class of Grade 1, 2, and 3 students described self-regulation as follows: "Being able to do your JOB without being asked, told, or shown." Furthermore, they identified three key pieces of information they needed to be successful self-regulators of their learning: "What is the JOB? How to do the JOB? And why we do the JOB?" Regarding their first task of understanding "jobs" in the classroom, they agreed it was important to identify "the steps" needed and then to ask yourself, "Can I do the job?" If the answer to that question is no, a second relevant question is, "Do I know who to ask for help?" Determining how to do their job required them to think about the "tools" they might need, where the best place is to do the job, and whether there are "extra skills" they need to finish their job. Of course having a purpose is important too. Options here included: "learning new content or skills; building STAMINA; or reinforcing and practicing."

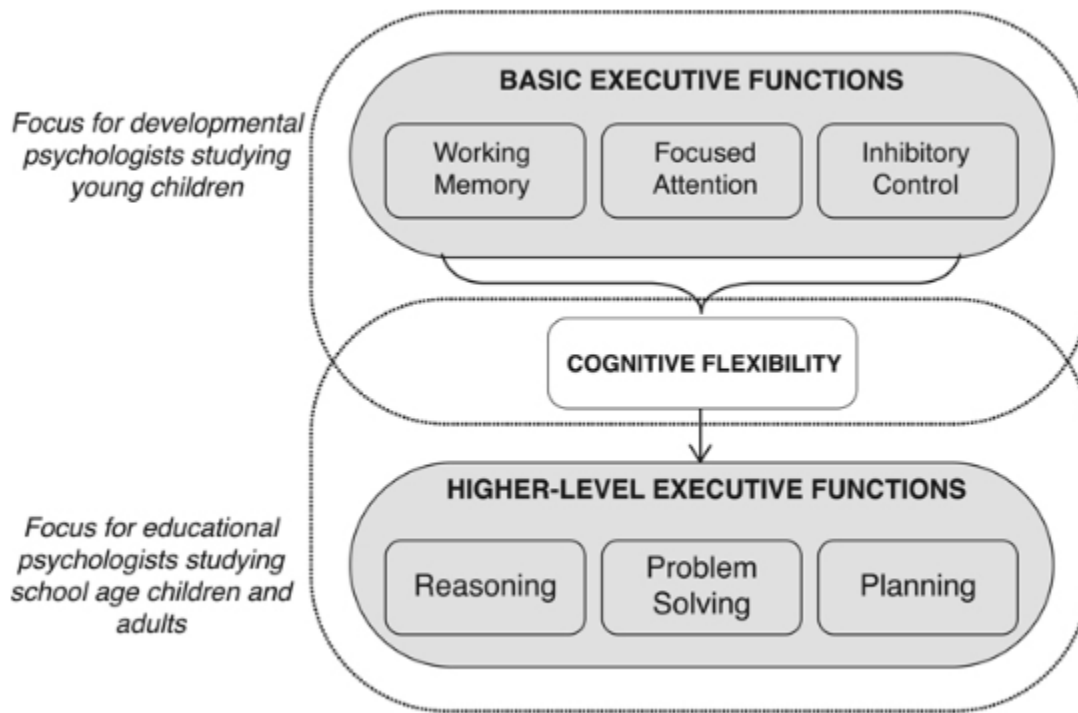
This "kid-friendly" representation of effective self-regulation aligns well with scholarly descriptions of the construct. "Self-regulated" describes individuals who control thoughts and actions to achieve goals (their own and others') and respond to environmental stimuli (Zimmerman, 2008). Attending to key features of the environment (e.g., listening for instructions; locating helpful resources), tailoring responses to suit specific circumstances (e.g., relating to teachers versus relating to peers), resisting distractions, and persisting when challenged are attributes researchers, teachers, and parents ascribe to productively self-regulating learners (Blair & Razza, 2007; McClelland & Cameron, 2012). These learners apply self-regulation to a wide range of processes (cognition, motivation, emotion, and behavior) and, consequently, can act appropriately and flexibly across a wide range of contexts (Diamond, 2016; Eisenberg & Spinrad, 2004).

Our scholarship seeks to understand how young children can be supported to self-regulate for learning. Predominantly, we focus on teachers and children in elementary general education classrooms. This chapter is divided into four sections. First, we consider theoretical perspectives from developmental and educational psychology to describe what children's self-regulation entails, when and how it develops, and how social and situated perspectives are particularly relevant for studying children's development as self-regulating learners in classrooms. Second, we examine research that demonstrates how self-regulated learning (SRL) is implicated in children's development and learning, how groups of children differ in their development of self-regulation, and how children's SRL can be supported in school. Third, we consider directions for future research. Finally, we close with a discussion of implications for practice.

Integrating Perspectives on Self-Regulation and SRL

Perspectives From Developmental and Educational Psychology

In our view young children's self-regulation continues to be an understudied topic in educational psychology. There is comparatively more scholarship about young children's capacities for self-regulation in developmental psychology. Adele Diamond (2016) provides a useful summary of that literature (see [Figure 29.1](#)), which can extend perspectives in educational psychology. Developmental psychologists have focused on children's development of basic executive functions, such as working memory, focused attention, and inhibitory control, as supports for higher-level processes that are the focus of studies of self-regulation and SRL in educational psychology. In particular, working memory and/or focused attention help children to keep goals in mind as they complete a task. Similarly, inhibitory control prevents internal and environmental distractions from interfering with the contents of working memory so that relevant information can be stored and manipulated to ensure successful task completion. According to Diamond (2016), these core processes come online during the preschool years and make cognitive flexibility possible. Flexibility and adaptability are critical for what Diamond refers to as higher-level executive processes that include reasoning, problem-solving, and planning, and which align better with models of SRL.



[Figure 29.1](#) Fundamental capacities for self-regulation

(Adapted from Diamond, 2016, p. 16)

Historically, developmental studies of young children’s self-regulation have tended to focus on either executive functions or children’s development of emotion and behavior control (see, for example, Eisenberg, Hofer, & Vaughan, 2007). With regard to emotions, developmental studies document how children’s effortful and voluntary control of emotions, attention, and behavior develop in the preschool years (Eisenberg & Spinrad, 2004). These capacities emerge as children’s self and other awareness increases and as key cognitive capacities mature so they can attend to environmental demands, anticipate consequences for actions, inhibit inappropriate responses, and initiate appropriate tactics and strategies to achieve their goals (Bronson, 2000). Understanding, labeling, and controlling emotions and actions are challenging but critical tasks for young children—developing strategies for regulating emotions and behavior enhances children’s ability to think effectively and act adaptively in a wide range of contexts, including school (Blair & Diamond, 2008). Recent research in developmental psychology is beginning to consider children’s emotions and motivations together with executive functions, recognizing that all are implicated in children’s self-regulation and learning (Diamond, 2016; Blair & Diamond, 2008).

Similarly, our view is that learners must regulate cognition, motivation, affect, and action to be successful in and beyond school. Moreover, we interpret the mechanisms that underlie self-regulation remain the same no matter what the target of our regulation happens to be (e.g., our emotions, behavior, or learning). A common view in educational psychology is that self-regulating in any domain involves metacognition, motivation, and strategic action (Winne, 2018/this volume; Winne & Perry, 2000). Successful self-regulating learners use metacognition to consider personal characteristics (strengths and challenges) relative to academic task demands (“What am I being asked to do?”) and, where gaps exist, they identify strategies that will help them succeed. Their motivation for learning reflects a “growth mindset” (Dweck, 2007)—they focus on personal progress plus deep understanding, and realize that errors are inevitable in any learning opportunity. These qualities make them willing to engage with new and challenging tasks, which is necessary for learning and SRL (Hadwin, Järvelä, & Miller, 2011). Moreover, when faced with a challenge, these learners purposefully choose from their developing repertoires of strategies knowing when, where, and how to apply them (Butler, Schnellert, & Perry, 2017).

Well-known models of SRL describe cyclical processes learners use to guide their thinking and behavior before, during, and after their engagement in learning tasks (Butler, 1995; Winne & Hadwin, 1998; Zimmerman & Campillo, 2003). These models commonly describe learners actively interpreting tasks, setting goals, making plans, enacting strategies, monitoring progress, and making adjustments to cope with the demands and challenges learning presents for them (Butler et al., 2017). In our earlier example, Kelsey's students operationalized self-regulation as a cycle. They created posters for their classroom that prompted them to interpret tasks, set goals, and make plans, according to criteria, each time they began a new task. They returned to the posters if they "lost their way" during a task (a process they referred to as "checking-in") to monitor progress and make adjustments. Monitoring and self-reflection are particularly powerful processes in these cycles (Winne & Perry, 2000), producing feedback loops that help learners recognize when they need to make adjustments to achieve their goals. Importantly, learners' motivations (e.g., their ability beliefs, expectations for success, and the value they place on success in particular situations) predict their willingness to engage in cycles of strategic action to facilitate learning (Zimmerman, 2008). In this regard, Kelsey observed her students engaging in cycles of strategic action to solve problems and increase "ownership" of their learning and "pride in their self-regulation," all leading to positive changes in "self-reflection" and "work stamina" (personal communication, January 18, 2013).

Perspectives on When and How Self-Regulation Develops

Self-regulation is a developmental process that begins well before children enter formal schooling (Blair & Dennis, 2010) and, because it is malleable, even children who struggle with it or have exceptional learning needs can improve their learning and SRL (Graham & Harris, 2003). Infants may not consciously regulate their emotions and behavior, but some evidence indicates they will re-orient or engage in self-distracting behavior to avoid or control exposure to loud sounds and scary images (Calkins & Johnson, 1998; Eisenberg & Spinrad, 2004). Toddlers engage in more self-distracting/coping behaviors than infants, especially when they receive support from adults who model or prompt self-regulatory strategies (Calkins & Johnson, 1998), and emotion and behavior regulation are pivotal achievements for children attending playgroups and preschool.

Self-regulation is influenced by "in-person" characteristics, such as temperament and cognitive abilities, but contextual factors also play a strong role. For example, home and school environments where children experience authoritative forms of parenting and teaching (e.g., warmth and responsiveness, support for autonomy, clear communication, scaffolding) are likely to exert a positive influence on children's self-regulation (Vernon-Feagans, Willoughby, & Garrett-Peters, 2016). Schunk and Zimmerman (1997) proposed a four-phase model to describe how self-regulation develops from other regulation to self-regulation through observation, imitation, self-control, and self-regulation. According to their model, children gradually assume control over their thoughts and actions by first watching how significant others (e.g., parents, older siblings, teachers, peers) self-regulate. Next they begin to imitate what they have observed and then, through practice, they increase their level of self-control and, finally, reach a point when they are able to modify and adapt their actions and reactions to suit a variety of settings and situations. According to Schunk and Zimmerman (1997), flexibility and adaptability distinguish self-regulation from self-control.

We were not observing when Kelsey was co-constructing a "kid-friendly" definition of self-regulation with her students, but Kelsey's documentation of their process includes her demonstrating support for self-regulation and then observing her students imitate the language she used and they developed together. For example, Kelsey described how she initially interrupted students at work to "check in" on their self-regulation ("What's our job? How are we doing at our job?"). Then she observed students providing the same support to one another ("Have you chosen a good work space? ... Do you need to check in?"). Over time, children began to "recognize patterns about their self-regulation ... anticipate the challenges they might encounter and take steps to avoid them ... students could communicate their work needs and [respect the needs of their peers]. (Kelsey, personal communication, January 18, 2013). These observations suggest Kelsey's students mastered self-control and were acquiring the flexibility and adaptability characteristic of self-sufficient self-regulating learners.

Increasingly, contemporary models of self-regulation focus on understanding its social and situated nature and introduce constructs such as co-regulation and socially shared regulation (see Hadwin, Järvelä, & Miller, 2018/this volume), which are particularly relevant to studies of young children's SRL and classroom-based research. Co-regulation builds from Vygotskian and neo-Vygotskian perspectives on learning, and emphasizes the importance of instrumental interaction and activity to support SRL (McCaslin, 2009). Co-regulation presumes at least one participant in an interaction has knowledge or skills that others need to achieve a goal and reflects a transitional phase whereby learners gradually appropriate SRL through, for example, instrumental feedback or metacognitive prompts. Although adults are typically thought to co-regulate children, children and adults can co-regulate one another (Perry, 2013). For example, during "Center Time" a teacher may co-regulate students by offering activity centers (e.g., with literacy activities, or arts and crafts, or science experiments) that support skills she thinks are important. The children might co-regulate the teacher's choice of activities if they are challenged by or no longer demonstrate interest in a particular center.

Shared regulation describes how learners regulate activity during interpersonal interactions or in collaborative tasks (Hadwin et al., 2011, 2018/this volume). Shared regulation occurs when learners co-construct understandings of tasks and pool meta-cognitive, motivational, and strategic resources (Hadwin & Oshige, 2011). It implies shared awareness of goals and joint monitoring of progress toward a shared outcome (Winne, Hadwin, & Perry, 2013). For example, a small group playing with blocks at a center may use shared regulation to build a tower together. They might share different strategies for building their project, periodically assessing their work.

Finally, productive co- and shared regulation of learning require socially responsible self-regulation (Hutchinson, 2013), which involves children regulating themselves in pro-social, socially competent ways to advance their own and others' learning. Children who engage in socially responsible self-regulation will regulate their own behaviors, motivations, cognition, and actions with particular sensitivity to the feelings, perspectives, and successes of other people in a group. Children who are working at a crafts center, for example, may or may not have a shared project, but might diplomatically offer ideas or strategies that could help one another to achieve their respective artistic visions.

Ideally, children's SRL develops in social contexts, through social interactions, with social support, as was the case in Kelsey's classroom. According to Kelsey (personal communication, January 18, 2013), the common language she and her students developed "helped them to reflect on their self-regulation and created an additional co-regulation support system." Similarly, Whitebread, Bingham, Grau, Pino, Pasternak, and Sangster (2007) observed children (ages 3–5) engaging in self-, co-, and shared regulation during activities designed to be meaningful for young learners and that provided them with opportunities to regulate their own and others' learning. Interestingly, Whitebread et al. (2007) observed more evidence of children regulating learning when they worked in pairs and small groups than when they worked alone or with support from their teacher. However, support from teachers was associated with qualitatively higher levels of metacognition, perhaps suggesting that adults assume regulation when they work with children, but that they also stimulate higher levels of self-reflection.

Demonstrating the Importance of Self-Regulation through Research

SRL Is Implicated in Children's Development and Learning

Self-regulation is recognized as a significant source of achievement differences among students across educational levels and settings (Zimmerman & Schunk, 2011). General and special education teachers have cited students' abilities to self-regulate learning and behavior as a major influence on their adaptive functioning and attainment of academic success (Cleary & Zimmerman, 2006). In the early elementary grades, self-regulation is a powerful predictor of children's adjustment to and success in school (Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009). In fact, research indicates skills associated with self-regulation are better predictors of children's early success in school than traditional measures of IQ and children's reading and math abilities

when they enter school (Blair & Razza, 2007). Kindergarten teachers have expressed greater concern over students' difficulties self-regulating emotions and behavior than about academic difficulties and delays (Rimm-Kaufman, Pianta, & Cox, 2000). They have reported that children who struggle with self-regulation have difficulty following directions, completing academic tasks, meeting behavioral expectations, and relating to peers and teachers, which places them on a negative trajectory that can be difficult to reverse (Diamond, 2016). Moreover, teachers have indicated that approximately one-sixth of children struggle with school adjustment when they enter kindergarten (Rimm-Kaufman et al., 2000).

Self-regulation is a longitudinal predictor of children's achievement in school (e.g., kindergarten through Grade 6), even after controlling for previous achievement, IQ, and demographic characteristics (Vernon-Feagans et al., 2016). As students advance through the grades, those who continue to struggle with self-regulation often have difficulty setting goals and following through on them (Butler & Schnellert, 2015), and they often have trouble recognizing when they need help and seeking out people who are appropriate help providers (Dunn, Rakes, & Rakes, 2014). Students who struggle with SRL are frequently poor self-advocates (Butler, 2004) and often adopt an external locus of control. Their experiences of failure can lead them to develop low self-esteem and self-efficacy for changing outcomes in their lives. Poor decision-making and high risk-taking behavior during adolescence have also been associated with poor self-regulation (Magar, Phillips, & Hosie, 2008).

Together, these findings make a strong case for focusing on self-regulation in school, and particularly supporting children who are "at risk" in their development of SRL in the early elementary grades. Improvements in self-regulatory capacities can steer initially discouraging learning trajectories toward better developmental and educational outcomes (Moffitt et al., 2011).

Children Differ in Their Development of SRL

It is well established that some children struggle more than others in their development of SRL. For example, children who are impulsive or easily frustrated have difficulty inhibiting inappropriate behavior, whereas children who are fearful or overly inhibited often experience difficulty adapting to new settings and situations (Eisenberg et al., 2007). Other authors in this volume discuss specific learning differences at length (see, for example, Mason & Reid, 2018/this volume; McInerney & King, 2018/this volume). To better understand how diversity impacts learning for young children, we highlight research findings linking three socio-demographic factors to children's development of self-regulation: gender, experiences of extreme adversity (e.g., poverty, abuse, familial stress), and cultural/linguistic diversity.

Gender

An emerging trend in research with preschool and early school age children's self-regulation is that teachers judge boys less proficient at self-regulating than girls (Cadima et al., 2016; Rimm-Kaufman et al., 2009). For example, teachers have rated boys lower than girls on indices of cognitive and behavioral control, and emotion regulation. They also have judged boys to have less positive work habits and spend greater proportions of time off task. These assessments have applied to both solo (e.g., following a set of rules or instructions) and social (e.g., working collaboratively or providing feedback to peers) aspects of self-regulation (Hutchinson & Perry, 2012). However, there is some question as to whether these observations truly reflect differences in SRL development across genders, or are indicative of early differences in how boys and girls express themselves (Ruble, Martin, & Berenbaum, 2006), relate to others (Berry, 2012), or are compatible with typical classroom contexts.

For example, young boys tend to be more active, more physically aggressive, and more assertive (Ruble et al., 2006) than young girls, who tend to be more agreeable in their interactions, more willing to take turns, and more likely to engage in conversation to solve problems. These differences may explain why boys get judged less "ready" for kindergarten than girls and more likely to experience difficulties negotiating the transition to school (McWayne, Fantuzzo, & McDermott, 2004). These qualities may also explain why teachers generally report more

conflictual relationships with boys than girls (Berry, 2012; Hughs & Kwok, 2007), which may interfere with teacher-student closeness (Cadima et al., 2016) and reduce the amount and/or quality of support boys receive in social, emotional, and academic domains. A third explanation for the observed differences between young boys' and girls' self-regulation is that school and classroom contexts do not accommodate their different learning and self-regulation pathways. Young boys may be challenged to meet expectations for behavior and learning that favor compliance and independent engagement in quiet activities. In general, research indicates that both boys and girls benefit when teachers implement SRL-supporting practices in their classrooms (Cadima et al., 2016; Rimm-Kaufman et al., 2009). However, Cadima et al.'s (2016) findings suggest girls may respond more “optimally” to teachers' instructional support than boys.

Experiences of Adversity

Research indicates children who have experienced extreme adversity (e.g., familial chaos and/or stress, abuse, exposure to violence, poverty) are “at risk” in their development of self-regulation (Diamond, 2016; Moffitt et al., 2011). Stressful events can have a direct negative impact on the prefrontal cortex of the brain when they result in the overproduction of hormones (e.g., cortisol) that impair executive functions that support self-regulation. Acute/uncommon stress events interrupt effective thinking and responding temporarily, but chronic, “toxic” stress—defined as strong, frequent, and/or prolonged adversity (National Scientific Council on the Developing Child, 2014)—can alter brain chemistry and architecture such that children's development of self-regulatory capacities is impaired (Center on the Developing Child at Harvard University, 2011).

Familial stress can indirectly impact children's development of self-regulatory skills. Research has found that parents who have experienced high levels of toxic stress may not have had the “freedom of mind” to provide rich and supportive opportunities for their children's self-regulation (Babcock, 2014). In addition, Vernon-Feagans et al.'s (2016) study has suggested that confusion, clutter, or loud noise in the home environment indirectly and negatively impacts children's development of self-regulation by altering qualities of parenting (e.g., responsiveness, scaffolding) even after controlling for income and maternal levels of education.

No child is immune to adversity and, in fact, research on resilience has indicated that learning to cope with manageable challenges in a supportive environment is an essential outcome of normal development (Rutter, 2013). At the individual level, assets associated with resilience and self-regulation overlap a great deal (e.g., a positive sense of self-efficacy and agency, effective regulation strategies, and the ability to form close, supportive relationships). As with other forms of co-regulation, the goal of instruction that addresses adversity should be to encourage initiative in children. In this way, self-regulation can become a protective factor for children who are at risk in learning and life.

Cultural and Linguistic Diversity

This is an area of SRL research and theory in need of development. The available research indicates that “self-regulation is an asset that cuts across socio-demographic boundaries and remains predictive of developmental outcomes” (McClelland & Wanless, 2012, p. 292). For example, in their longitudinal study of children's transition from prekindergarten to kindergarten, McClelland and Wanless (2012) found self-regulation was a statistically significant and positive predictor of academic achievement irrespective of individuals' socio-demographic status (i.e., English Language Learner—ELL—and socioeconomic status). Higher levels of self-regulation were positively correlated with school achievement and adjustment for diverse students. These results are supported by Garrido-Vargas (2012), who found a significant relationship between SRL motivational strategies and middle school ELL (Hispanic) students' academic performance. Furthermore, preliminary findings from our longitudinal study (Hutchinson, Perry, Yee, Restrepo, Dantzer, & Lo, 2015) indicated self-regulation and teaching practices that foster SRL can support academic achievement across linguistic, cultural, and socio-economic status (SES) groups.

One of the most challenging tasks for students from diverse socio-demographic groups is becoming “school literate”—developing essential understandings about a set of beliefs and practices (social norms) that reflect the predominant classroom culture (Orosco & O’Connor, 2014; Trommsdorff, 2009). For example, cultural rules for help giving and seeking, asking questions, individual work, and collaborative learning may vary significantly across children’s home and school contexts (McInerney & Ali, 2013). These challenges are exacerbated when educational systems lack the capacity to meet student needs (Truth and Reconciliation Commission of Canada, 2015), or environments are untrustworthy or unsafe for some groups of children (Marker, 2009). However, SRL-promoting practices can accommodate individual interests and abilities, and in fact build up diversity to expand the range of thought and strategies used within the classroom. We elaborate on these practices next.

Children’s Self-Regulation Can Be Supported in School

We focus on two programs of research examining how features of classroom tasks, instructional practices, and interpersonal relationships support children’s development of SRL.

Linking Classroom Qualities and Children’s Self-Regulation in School

Sara Rimm-Kaufman et al. (2009) used a multi-method research design to examine the extent to which children’s self-regulatory abilities upon entry to kindergarten, and qualities of their classroom environments (i.e., emotional support, organizational support, and instructional support) predicted their adaptive behavior across the school year. Children (N = 172) in the study were enrolled in seven rural elementary schools. Most children were Caucasian, from low- to middle-SES families, and had not attended preschool prior to kindergarten.

Researchers administered direct assessments of children’s self-regulation (emotion and behavior control) in September. During the school year, they observed children in classrooms and coded dimensions of their engagement in tasks. Teachers rated children’s adaptive classroom behavior at the end of the school year. Specifically, they provided assessments of children’s behavior control (e.g., does the child talk out of turn or disrupt other children while they are working?), cognitive control (is the child able to work toward goals and persist at tasks, even when they are lengthy and unpleasant?), and work habits (e.g., is the child able to work independently and use time wisely?). Finally, the Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2008) was used to assess three dimensions of classroom quality (i.e., emotional, organizational, and instructional supports). Researchers rated these qualities after each of five 15-min. observations.

The results of Rimm-Kaufman et al.’s (2009) investigation revealed a statistically significant and positive relationship between classroom qualities and children’s self-regulation at the end of the school year. In particular, children in classrooms where teachers used high-quality organizational strategies received higher ratings of behavior control, cognitive control, and positive work habits than peers in classrooms rated lower for organizational quality. In addition, researchers’ observations indicated students in high-quality classrooms spent less time off task and were more productively engaged in learning. Consistent with previous research, teachers rated boys in this study lower on indices of behavior and cognitive control, as well as work habits. Children from low-SES families and children who did not attend preschool prior to kindergarten also received lower ratings of self-regulation than their peers.

A question for studies involving children potentially at risk in their development of SRL is whether high-quality instruction can change children’s SRL trajectories over time. This was not the finding in Rimm-Kaufman et al. (2009)’s study—classroom quality did not moderate the relationship between children’s self-regulation at the start and end of the school year. However, using the same indices of classroom quality, Cadima et al. (2016) did find a statistically significant and positive relationship between classroom instructional quality and growth in self-regulation in preschool children from low-SES communities in Portugal. In particular, girls who received low ratings of self-regulation at the beginning of the school year benefited more than boys from high-quality instructional contexts.

These studies provide evidence that skill in SRL can ease children's transition to school and that classroom organizational qualities and instructional supports can impact children's development of/engagement in SRL. They are unique in the field of developmental psychology in that they examine children developing SRL in naturalistic versus laboratory settings. Importantly they contribute to understanding what it means to self-regulate for learning in the preschool and early elementary years and indicate that focusing on SRL with these age groups is worthwhile. Dependent variables in these studies targeted basic executive functions and adaptive behavior, but not the higher levels of cognition (e.g., metacognition and strategic action) and aspects of social interaction (e.g., co-regulation and collaboration) that distinguish self-regulation from self-control (Schunk & Zimmerman, 1997). Also the classroom observations were short (15 min.) in duration, so researchers may not have observed qualities of lessons/activities from start to finish. Our own program of research uses a more qualitative approach to observation to provide detailed, contextualized descriptions of high-quality opportunities for children to develop and engage in SRL. We report on these below.

Classroom Processes That Support Children's SRL

Currently, we are in year four of a seven-year mixed-method, multi-level, longitudinal study following approximately 200 children (118 boys) from kindergarten through Grade 6. Our sample is diverse with fewer than 40% of parents reporting a European-North American ethnic heritage and 26.6% indicating they speak a language other than English or French at home. Families reflect the full range of SES categories. Like Rimm-Kaufman et al. (2009), we are engaging in multiple forms of data collection: teacher ratings, classroom observations, semi-structured retrospective interviews, and student work sampling. Initial findings indicate children's skill at SRL is associated with success in school for boys and girls and diverse linguistic, ethnic, and SES groups in the study.

See Perry (1998) and Perry, VandeKamp, Mercer, & Nordby (2002) for a detailed description of our observation protocol, which includes space to keep a running record—an anecdotal/narrative account—of “what is going on” in classrooms, including verbatim samples of teachers' and students' speech and a record of time spent on particular facets of instruction and task completion. Running records are coded using a set of conceptual categories that reflect qualities of tasks, instructional practices, and interpersonal interactions believed to promote SRL. These observations reveal opportunities for children to regulate learning when they are engaged in complex meaningful tasks and when student autonomy—including choice, control over challenge, and opportunities to self-evaluate learning—are promoted and supported through highly effective forms of co- and shared regulation (i.e., teacher and peer support that is instrumental to developing and engaging in SRL; Perry, 2013).

Tasks

Complex tasks address multiple goals, focus on large chunks of meaning, and extend over long periods of time (Perry, 1998; 2013). In classrooms, these tasks are often operationalized as projects and integrated units of study. For example, Heather, a teacher participating in our longitudinal study, engaged her Grade 2/3 class in a year-long study of a local bog. Heather used this project to support children to develop skills for scientific inquiry and learn about a natural eco-system, including how plants, animals, and humans have benefitted from and preserved the bog. She linked this study to math and science (e.g., children inventoried and graphed different species of trees), art (e.g., they painted scenes in the bog in the style of a famous Canadian landscape artist, Emily Carr), and literacy (e.g., they used poetry, Haiku, to synthesize and reflect on their learning; “Why are we doing this? Why is it important?”).

As children worked to accomplish the goals of this task, they engaged in a variety processes (e.g., questioning, information seeking and sorting, planning for writing, writing, and revising) and with a variety of resources, including teachers, parents, library resources, community members, the Internet, and one another. Inevitably, they were required to think metacognitively and strategically and, because this task and its embedded projects permitted children to demonstrate their learning in diverse ways (e.g., reports, illustrations, poems, graphs), it

appealed to their interests and abilities, which supported their motivation for learning. Tasks like this tend to nurture the unique perspectives of diverse students.

Autonomy

Tasks that support autonomy prompt metacognition (ask students to consider features of tasks in relation to their strengths and weaknesses as learners) and strategic action (encourage students to consider and apply tactics and strategies that will increase their likelihood of success), and enhance motivation for learning (students' interest and perceived competence increase when they value the work and feel in control of their learning; Stefanou, Perencevich, DiCintio, & Turner, 2004). In our bog example, children chose an area of inquiry after an initial exploration of the bog. Heather described how, at first, children's questions were very general (e.g., "I wonder about the plants in the bog"), but deepened as children observed changes during repeated trips to the bog (five across the school year) and as they engaged in research to address their wonderings (e.g., "Are there plants in the bog that don't exist anywhere else?" ... "Is the water table the same everywhere in the bog?"). Children could control challenge through the choices they made (e.g., the materials and resources they accessed to support their inquiry), and they were expected to monitor their progress and assess their learning (i.e., judge whether they were getting good answers to their questions).

Research has consistently found that students in autonomy-supportive classrooms (like Heather's) choose moderately difficult tasks, strive for deep understanding, and persist through challenges, which supports SRL development (Hadwin et al., 2011; Stefanou et al., 2004). In contrast, students who have perceived low autonomy in their classrooms are more likely to be anxious, prefer easy tasks that ensure success, and depend on others' evaluations of their work.

Co-Regulation

Earlier in this chapter, we characterized co-regulation as support that is instrumental to the development of SRL. Effective co-regulators do more than provide procedural knowledge (telling an answer or what to do). Instead, they transfer knowledge in a way that enables recipients to act without support in the future. Toward this end, Heather staged five trips to the bog to support children's inquiry, writing, and art projects. The first trip (in Fall) was a "wonder walk." Heather posed "an essential question" ("Why is [the] bog important?") and encouraged children to be present with their senses, to observe and store questions in their heads. Back in the classroom, she gave them time to record their questions. Subsequent trips to the bog helped children refine their questions through observations. "Scientists don't look at things in a general way ... [they] hone in on important aspects ... put information together to answer overarching questions." Heather provided material resources and instructional guidelines to support children's writing of reports and she introduced a template for self-assessment ("What worked?" "What didn't?" "What could we do differently next time?" "Action plan?"). Finally, she encouraged children to share questions and information when they came across something that could help someone else.

These supports are common in high-SRL classrooms. Teachers engage in extensive scaffolding and then fading to co-regulate students' development of independent and academically effective learning processes (Englert & Mariage, 2003; Perry et al., 2002). Familiar classroom routines, or participation structures, support teachers and students to pursue SRL goals and learning agendas (Brown & Campione, 1994). Productive peer collaborations present students with opportunities to engage in academic discourse and practices, solve problems, and offer and appropriate knowledge, resources, and strategies (Englert & Mariage, 2003). Finally, non-threatening, formative assessments (e.g., templates for assessing progress on the bog project) focus students' attention on learning processes, as well as products, which reduces social comparisons and anxiety connected to assessment, and communicates the value of SRL.

We close our chapter with an examination of what more researchers and educators need to know and can do to help children optimize their self-regulatory capacities for learning and living.

Future Directions for Research

In general, the research we reviewed suggests SRL is an asset that cuts across socio-demographic boundaries and is a powerful predictor of the success all children experience in school (McClelland & Wanless, 2012; Perry et al., in press). More research is needed, however, to understand the differences teachers observe in young boys' versus girls' self-regulation, whether and how these differences impact their "readiness" for school, and how schools and teaching practices might be contributing to a perceived versus real problem. Also, more research is needed to understand the relevance of self-regulation and SRL-promoting practices for children from linguistically and culturally diverse communities. For example, there is need to consider the extent to which SRL-promoting practices can complement a wide range of cultural perspectives. Constructs such as co- and shared regulation might be particularly relevant for some groups of children. Perhaps most critically, more research is needed about the ways in which children's exposure to extreme forms of adversity (e.g., familial stress/chaos, violence, poverty) directly and indirectly impacts their development of self-regulatory capacities. It seems these children are particularly vulnerable and schools and teachers could be well positioned to provide them with a much-needed "leg up" in their development of self-regulation for learning and living.

Also, we see inherent value in merging theoretical and research perspectives about self-regulation from developmental and educational psychology. Developmental studies contribute a comparatively large body of research about children's development of self-regulation from birth through the early years. They have revealed when executive functions and capacities for controlling affect and behavior are coming on line and have signaled how these capacities are foundational for later, more sophisticated forms of SRL. In particular, their focus on attention and inhibition are highly relevant to skills that are emphasized in the early school years (e.g., paying attention, taking turns, managing frustration). However, much of the research in developmental psychology has taken place in highly controlled research settings and there is now growing agreement these investigations offer limited insight into how children function in classrooms (Perry, Brenner, & MacPherson, 2015; Rimm-Kaufman et al., 2009).

Research in educational psychology has provided some more ecologically valid investigations of self-regulation, occurring in naturalistic settings (e.g., classrooms) and using measurement tools that try to reflect what children actually do in those settings (Perry, 1998; 2013; Whitebread et al., 2007). These investigations also provide insights into how even young children have managed higher levels of thinking that are implicated in SRL (e.g., metacognition and reasoning about motivation and strategic action). And recent advances in research about co-, shared, and socially responsible self-regulation have been particularly relevant for studying teacher to student and student to student support for regulation in school. We perceive more research in naturalistic environments is needed to improve opportunities and outcomes related to SRL.

Implications for Practice

Research has established that children are developing capacities for SRL long before they begin formal schooling. Research also now highlights the significance of self-regulation, as both a risk factor and protective factor, in children's early adjustment to and success in school. Children who struggle with it tend to experience a wide range of learning and interpersonal difficulties both in near and far terms. Fortunately, self-regulation can change and improvements in this domain lead to positive changes in other areas as well (e.g., academic achievement, interpersonal relationships). Therefore, finding ways to support children to acquire knowledge and skills for effectively regulating learning and living across a wide range of settings and situations, and early in their educational careers, should be a priority in both research and practice.

In general research links classroom characteristics, such as emotional climate, organization, and instruction, to young children's development of self-regulation (Cadima et al., 2016; Fuhs, Farran, & Nesbitt, 2013; Perry, 2013; Rimm-Kaufman et al., 2009). Specifically, in classrooms Rimm-Kaufman et al. (2009) characterized as "high quality," students could feel emotionally safe and supported to do their work, increasing the likelihood they would

try and persist at tasks and activities that are novel or challenging, which is a key criterion for developing SRL (Hadwin et al., 2011). Moreover, familiar and well-structured routines likely helped children develop clear understandings about how to carry out particular tasks (“What’s my job?” “What do I need to do my job?”). Finally, instructional emphases on higher-order thinking, talking about learning, and engaging children in meaningful work with formative feedback have been shown to support children’s development of metacognition as well as motivation and strategies for learning and SRL (Perry, 2013). We would stress, however, that teaching toward SRL is a complex task for teachers and they need to be supported in this regard.

One way to support teachers’ implementation of SRL-promoting practices is through research practice partnerships (Coburn & Penuel, 2016). A main goal of Perry’s research, which has involved both preservice and inservice teachers, has been to engage teachers with researchers in collaborative inquiry groups, or teacher learning teams (Perry et al., 2015). This approach to research and professional learning has brought teachers and researchers together to work on a shared goal of supporting children’s SRL. Teachers are supported to hone their self-, co-, and shared regulation of teaching in a learning context that is much like the one they are trying to create for their students. This approach to professional learning recognizes teaching requires contextualized decision-making that situates pedagogical principles in practice to meet the diverse needs of students in particular classrooms and schools (Butler & Schnellert, 2012; Perry et al., 2015). It contrasts with traditional researcher designed and led interventions that are prevalent in the self-regulation literature and have seldom led to lasting changes in teachers’ practices. We perceive advancing research and practice in SRL depends on productive collaborations between researchers and teachers, and likely requires researchers to think differently about interventions, fidelity, and what constitutes an evidence base.

Currently, interest in self-regulation and its contributions to productive and healthy functioning spans virtually all the social and behavioral sciences (Moffitt et al., 2011). Self-regulation may be the great equalizer in children’s development and learning. Therefore it seems prudent for researchers and practitioners to focus on this area and to utilize knowledge gained across disciplines and through partnerships to broaden understandings about all aspects of regulation involved in learning and living.

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30 Self-Regulation

Implications for Individuals With Special Needs

Linda H. Mason and Robert Reid

It is well documented that individuals with special needs have difficulties with self-regulatory processes, often resulting in poor academic, behavioral, and social outcomes (Schunk & Bursuck, 2012). Individuals with special needs may have difficulties with attention, processing information, rehearsal, and problem solving, as well as have maladaptive beliefs regarding learning capabilities (Schunk, 1986). In this chapter the term “special needs” is used when referring to a range of disabilities such as learning disability (LD), attention deficit hyperactivity disorder (ADHD), emotional disorders (ED), speech or language impairment (SLI), autism spectrum disorder (ASD), developmental disability (DD), and intellectual disability (ID). Individuals in these heterogeneous groups often have similar difficulties with the self-regulatory processes needed for goal setting, for self-monitoring and evaluation, for effective self-speech, and for self-reinforcing academic and social behaviors (Taft & Mason, 2010).

Despite common challenges across disability groups, etiology of each of these challenges may vary. Individuals with LD, for example, may have cognitive deficits in memory that hinder the use of strategies for self-regulating organization and task completion (Snyder & Bambara, 1997). Individuals with ADHD and ED may have difficulty with self-regulating attentional skills while individuals with SLI, ASD, DD, and ID may experience more difficulty with self-regulating the oral and written language needed for effective communication (Reid, Trout, & Schwartz, 2005). Many individuals with special needs will have comorbid difficulties across self-regulatory processes; therefore, they may require uniquely individualized interventions for self-regulation. The chapter sections that follow include (a) theoretical perspectives and factors that influence self-regulation for individuals with special needs; (b) research on self-regulation intervention for improving on-task behavior, academic productivity, accuracy, and preparedness, and for decreasing disruptive behavior and for improving social skills and self-determination; (c) future research directions; and (d) implications for educational practice.

Theoretical Perspectives and Influencing Factors

Operant theory, social constructivist theory, and social cognitive theory have all contributed significantly to research on self-regulation for individuals with special needs (Schunk & Zimmerman, 2003). Research with these individuals, over time, has resulted in theoretical revision and overlap; furthermore, implementation and effectiveness of self-regulatory processing among individuals with special needs is often influenced by other factors such as self-efficacy, metacognition, and executive functioning (Reid, Harris, Graham, & Rock, 2012). These theories and factors are covered in detail in this volume (see Usher & Schunk, 2018/this volume). Theory and factors, in the context of self-regulation for individuals with special needs, are summarized next.

Operant theory has the earliest foundation in self-regulation development for individuals with special needs (Mace, Belfiore, & Hutchinson, 2001). In this perspective behavior is explained through environmental antecedents and consequences, with a focus on observable and measurable outcomes. Single case research for evaluating effects of self-regulation interventions, for example, fits well into this paradigm and has been widely used (Reid et al., 2005). In the 1970s, the behaviorist perspective was expanded to include a greater role for cognition (Kanfer & Karoly, 1972) and social learning (Mahoney & Thoresen, 1974).

Social constructivists view self-regulation as grounded in theories of cognitive development. From this perspective all individuals are intrinsically motivated and active learners (Schunk & Zimmerman, 2003). Beliefs and theories in social constructivism are related to an individual's level of development and experiences and are especially important when contextualizing self-regulation for individuals with special needs (Harris, 1990). Social cognitive theory is grounded in Bandura's (1986) description of the reciprocal nature of interactions between

behaviors, environment, cognition, and affect where self-regulation is strongly influenced by an individual's self-efficacy beliefs.

Self-efficacy refers to an individual's expectations or beliefs regarding whether or not they can successfully perform a given task or activity (Bandura, 1986). The relationship between self-efficacy and self-regulation is generally reciprocal: strong self-efficacy may lead to greater and more effective self-regulation, while successful self-regulation and completion of a task may, in turn, strengthen self-efficacy (Zimmerman, 2008). In effect, individuals who believe they are capable of successful performance are likely to choose challenging activities, work hard, and persist when difficulties are encountered. However, the relationship between self-efficacy and self-regulation is not always clearly established for individuals with special needs. For example, in Graham and Harris's (1989) study of a self-regulation writing intervention, students with LD consistently overestimated their abilities resulting in misrepresentations. While writing performance improved, there was no significant finding for students' sense of self-efficacy.

Metacognition, or awareness of task demands, personal capabilities, and strategies for the task, are critical for self-regulated learning (Reid, Harris, et al., 2012). Boekaerts and Corno (2005) noted that although the relationship between self-regulation and metacognition is sometimes unclear, metacognition is commonly agreed to include an awareness of the skills, strategies, and resources needed to perform effectively, and the knowledge of how to self-regulate behavior to achieve success. Using metacognition to consciously self-regulate "actions that are too complex to be controlled automatically" can be an effective compensation strategy, as noted in Trainin and Swanson's (2005, pp. 261–262) study with college students with LD. In this study, students with higher self-regulation for learning, time management, and help-seeking (e.g., seeking assistance from instructors, college resources, families) strategies had higher grade point averages and achievement.

Executive functioning has been viewed as overlapping with metacognition and self-regulation, making clear delineation of all these terms somewhat challenging (Reid, Harris, et al., 2012). Barkley (2004) defined executive function as self-directed mental activities that occur during responding and primarily serving inhibitory functions. Deficits in executive function have been defined as the impacting primary factor for individuals with ADHD (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and LD (Meltzer, 2011). These individuals often struggle with basic executive functioning skills such as applying previously learned information to new tasks, time management, persistence, and work completion. Many individuals with special needs especially struggle with the executive functioning skills needed for starting and completing multi-stepped tasks.

While theoretical perspectives in the context of factors influencing self-regulation interrelate and differ, each has informed research for individuals with special needs. These perspectives are related to self-regulation strategies, which are addressed next.

Self-Regulation Strategies

A number of effective strategies can be taught to students with special needs to aid in their development of self-regulation for improving academic and behavioral outcomes. Major self-regulation strategies include: self-monitoring (also called self-assessment or self-recording), self-evaluation, self-instruction, goal setting, and self-reinforcement.

Self-monitoring is one of the most thoroughly researched self-regulation techniques for students with disabilities and has been called one of the most important sub-processes of self-regulated learning (Shapiro & Cole, 1994). Self-monitoring occurs when an individual first self-assesses whether or not a target behavior has occurred, and then self-records the occurrence, frequency, duration, or so on of the target behavior (Nelson & Hayes, 1981). External reinforcers typically are not used in self-monitoring interventions except in cases involving individuals with significant attention and behavioral difficulties (Reid et al., 2005). Self-evaluation is closely related to self-

monitoring. It differs from self-monitoring in the use of external comparisons. Self-evaluation requires students to rate a behavior and then compare the ratings to an external observer (Reid, Harris, et al., 2012).

Self-instruction involves using self-statements to direct or self-regulate behavior (Harris, 1990; Schunk, 1986). Students literally learn to “talk themselves through” a task or activity. Individuals with special needs often have negative self-talk that results in negative behavioral, social, and academic outcomes. Goal setting helps to structure effort, to provide information on progress, and to motivate performance (Schunk, 1990). Goals are an important aspect of self-regulation; however, if a goal has little or no importance, then it is unlikely to improve performance or maintain motivation or effort (Bandura, 1986). Progress toward a goal should be perceived as being the result of effort rather than external factors. Goal-setting interventions often involve a self-evaluation process where students compare current performance with their performance goal (Schunk, 1986).

Self-reinforcement occurs when a student selects a reinforcer and self-awards using it when a predetermined criterion is reached or exceeded (Reid, Harris, et al., 2012). This process is similar to the natural developmental process where a child learns that meeting expectations will result in positive reinforcement while failing to meet expectations will result in no response or a negative response (Zimmerman, 2008). Self-reinforcement is often the final step in a sequence of self-regulation processes.

Self-Regulation Interventions

Self-regulation strategies have been thoroughly researched and classroom tested, and have demonstrated efficacy for individuals with LD and ADHD (Mace et al., 2001; Reid et al., 2005), and to a lesser degree for ASD (Reid, Mason, & Asaro-Saddler, 2012), ED and SLI (Taft & Mason, 2010), and ID and DD (e.g., Wehmeyer, Yeager, Bolding, Agran, & Hughes, 2003). Outcomes include improved on-task behavior, academic productivity, accuracy, and preparedness; decreased disruptive behavior; and improved social skills and self-determination. In the following examination, exemplar studies to illustrate interventions and findings are described.

Improving On-Task Behavior

Increasing on-task behavior is a natural focus for self-regulation interventions because attending to a task and maintaining effort are important prerequisites to academic success. Additionally, increasing on-task behavior can have beneficial effects on classroom climate and the teacher-child relationship (Reid, Harris, et al., 2012). Thus, it is not surprising that on-task behavior is the most widely studied outcome for students with special needs.

Self-Monitoring

Self-monitoring has demonstrated effectiveness for increasing on-task behavior for children with LD, ADHD, ED, SLI, and ASD (Reid, Harris, et al., 2012; Reid, Mason, & Asaro-Saddler, 2012; Taft & Mason, 2010). Although the majority of research has focused on elementary and middle school students, self-monitoring has been used effectively with children as young as 4 (e.g., De Hass-Warner, 1992). Effects have been demonstrated across general education, resource, and self-contained classrooms and it has been used effectively with individual, small group, and large group instruction (e.g., Hallahan, Marshall, & Lloyd, 1981).

Self-monitoring interventions have demonstrated large effect sizes (1.92) for on-task behavior for children with ADHD and ED (Reid et al., 2005). Mathes and Bender (1997), for example, used self-monitoring to increase on-task behavior with three elementary school students with ADHD and ED in a self-contained classroom. Students were trained to check a self-monitoring sheet in response to random taped tones. Students’ on-task behavior improved from 37–40% at baseline to 87–97% post-intervention; after the cuing tones were faded, on-task behavior maintained. Similarly, De Haas-Warner (1992) used self-monitoring (cuing tones and self-monitoring sheets) with four preschool students in an integrated preschool setting. On-task behavior improved from 24–50% at baseline to 87–96% post-intervention. De Haas-Warner noted the importance of language, social learning, and

operant theory for designing self-monitoring interventions for young students. Self-monitoring interventions have also demonstrated durable effects four weeks after intervention (e.g., Rock & Thead, 2007).

Self-Monitoring Plus Reinforcement

Self-monitoring plus reinforcement (SM + R) interventions have been effective (Reid et al., 2005). Stahr, Cushing, Lane, and Fox (2006) combined self-monitoring with a signaling system, contingent teacher praise, and planned ignoring to increase time on-task for a 9-year-old boy with SLI, ADHD, and internalizing behavioral problems in a self-contained classroom. After the intervention, the student's on-task behavior improved from a mean of 32.38% to 74.44%. In a study with three 9- to 11-year-old students with ASD, Coyle and Cole (2004) used video modeling of on-task behavior plus self-monitoring using pictures of students working and not working with self-reinforcement. Students' off-task behavior immediately decreased. Graham-Day, Gardner, and Hsin (2010) used self-monitoring for improving on-task behavior with three 10th-grade students with ADHD during a study hall period. Although self-monitoring was effective for improving on-task behavior for two students in this study, one participant's performance was improved only when provided external reinforcement of a small piece of candy.

Self-Evaluation

Self-evaluation techniques have also demonstrated effectiveness for improving on-task behavior for individuals with ADHD. Ervin, DuPaul, Kern, and Friman (1998) increased on-task behavior for a 14-year-old student in a residential placement. Shapiro, DuPaul, and Bradley-Klug (1998) found similar results for two 12-year-old children. Terenzi, Ervin, and Hoff (2010) used self-monitoring in combination with teacher ratings as a class-wide support system in a resource room setting. Students were taught to self-monitor two school-wide rules, and then compare their ratings with those of the teacher. Findings indicated that the intervention resulted in increased on-task behavior and decreased disruptive behaviors for the three students.

Improving Academic Productivity

Self-regulation intervention research for improving students' academic productivity (i.e., the amount or rate of academic responding) is more limited and mixed than studies on improving on-task behavior (Reid, Harris, et al., 2012). Some early studies found pronounced effects (e.g., Roberts & Nelson, 1981) while others reported no effects (e.g., Lloyd, Hallahan, Kosiewicz, & Kneedler, 1982). Joseph and Eveleigh (2011) reviewed the effects of interventions that included self-monitoring for students with LD and found a strong impact for reading comprehension and for academic productivity in reading.

Effects of self-regulation interventions for academic productivity for students with ADHD are not clear due to a small number of studies. Shimabukuro, Prater, Jenkins, and Edelen-Smith (1999) found that self-monitoring academic performance in reading, mathematics, and written expression increased academic productivity for three 12- to 13-year-old students with LD and ADHD. Results indicated the strongest findings for productivity in mathematics (ranging from 90.9% to 98.1% for mean productivity) and lowest for accuracy in written expression (ranging from 70.8% to 78.4% for mean accuracy). Ajibola and Clement (1995) used goal setting and self-reinforcement and reported gains in academic reading comprehension task productivity for six children with ADHD in a tutoring class (mean effect size = 2.66). Only one study has used self-evaluation with children with ADHD for academic productivity. Barry and Messer (2003) increased the percentage of completed assignments for five 6th-grade students in the general education classroom. All students were receiving physician-prescribed psycho-stimulants; researchers noted the limitations in evaluating effects of self-evaluation as a single intervention. Despite the mixed findings for self-regulation in improving academic productivity, this is an area that should receive increased attention because of the chronic difficulties of children with disabilities and assignment completion (DuPaul & Stoner, 2003).

Improving Academic Accuracy

The effects of self-monitoring on academic accuracy are not well established. Three studies for students with LD have included accuracy levels as a dependent measure. Dunlap and Dunlap (1989) used self-monitoring with three students with LD in a resource setting with “clearly superior” results in subtraction accuracy (p. 312). Crabtree, Alber-Morgan and Konrad (2010) used self-monitoring for a reading task with three high school seniors. They found improved quiz score accuracy, 0% to 60% correct at baseline to 60% to 100% correct post-intervention. Researchers have also noted positive effects on accuracy for children with ADHD (e.g., Varni & Henker, 1979) and with LD and ADHD (e.g., Shimabukuro et al., 1999). Farrell and McDougall (2008) found that self-monitoring of accuracy for goal setting with self-graphing of performance increased the addition and subtraction accuracy of six 9th-grade students with LD and ADHD.

Improving Academic Preparedness

Classroom preparedness (e.g., coming to class on time, bringing needed materials) is a chronic problem for many individuals with special needs (Snyder & Bambara, 1997). Self-regulation strategies such as self-monitoring with goal setting and self-evaluation can improve preparedness. In Gureasko-Moore, DuPaul, and White’s (2007) self-monitoring and evaluation study, for example, students with ADHD were taught classroom preparation behaviors (i.e., be seated when bell rings, make eye contact with the teacher at the beginning of instruction, have pen or pencil and relevant materials on desk) and homework completion skills (i.e., write homework assignments and items needed in a notebook, take notebook and items home) and then were taught how to monitor the taught skills by using logs and checklists. After the intervention, the six students performed as well as their typical classmates in both classroom preparation and homework completion measures. Similarly, Merriman and Coddling (2008) combined self-monitoring with goal setting and systematic fading of self-regulation procedures, and improved homework completion for three high school students with ADHD. In a larger study with 42 6th, 7th, and 8th grade students, Meyer and Kelley (2007) found that self-monitoring alone increased homework completion.

Improving On-Task and Academic Performance: Self-Monitoring of Performance Versus Self-Monitoring of Attention

Harris, Friedlander, Saddler, Frizelle, and Graham (2005) studied the relative effects of self-monitoring of performance (SMP) versus self-monitoring of attention (SMA) among six elementary school students with ADHD for on-task behavior and academic performance. Improved on-task behaviors were positive and similar across the two interventions. In contrast, SMA resulted in greater gains in academic performance for four of the six students. Differential effects for SMA and SMP have also been reported among students with LD. However, in this case, SMP tended to result in higher academic performance than SMA (e.g., Reid & Harris, 1993). It is possible that the more frequent self-recording used in SMA provides more feedback on behavior, and thus would be more effective for students with ADHD (Barkley, 2004).

Although SMA and SMP have both been used effectively, few studies have examined the effects of using a combined approach (i.e., SMA + SMP). Takeuchi and Yomamoto (2001) implemented self-monitoring of SMA and SMP for reading homework performance across three subject areas—Japanese, social studies, and science—with one 6th-grade student with ASD. Results indicated improved classroom test performance in target subjects and one non-related subject, home economics. Takeuchi and Yamamoto noted the simplicity of the intervention for both home and school application. Rock (2005) found that a concurrent SMA and SMP intervention, developed for the inclusive classroom, increased students’ on-task behavior and academic productivity for one typically developing student, three students with LD, and one student with ADHD. In a follow-up study, Rock and Thead (2007) replicated findings with two students with disruptive behaviors, one student with ASD and a moderate ID, and two students with LD and ADHD. All students demonstrated improved levels of academic productivity and accuracy; however, during fading by gradual removal of the self-monitoring sheet, students’ accuracy fluctuated.

Decreasing Disruptive Behavior

Children with disabilities commonly demonstrate problem behavior such as excessive motor activity, impulsive or inappropriate behaviors, or inappropriate verbalizations (Barkley, 2004). These behaviors have a negative effect on learning environments because they result in less time spent in academic and social activities. Problem behaviors can also have a negative effect on teacher-student and student-student relationships. Self-regulation approaches can help to ameliorate problems with disruptive behaviors of children. Research conducted, for example, in hospital and research settings demonstrated the positive effects of combined self-monitoring and external reinforcement procedures in reducing disruptive behaviors of children with ADHD (Kern, Ringdahl, Hilt, & Sterling-Turner, 2001).

Self-regulation approaches have also shown effectiveness at diminishing disruptive behavior in the school settings. Coogan, Kehle, Bray, and Chafouleas (2007) used a multicomponent intervention that included self-monitoring and reinforcement to decrease disruptive behaviors in five 12-year-olds. Christie, Hiss, and Lozanoff (1984) successfully used self-monitoring in a general education classroom. Similarly, Stewart and McLaughlin (1992) reduced off-task behaviors in a self-contained special education setting. In these studies, carried out in school settings, external reinforcers were not needed to decrease disruptive behaviors.

The setting in which self-regulation interventions are used is particularly important because most children with LD, ADHD, and/or ED will spend the majority of their school day in the general education classroom (Reid, Harris, et al., 2012). Self-regulation interventions are particularly appropriate because they have been shown to be acceptable to classroom teachers and can be readily implemented in the general education classroom. We would caution, however, that more research is needed to determine how self-regulation can best be used to aid inclusion.

Improving Social Skills

Barkley (2004) notes the difficulties of children with special needs go well beyond academics and behavior; impaired social skills are common and particularly serious for children with ADHD. Deficits in social functioning may be even more serious than academic difficulties because they are more pervasive. Research indicates that for many children with special needs social skills problems are due to an inability to activate skills rather than a lack of social skills (Barkley, 2004). This distinction is critical because for self-regulation techniques to be effective prerequisite skills/behaviors must be present. Self-regulation interventions for children with special needs within a social context are sparse (Shapiro & Cole, 1994). However, some successes have been reported with children with ADHD; for example, Gumpel and David (2000) used self-monitoring with a 10-year-old to improve playground behavior. Self-monitoring markedly decreased the rate of aggressive playground behavior and increased positive social interactions.

Improving Self-Determination

Self-determination is a broad framework used in the study of motivation, personality, and human functioning (Deci & Ryan, 1985). Wehmeyer et al. (2003) note that for an individual to be self-determined, they must be autonomous, psychologically empowered, self-realized, and self-regulated (i.e., use goal setting, self-instruction, self-evaluation, and self-delivered reinforcement). A strong line of research has supported self-determination as an effective approach for improving outcomes of individuals with ID and DD (see Malian & Nevin, 2002). Research for individuals with ASD is more limited but promising. Fullerton and Coyne (1999), for example, used “life maps” (i.e., a drawn square representing life at present linked to hoped-for work, social activity, residency, etc.) to graphically represent the future for goal setting. Although to date self-regulation within the framework cannot be disaggregated in terms of impact, it would be remiss to not mention self-determination as an important theoretical model for improving outcomes for individuals with special needs.

The target behaviors for self-regulation discussed were largely discrete behaviors such as academic productivity or accuracy and on-task behavior. However, self-regulation interventions are not limited to these behaviors and can be successfully combined with more complex approaches such as learning strategies (Schunk & Zimmerman, 2003). In fact, the development of strategy instruction was strongly influenced by early seminal self-regulation researchers such as Donald Meichenbaum (1977) and others who stressed the importance of self-regulation in strategy training (see Graham, Harris, MacArthur, & Santangelo, 2018/this volume).

Future Directions

Educational policy and system resources (e.g., technology) often dictate instruction for individuals with special needs. With the implementation of multi-tiered systems of support (MTSS) for improving academic and behavioral outcomes for all students through a three-tier instructional delivery model, teachers are responsible for providing high-quality, evidence-based core instruction and progress monitoring (Sugai & Horner, 2009). MTSS, adopted by the majority of U.S. states, is an integrated instructional framework focused on core instructional and behavioral standards and differentiated instruction that supports students, including students with special needs, through school wide team-based decisions. In this model, students who are not making adequate progress, academically or behaviorally, receive additional intensive intervention support at three levels—classroom, small group, or individual. Berry Kuchle, Zumeta Edmonds, Danielson, Peterson, and Riley-Tillman (2015) describe four practices necessary for planning intervention within the MTSS: (1) increase instructional time and practice, (2) change environment to increase attention and engagement, (3) evaluate and modify instruction to prioritize skills for instructional match, and (4) combine “cognitive processing strategies with academic learning, as students with intensive needs often struggle with processes related to executive function and self-regulation” (p. 153). In this context, research aimed at evaluating self-regulation intervention for academic, behavioral, and social outcomes for individuals with special needs across MTSS school settings is timely.

In a 2005 review of literature, Boekaerts and Corno noted that new technological tools for self-regulated learning resulted in interventions that look much different from those in prior decades when technology was limited to tape recorded tones for monitoring attention. However, the interventions at the time of the 2005 review were also limited and primarily focused on the development of interactive software programs that included procedures for self-regulated study. Subsequent study has shown the benefit of technology (a) such as cell phones and iPads for self-monitoring and self-recording attention to task for individuals with ADHD and ED (e.g., Bedesem & Dieker, 2014) and (b) for communication in a coaching model for self-regulating study skills with college-age students with ADHD (Field, Parker, Sawilowsky, & Rolands, 2013). In addition, there is a significant number of technology-based research for individuals with special needs that has focused on using tools such as outlining and concept mapping, word processing, and word and speech production software, within a self-regulated strategy development model to support writing (see MacArthur, 2009). Despite the positive effects of these interventions, all researchers have noted caution when designing interventions—technology should not supplant effective instruction for self-regulated strategy use.

The use of technology to support self-regulatory process is still “in its infancy, but its potential for assisting students to use SRL strategies is impressive” (Zimmerman, 2008, pp. 171–172). When evaluating the potential use of technology, researchers may ask questions such as, “How might cell phone or tablet technology be incorporated into instruction to improve the written composition skills and writing self-efficacy of students with special needs?” Although desired student outcomes may remain relatively stable over time, it is expected that future technology that supports the self-regulatory abilities of students with special needs will vastly change.

When taught to meet individual students' needs, self-regulation strategies have demonstrated effectiveness for a wide range of individuals with self-regulation difficulties. Self-regulation procedures (e.g., self-monitoring, self-evaluation, self-instruction, goal setting, and self-reinforcement) should be individualized and adapted to meet the needs of individuals with special needs. Negative attributions, for example, should be addressed by modeling student-focused positive self-speech (Harris, 1990). Attention should be given for students' self-monitoring and self-evaluation efforts, noting that regardless of errors, researchers have found that positive effects on behavior still occur (Reid, Harris, et al., 2012). Although goal setting and self-reinforcement are generally effective without external reinforcement, some individuals with special needs will need external reinforcers to achieve maximum effects and stable gains. Current "in-place" plans to support behavior should be considered during intervention planning and potentially imbedded with and maintained during self-regulation intervention implementation.

This chapter discussed a number of strategies that can be taught to assist individuals with special needs in developing self-regulation capabilities. These individuals will often require multiple sessions to reinforce the targeted skill (Reid, Harris, et al., 2012; Taft & Mason, 2010); therefore, it is critical to use explicit instruction that has a strong focus on modeling and provides students with sufficient guided practice. One of the greatest challenges for individuals with disabilities is their difficulty in generalization. Supplementing self-regulation intervention with other interventions such as video modeling and feedback may increase generalization (Reid, Mason, & Asaro-Saddler, 2012).

In closing, we stress the significance of environment as a factor in self-regulation from both the operant and social-cognitive perspective (Mace et al., 2001; Schunk & Bursuck, 2012). Put simply, environmental manipulations can enhance or enable self-regulation. A safe, welcoming, and structured environment with predictable stable routines, for example, is a critical prerequisite for effective self-regulation. Even in the best possible environment, individuals with special needs will have some difficulties with self-regulation. In a disordered, chaotic environment, successful self-regulation is unlikely to occur.

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31 Culture and Self-Regulation in Educational Contexts

Dennis M. McInerney and Ronnel B. King

The aim of this chapter is to review the role of culture on self-regulated learning (SRL). The chapter begins with a theoretical overview of what SRL and culture are. Next, a survey of cross-cultural research on SRL before and after 2010 is presented. Finally, key themes and trends in SRL research are identified and directions for future research are suggested.

Theoretical Ideas Underlying Self-Regulation in Cross-Cultural Context

The theoretical construct of SRL is well presented in numerous publications and so an extensive treatment of its nature and component constructs will not be provided in this chapter (see Usher & Schunk, 2018/this volume). Because self-regulatory skills are acquired through social modeling, social guidance and feedback, and social collaboration McInerney (2008, 2011; see also King & McInerney, 2014, 2016) argued that cultural factors are likely to play an important role in the development and nature of self-regulation.

In this context, and in line with the increasing diversity of classrooms and educational environments internationally, the study of ‘culture’ as a mediating and/or moderating variable has become increasingly prominent. Indeed, studies that purport to investigate a multitude of education-related issues such as self-regulation that ignore a ‘cultural perspective’ are probably limited studies (King & McInerney, 2014). How culture is conceptualized makes an essential contribution to how we interpret the role of culture in studies of learning and a whole host of other learning and achievement-related variables.

In McInerney (2011), culture was conceptualized from a subjective perspective, which included values, traditions, and beliefs that mediate the behaviors of a particular social group (Parsons, 2003) and as a society’s characteristic way of perceiving its social environment (Triandis, 2002). Subjective culture was defined as the “how and why we behave in certain ways, how we perceive reality, what we believe to be true, what we build and create, and what we accept as good and desirable” (Westby, 1993, p. 9). McInerney (2011) argued that embedded in such definitions of subjective culture are values and belief systems which potentially influence academic task engagement and performance and that can be used to benchmark the relevance of constructs (reflecting values) that are embedded within particular theoretical perspectives on self-regulation (McInerney, 2008). King and McInerney (2014) scrutinized the notion of ‘culture’ closely as it relates to educational psychology research and, building on the work of Triandis (2002), argued that it is important to look at both emic (culture-specific) and etic (universal) aspects when studying subjective culture. Triandis put it nicely when he said:

If we compare apples and oranges we can use etic elements like weight, size, thickness of skin, price, and the like. But obviously one does not learn much about the fruit with this kind of information. One needs to learn about apple flavor and orange flavor, apple texture and orange texture and the like. These are emic qualities. So when we compare fruits we can do it with etic qualities, e.g. say that apples are more expensive than oranges today, but when we want to do a good job of describing the fruit we also need to use emic qualities.

(p. 5)

Using this as a starting point it is essential to use an etic-emic framework for examining any psychological construct and therefore this applies to cross-cultural research on self-regulation. In our 2014 publication in *Educational Psychologist* (King & McInerney, 2014) we provided a framework that we believed would be useful in designing, conducting, and evaluating research which we have used to guide our critique of articles.

In brief, we emphasized that there is a need for psychological theorizing that attempts to be truly universal to incorporate both cross-cultural similarities and cross-cultural differences. However, the vast majority of existing

studies rely only on the etic perspective. They focus on cross-cultural similarities and neglect cross-cultural differences. Because of this, when researchers find something that does not conform with Western models, these findings are neglected, downplayed, or explained post-hoc. On the other hand, emic studies that only focus on the culturally indigenous and knowledge generated from the bottom-up may fail to see the big picture. The findings of purely emic studies are in danger of becoming irrelevant to the wider scientific community.

Fortunately, there is a middle ground in between these two extremes. One can utilize both an etic and emic approach and combine these two perspectives when looking at psychological phenomena. Doing so can help researchers advance a truly universal psychology.

An Overview of Research on Self-Regulated Learning Until 2010

In the 2011 Handbook chapter McInerney examined three research themes. The first considered the nature and correlates of self-regulation and its relationship to achievement outcomes; the second considered family influences and self-regulation; the third considered self-efficacy and self-regulation. He followed this with a critique of the research and what generalities might be drawn from the research for future research and educational practice. This section of the chapter summarizes the findings of this earlier review.

First, although the nuances of what comprised appropriate and effective self-regulatory behavior varied from cultural context to cultural context, major elements of self-regulation theory seem to have had universal application. In other words, self-regulation in all its many faces appeared to be an important determinant of school engagement and achievement cross-culturally (e.g., Nota, Soresi, & Zimmerman, 2004; Pintrich, Zusho, Schiefele, & Pekrun, 2001; see Tang & Neber, 2008, for a contrasting view).

Second, the preponderance of evidence reviewed indicated that there was a positive relationship between students' use of specific self-regulatory strategies and enhanced achievement outcomes across cultures. It appeared, for example, that effective meta-cognition, adaptive self-regulatory learning strategies, and deep over surface learning were, in most studies, related to enhanced student achievement (e.g., Blom & Severiens, 2008; Camahalan, 2006; Zhu, Valcke, & Schellens, 2008). Use of self-regulatory strategies also appeared to be related to a range of other important psychological variables such as academic self-concept, self-efficacy, and an incremental view of intelligence (Ommundsen, Haugen, & Lund, 2005).

Third, a mastery goal orientation appeared to be the most adaptive goal orientation to adopt in terms of developing self-efficacy, interest, strategy use, and performance across cultural groups studied. In a number of studies the relations between goals and SRL were similar, with mastery orientation being the strongest and most consistent predictor of SRL. Across cultures mastery goals appeared to enhance self-regulation whereas performance goals appeared to undermine self-regulation (Blom & Severiens, 2008; Pintrich et al., 2001).

Fourth, while in Western studies memorization is often related to lower academic achievement, in Asian societies this pattern did not seem to hold. When considered in cross-cultural contexts categorizing memorization as a surface learning strategy appeared to be too simplistic (e.g., Chiu, Chow, & McBride-Chang, 2007; Neber, He, Liu, & Schofield, 2008; Zhu et al., 2008). Some studies found that Asians do not use memorization any more than non-Asians (e.g., Chiu et al., 2007; Zhu et al., 2008). Other studies found Asians used memorization more frequently, but that it was associated with deep, not surface, learning (e.g., Neber et al., 2008).

Fifth, family closeness appeared to be a salient predictor of the use of self-regulatory learning and, within the Asian context as well as within Western comparator groups, authoritative and 'teaching' parenting styles was related to self-regulation (Huang & Prochner, 2004). Within some cultural contexts family influence was associated with 'fear of failure' or 'saving face' which acted as a positive drive for engagement in learning (e.g., Chong, 2007; King & Ganotice, 2015; King, Ganotice, & Watkins, 2014; King, McInerney, & Watkins, 2012;

Klassen, 2004). Confucianism and collectivism appeared to underpin the findings of many studies (e.g., Huang & Prochner, 2004; Lee, Hamman, & Lee, 2007).

Sixth, students across cultures who regulated their cognition, motivation, and behavior had higher academic achievement, and students who used all three forms of SRL to a high degree had the highest levels of achievement, even in relation to students of equal ability (Yang, 2005).

Finally, despite the commonalities described above, stereotyped views on what learning strategies are most salient to diverse cultural groups, such as Asian learners use more rote learning and are non-competitive compared with Western learners, perpetuated in much theoretical and research literature, are problematic. There were as many studies contradicting stereotypes as supporting them. Issues of the underlying meaning of labels such as memorizing needed to be reconsidered in the light of these studies (Chiu et al., 2007; Neber et al., 2008; Rao, Moely, & Sachs, 2000; Zhu et al., 2008).

Despite the importance of the reviewed studies to educational settings, few of the studies made specific recommendations for educational practice based on their findings. What was of more importance for the purposes of this current chapter were the theoretical paradigms and methodologies used in these previous studies. The predominant paradigm of self-regulation utilized in the reviewed research was based on Western theorizing. There were no non-Western 'indigenous' theories or paradigms of self-regulation proposed to guide any reported research. Few of the reviewed articles examined or challenged the essential components or meaning of SRL, as articulated in particular theoretical models, within different cultural contexts, but rather assumed their universality and proceeded to model relationships between these theoretical components of SRL and various outcome measures.

Apart from some exceptions, most of the cross-cultural studies of self-regulation reviewed used weak methodologies and relatively unsophisticated analyses. In studies purporting to compare across two or more cultures or societies, there was very little attention paid to defining 'culture' or 'groups'. Little attention was also paid to multi-group invariance tests or other appropriate tests to ensure the cross-cultural (or cross-group) validity of the instrumentation. Few studies utilized rigorous cross-cultural validation checks, such as CFA and invariance tests across cultural groups. A number of studies did not report validity evidence.

The theoretical and measurement boundaries defining self-regulation, motivation, self-efficacy, and a number of other related constructs were not 'sharp' or 'hard', making it difficult to evaluate which dimension researchers were actually investigating. This became more complex when several of these dimensions were included in the one study, which often was the case. The conceptual boundaries were permeable, making definitive conclusions on what relates to what and why, difficult.

Chinese and Asians in general formed a greater percentage of the groups studied, followed by Europeans (in particular, participants from Scandinavia). For the Asian studies, the theoretical framework for establishing hypothesized differences most often related to the individualism/collectivism typology, with the Asian societies being categorized as collectivist or as Confucian heritage societies. In both cases dualities were posited that predicted that the Asian societies would be different from the non-Asian Western societies on dimensions of self-regulation (as defined by Western models of self-regulation). In general, the stereotypes based on these typologies were not sustained by evidence. While there were variations in some elements of the content of self-regulation scales, in general Asian students were more similar than different to non-Asian students and there was a strong and consistent relationship between the number and nature of self-regulation strategies used and which enhanced school achievement. There were no ground-up, culturally based models of self-regulation tested.

Finally, it is of interest to note that although the studies reviewed were cross-cultural in the sense of dealing with groups outside the dominant Western Anglo samples, none of the reviewed literature appeared in journals dedicated to cultural issues such as the *Journal of Cross-Cultural Psychology*, the *International Journal of Intercultural Relations*, the *Journal of Intercultural Studies*, and the *International Journal of Educational Research*.

But perhaps the nature of the topic lay outside the scope and mission of these particular journals, or the search strategy used was not sufficient to locate relevant articles in these journals.

At the conclusion of the 2011 Handbook chapter McNerney argued that given the dearth of research and lack of strong methodologies, it was important that future research in self-regulation include a wider range of cultural groups and stronger methodologies, and in particular ones that built on the emic-etic typology.

In this context McNerney suggested that it would be appropriate for more emic-based, perhaps initially qualitative, research to be conducted to derive models of self-regulation that might be more indigenous as it is only through this approach that the universals of self-regulation (the etic dimension) can be established. Currently, these universals are assumed and then tested. But alternative models that might more effectively capture what self-regulation means to Asian and other societies can only emerge from effective and high-quality emic research. Across a number of such emic-based research studies, specific and localized definitions of the self-regulation construct may be established, while also allowing for commonalities across groups to emerge, giving strong evidence as to what might be considered as the universal or etic dimensions of self-regulation. These latter studies are sorely needed to give true richness to this important self-process.

What is the Current State of Cross-Cultural Studies of Self-Regulation?

The above reprise of the 2011 review provides a platform for the analysis of post-2011 research on self-regulation in cross-cultural contexts. A literature search was conducted focusing on research post-2011 and any new insights such research has provided. An emic-etic lens was used to explore what, how, and why researchers studied self-regulation in cross-cultural contexts. Emerging from this review were many new themes/research that have developed since 2011.

To source relevant papers, an electronic search of the following databases was conducted after January 2011: Academic Search Premier, Eric, Primary Search, Teacher Reference Center, ProQuest Educational Journal, and PsychINFO. The following terms were used: 'self-regulated learning', 'self-regulation of learning', 'self-regulatory process', 'motivated strategies for learning questionnaire', 'culture', and 'cross cultural'. Secondly, the reference lists of all obtained review articles and research studies were perused, followed by a manual search of relevant peer-reviewed journals. At the initial stage, studies were excluded when they (1) were published in a language other than English, (2) were a review paper, and (3) presented unpublished material such as theses and dissertations. This resulted in 311 articles remaining. After screening titles and abstracts, at the broadest level of analysis we located approximately 144 articles on SRL which had a relationship to cultural contexts either through participants used or country of research.

Although a smaller number of articles was ultimately reviewed because we excluded articles dealing predominantly with theoretical frameworks (such as self-determination, self-efficacy, self-concept, achievement goals, emotions) deemed peripheral to our major concern or focused on issues such as parental involvement, complex problem solving, assessment, e-learning and computer learning contexts, and so on, rather than self-regulation per se, this large number of articles clearly indicates that self-regulation of learning in a variety of cultural contexts is continuing to be a significant research area of educational psychology. Furthermore, we found that there was a broader spread of countries researching self-regulation than was captured in the 2011 Handbook review, including Belgium, the Netherlands, Germany, Croatia, Greece, Turkey, Italy, France, Portugal, Spain, Chile, United Kingdom, France, China, Hong Kong, South Korea, Japan, Taiwan, Indonesia, the Philippines, Singapore, and Australia. The largest concentration of research appears to be emanating from the Netherlands, German, Italy, Hong Kong, Korea, and Turkey.

At a more macro-level most of the reviewed articles dealt with issues related to SRL in one cultural context (although culture was quite incidental in the papers—there was little or no attempt to use culture, ethnicity, etc., as an independent variable). An overview of the bulk of the articles indicates that an imposed etic is the predominant approach used. The theoretical construct of self-regulation and its various measurements are ones that have been developed and validated in the West, largely the United States-Northern American context, although many European studies have expanded the SRL theoretical framework and developed specific measurements. As SRL research is at a mature stage of development, having been an active area of research for almost two decades, it is not surprising that researchers from diverse cultural settings will use what is already established in the (Western) research literature as core theoretical constructs and measures to shape their enquiries and methodology. This is particularly the case with countries that have a predominantly Western orientation such as Western Europe (Germany, Netherlands, Belgium, Italy) and the United Kingdom and Australia. We see this reflected in the articles emanating from Western Europe reviewed for this chapter (e.g., Chatzistamatiou, Dermitzaki, & Bagiatis, 2013; Efklides, 2011; Sontag & Stoeger, 2015).

However, with other contexts, such as Eastern Europe, the Middle East, Asia and East Asia, and South America, it could be expected that a more critical stance would have been applied to adopting Western models of self-regulation and more careful attention paid to the generalizability of Western constructs to non-Western contexts. However, what is apparent from much Asian and other research is that while SRL theorizing is largely based on Western platforms, there are a number of measurement scales developed and validated for specific cultural or thematic purposes (see, for example, Ersozlu & Miksza, 2015; You & Kang, 2014).

As mentioned above, while an imposed etic approach is not without considerable value as we can develop a list and then check off similarities (see Christopher & Hick-inbottom, 2008, p. 578) such an approach does not, as its primary focus of attention, elucidate any special nuances of self-regulation that might characterize particular societies. Any such special nuances are ‘discovered’, if at all, by accident and as anomalies in the data. It is not possible here to review all the research following an imposed etic methodology; suffice it to say that most articles authored by European and non-U.S. and Canadian researchers, including those from Asia, use an imposed etic methodology. We provide a brief review of several of the studies in the section below.

Brief Review of Findings

One of the key themes that emerged is the number of etic-based studies that examined the positive relationship between the use of SRL strategies and enhanced learning (e.g., Effenev, Carroll, & Bahr, 2013; Harris, Graham, & Adkins, 2015; Mizumoto, 2013). In these studies researchers found that SRL was associated with more optimal student learning outcomes such as self-efficacy and writing proficiency, among others.

There were also a number of etic studies that examined various self-regulation intervention strategies (e.g., Beaumont, Moscrop, & Canning, 2014; Endedijk, Brekelmans, Verloop, Slegers, & Vermunt, 2014; Festas et al., 2015; Kostons, van Gog, & Paas, 2012; Sontag & Stoeger, 2015). These studies showed that interventions are generally effective in raising self-regulatory competence and student learning outcomes.

We also found many studies which emphasized the relationships between classroom structure, personal achievement goals, and SRL strategies and student learning, emotions, and test/class anxiety (e.g., Ahmed, van der Werf, Kuyper, & Minnaert, 2013; Burić & Sorić, 2012; Hiemstra & Yperen, 2015; Kesici, Baloglu, & Deniz, 2011; Mega, Ronconi, & De Beni, 2014). These studies show that self-regulation is a key part of an effective student’s network of beliefs, processes, and resources.

Other etic studies focused on the relationships between self-regulation and self-efficacy beliefs (e.g., Joët, Usher, & Bressoux, 2011; Kim, Wang, Ahn, & Bong, 2015; Lee, Lee, & Bong, 2014; Wang, Schwab, Fenn, & Chang,

2013; Chatzistamatiou et al., 2013; Di Giunta et al., 2013; Efklides, 2011; Joët et al., 2011; Zuffianò et al., 2013). These studies found that self-regulation and self-efficacy were positively associated with each other.

Finally, there were also a significant number of studies which focused on the examination of SRL in online learning contexts (e.g., Chen & Huang, 2014; Chiu, Liang, & Tsai, 2013; Dunn, Rakes, & Rakes, 2014; Lawanto, Santoso, Goodridge, & Lawanto, 2014; Rowe & Rafferty, 2013). These studies showed that self-regulation is also a key component of effective learning in online settings and not just in regular classroom settings as has been amply demonstrated in previous research. Because of space limitations the articles cited above are representative and not inclusive of all the articles reviewed.

Of more interest to this chapter is a focus on the smaller number of articles that have, in one way or another, advanced our understanding of the role of culture on self-regulatory processes, or provided some methodological advances.

Large-Scale Cross-Cultural Studies

In the 2011 Handbook chapter McNerney commented that there were few large-scale cross-cultural studies of self-regulation. This continues to be the situation. One example, however, of a relatively large-scale cross-cultural study is Rosário et al. (2014). Rosário et al. sought to examine the effectiveness of an intervention program designed to enhance SRL strategies at the university level across four universities in four different countries and continents, viz., Portugal, Spain, Chile, and Mozambique, with an experimental and control group in each university (Total Experimental N = 263, Total Control N = 247). The theoretical framework for the study was drawn from the work of Zimmerman (2002) and colleagues.

The tools and methodology were ones that had been used in previous cross-cultural studies in Portugal and Spain (Núñez et al., 2011). In line with previous findings the researchers hypothesized that (a) after the intervention program, students from the experimental groups, compared to students from the comparison groups, would show higher levels of reported use of SRL strategies, higher levels of structural complexity when dealing with a task, and report more self-efficacy for SRL and higher perceived instrumentality of the use of SRL strategies; and (b) the post-test differences in these variables would show the same tendency in all four countries (cross-cultural consistency).

An important aspect in this study is the degree to which the researchers considered ‘cultural background’ as a variable in the research. The major training tool was a program entitled ‘Letters from Gervase’, developed by Rosário et al. (2007, 2010) and based on the social cognitive model of Zimmerman and the work of Zimmerman and Martinez-Pons (1986), which is intended to train university students in SRL strategies.

‘Letters from Gervase’ is a narrative tool which is used to teach students about effective self-regulation. It describes a set of 13 letters from a freshman named Gervase addressed to his own navel (Rosário et al., 2010). Each letter is organized around a repertoire of SRL strategies (e.g., goal setting or time management) corresponding to different phases of the SRL process (forethought phase, performance phase, and reflection phase). The Gervase letters program gives students the opportunity to learn a broad range of learning strategies and to reflect on different learning situations. For example, in the first letter Gervase discusses the challenges of adapting to university life and key principles underpinning planning and time management.

Several scales measuring SRL knowledge, strategies and instrumentality, self-efficacy, and complexity of learning outcomes were used. An identical method was used in each of the universities (it is not indicated what language the tasks were presented in, but the presumption is that it was the local language). While ‘culture’ was used as a covariate in one set of analyses, there was no further reference to any cultural element that might have impacted on the results, nor was there any validation evidence presented for the various scales used in the different cultural situations. In separate analyses for each of the groups the results of the study showed that the program

was efficacious across the four cultural groups. When culture was used as a covariate, results indicated a significant main effect of the variable country for the use of SRL strategies. Other than for this, there were no statistically significant main effects for the structural complexity of students' responses to the proposed task, for the perceived efficacy for SRL, and for the perceived instrumentality. The authors conclude that the inclusion of country within the predictive model is not relevant.

While the research is interesting and presents a recent example of an imposed etic study, it has a number of limitations from a cross-cultural perspective, in particular, no cross-cultural validation evidence is provided for the various scales used, there is little comparison across groups (just within groups of experimental and comparison groups), and there is no indication of the language of administration and any special cultural characteristics that may have influenced the results.

The study of Marambe, Vermunt, and Boshuizen (2012) provides an overview of learning strategies used by higher education students across three cultural groups: Sri Lanka, Indonesia, and the Netherlands. They performed a meta-analysis on three large-scale studies that used the same research instrument (i.e., the Inventory of Learning Styles, or ILS). A range of relatively low-level analyses were conducted to establish construct validity of the 18 scales across the three groups, including principal components analysis and reliability tests. The authors then compared the endorsement of the various scales across the groups using ANOVA. The authors illustrated sensitivity to possible cultural differences in the nature and operation of their scales and the need to validate the scales both within and across the cultures before proceeding to make comparisons.

Differences were found in factor structure across the three groups, and many differences were found between the three groups on the particular scales. The authors proposed that some patterns of learning were universal and occurred in all groups, and other patterns were found only among the Asian and the European students. The findings were discussed in terms of learning environment and culture as explanatory factors. The strength of the research lies more in the sensitivity the authors have shown to issues involved in studying learning processes across cultures than in the strength of their methodology.

Lopez, Nandagopal, Shavelson, Szu, and Penn (2013) sought to identify ethnically diverse (Asian, Latino, White) students' study strategies in organic chemistry and their relationships to course outcomes. Acknowledging the limited research examining study strategies across ethnic and cultural groups and basing their study explicitly on Zimmerman's (2002) theoretical framework, Lopez et al. (2013) found that students engage in four commonly used reviewing-type strategies (organizing and transforming, reviewing previous problems, reviewing notes, reviewing text), regardless of ethnic group affiliation. The frequency of use of these four strategies varied across the groups, with Latino students applying the strategies more frequently than Asian and White students. However, these common strategies were rarely associated with students' problem solving, concept mapping, or course performance. In addition, students seldom engaged in metacognitive and peer-learning strategies despite their reported benefits.

While Lopez et al. (2013) based their research on a key element underlying SRL, namely the use of effective learning strategies, they utilized a range of novel tools for assessing the reported study strategies of the students and related these to a list of 14 strategies generated from SRL theory. In this way, they incorporated an emic level of analysis, which potentially may have elicited other strategies not previously categorized, as well as identifying the priority of use of strategies across ethnic groups. It appears from the results that no alternative ethnically related strategies were derived. It also appears that the priority of the use of strategies across the groups is similar. However, there is no attempt in the study to address a core issue, namely, whether the theorizing and methodology are appropriate across the ethnic groups included in the study.

There were very few two-culture studies conducted over the period of the review, most studies being one culture, and as noted previously in the chapter, most neglected to use culture as an independent variable, or even refer to it in any other circumstance than as the source of the data. In our search we found two two-culture studies. Wang et al. (2013) compared the self-efficacy and SRL strategies for English language learners of German and Chinese college students. Their study was based largely on the theorizing of Zimmerman (2000) and Pintrich (2004). Two hundred Chinese and 160 German college students completed two existing surveys about self-efficacy for learning English and self-regulation for learning English. The researchers tested the construct validity of the surveys by CFA and factorial invariance testing. Both tests had good reliability. The self-efficacy scales were invariant across the two groups. However, the SRL scale was not invariant, with differences in latent structure. The article does not explicitly describe the invariance, nor does it delve into what this might mean in terms of conducting various MANOVA describing differences between the two groups. The lack of fit between the two groups is ignored. This is a significant limitation in the study. Nevertheless the article, while clearly using an imposed etic approach, is sensitive to possible differences in construct structure across cultural groups and uses appropriate statistical techniques to demonstrate validity. It falls short in not describing the implications of the lack of fit of the SRL questionnaire across the two groups. Nevertheless, the anomalies in their findings regarding the positive (for Chinese) and negative (for German) relationship of SRL to English outcomes is explained by reference to potential cultural differences in SRL strategies salient to either cultural group. Indeed, the authors state: “Future studies should develop a unique measure of SRL strategies that reflects contextual factors in German culture for German students” (p. 185).

Another study, conducted by Loong (2012), compared Malaysian students’ and international students’ (who came from 25 different countries in Europe, Asia, and Africa) SRL strategies. He used a well-developed SRL instrument, the LASSI (Weinstein, Palmer, & Schulte, 2002), and found that the instrument had acceptable internal reliabilities for the Malaysian and international students. He found that a positive attitude and interest towards school positively predicted math performance across both samples. In terms of cross-cultural differences, he found that self-testing was a significant positive predictor for Malaysian students but test strategies (knowledge of different types of tests) was more important for international students. Despite these interesting cross-cultural differences, his study did not focus on explaining the cross-cultural differences between the Malaysian and international students given that the international student group was extremely diverse.

Etic-Emic Studies

In the earlier Handbook chapter, as well as in King and McInerney (2014), McInerney called for more etic-emic studies to help researchers and educators understand the role of SRL in cross-cultural contexts. Again, there were few examples in the reviewed literature.

To recapitulate, a study can be considered as etic if it focuses on the similarities of psychological processes across cultures. Usually (if not always) this takes the form of applying Western theories or models to non-Western contexts. Much of the existing SRL research uses only an etic approach. A downside is that when confined by a purely etic perspective, researchers tend to ignore or downplay processes that cannot be explained by purportedly universal (but are in fact Western) models.

An emic study, on the other hand, takes a bottom-up approach and aims to come up with indigenous models and theories that could effectively capture the relevant psychological phenomena. Etic-emic studies combine the strength of both the etic and emic approach. While they recognize that certain psychological processes and phenomena are universal, they also acknowledge the possibility that there may be culturally specific phenomena not captured by Western models and theories. The combined etic-emic approach therefore is more sensitive to capturing both cross-cultural similarities and differences (see King & McInerney, 2014, for a review).

Lau (2011, 2012) questioned whether the positive effects of SRL on students' learning clearly demonstrated in Western research would apply in Chinese societies with a strong Confucian background. Specifically, Lau examined the moderating effects of cultural and contextual factors on the implementation of principles of SRL in Chinese language classes in Hong Kong. Lau's primary concern was whether teachers schooled in the Confucian way of teaching could easily adapt their teaching to SRL principles espoused in the new curriculum.

While the theorizing was based on etic views of self-regulation, the use of classroom observation and the use of teacher-student interviews to interrogate the meaning and efficacy of instruction in self-regulation provided an emic platform for data generation. Given that the interviews with both teachers and students used in the study were relatively open to the endorsement of various self-regulation strategies, a degree of emic validity evidence not evinced in purely imposed etic studies was provided. As stated by Lau (2012), "When asked what kinds of learning materials and activities they liked most, most of the [student] answers were consistent with the principles of self-regulatory instruction", but when referring to autonomy Lau states, "Most of the students regarded teacher control in the classroom as very natural. They preferred increasing involvement rather than autonomy or choices in class" (p. 58).

Therefore, while most of the elements of SRL were supported in the research, the role of teacher control (i.e., top-down dissemination of knowledge) did not match the concept of SRL for either teachers or students. Furthermore, the explication of difficulties teachers had with both the theory and implementation of SRL in Hong Kong classrooms highlighted further areas for investigating the applied usefulness of the approach in a culturally different setting. The effects of the training program in SRL were positive and supported the implementation of self-regulatory instruction in Chinese language classes in Hong Kong, albeit with appropriate cultural modifications. This study provides an effective example of an etic-emic study.

Another example of an etic-emic study is provided by Kaplan, Lichtinger, and Margulis (2011). While based on the theorizing of Zimmerman and Schunk (2001) and Schunk and Zimmerman (2007), Kaplan et al. argued that motivational constructs and self-regulation strategies are integrated for individuals in a "situated meaning that a student constructs for engagement in an achievement situation". Kaplan et al. described this as "a comprehensive psychological framework, or sociocognitive scheme, that involved the purpose of engagement in the task as well as the actions that are perceived to serve the pursuit of this purpose" (p. 285).

The authors argued that the use of certain self-regulation strategies should be considered inseparable from the situated purpose for engaging in a task. From this perspective, therefore, each person's self-regulation dynamic would reflect individual capacities embedded in their meaning-making world, which is strongly socioculturally determined. In other words, "situated purposes of engagement and regulation strategies may be integrated in 'purpose-strategy' action orientations: A situated and dynamic phenomenological network of reasons for engagement, goals of engagement, and engagement strategies in a particular task" (p. 285).

To test this Kaplan et al. adopted a mixed-methods case study investigation to investigate the dynamic integration of spontaneous and naturally constructed purposes of engagement and self-regulation strategies. As such, it was a bottom-up study looking for evidence of what was used, rather than imposing a set of strategies and motivators and evaluating to what extent the participant self-reported using them. To accomplish this the authors used a range of creative methods, most of which facilitated a bottom-up set of data with enhanced validity, namely, (a) a microprocesses observation on the writing process; (b) a stimulated-recall interview (SRI) using the observations as a memory trigger; and (c) a more general interview about the experience of engagement in the task, self-processes related to writing, and self-regulation aptitude. A correlation check was included which consisted of 14 closed questions related to self-regulation (which might be construed as an imposed etic).

To illustrate the process the authors presented a case study of one Israeli-Jewish ninth grade girl engaged in a writing task. Results showed that 'purpose of engagement' is integral to self-regulation strategies employed. For purposes of this chapter the major finding is methodological, namely that a socioculturally sensitive approach to

teaching about self-regulation, and the assessment of its utility and usefulness must be context sensitive. The authors conclude:

[S]tudents' subjective purposes of engagement and their related type of self-regulation may be more or less compatible with the purposes that educators would like them to adopt.... [It] seems that for promoting an effective change in the quality of students' engagement, what may be needed is an open and explicit dialogue between educators and students about the purposes of engagement, their consequences, and the strategies that would serve their pursuit.

Summary

In our review of the research literature since 2011 new themes emerged. The examination of the nexus between emotions and SRL was a popular theme (e.g., Ahmed et al., 2013; Burić & Sorić, 2012; Efklides, 2011; Kesici et al., 2011; Mega et al., 2014; Schnell, Ringeisen, Raufelder, & Rohrmann, 2015). Electronic performance systems, cyber learning environments, and self-regulation is also a growing area of interest (e.g., Joo, Joung, & Kim, 2012; Kert & Kurt, 2012; Sha, Looi, Chen, Seow, & Wong, 2012).

As indicated above, the reviewed research also demonstrated more sophisticated methodologies and statistical analyses than in the pre-2011 studies including cluster analysis, growth mixture modeling, growth curve analysis, and latent profile analysis used to determine the complex range of cognitive, metacognitive, and behavioral strategies used by students related to achievement outcomes and their development over time (e.g., Ahmed et al., 2013; Endedijk, Vermunt, Meijer, & Brekelmans, 2014; Ning & Downing, 2015; Peetsma & Veen, 2013).

The findings of the imposed etic research reviewed for the second Handbook reiterated findings of the first. Self-regulation in all its many faces appeared to be an important determinant of school engagement and achievement cross-culturally, and effective metacognition, adaptive self-regulatory learning strategies, and deep over surface learning were, in most studies, related to enhanced student achievement. Students' use of specific self-regulatory strategies enhanced achievement outcomes across cultures. While the focus on mastery-approach goals had diminished somewhat in the reviewed research, the positive association between mastery-approach, self-regulatory behavior, and achievement were consistent with previous research. The focus on memorization as an SRL behavior and its different effects in different cultures was not mentioned in the studies reviewed post-2011. In a similar vein a research interest in the relationship of family to self-regulatory behavior and a focus on collectivism/individualism and Confucianism had diminished in the post-2011 Asian literature.

There were limited studies reflecting the concerns of McInerney (2011) and King and McInerney (2014) and their belief that more bottom-up, emic, and etic-emic studies should be conducted. There were very few larger scale and truly cross-cultural studies conducted. One bright spot in the reviewed literature was that in contrast to the pre-2011 studies, which used relatively weak methodologies and unsophisticated analyses, the post-2011 studies, in general, used more sophisticated methodologies and analyses including the use of cross-cultural invariance testing (e.g., Wang et al., 2013), confirmatory factor analyses (e.g., Adnan, Nordin, & Ibrahim, 2013; Ayatollahi, Rasekh, & Tavakoli, 2011), structural equation modeling and multi-level modeling (e.g., Hong & Park, 2012), Rasch modeling (e.g., Leana-Taşçılar, 2015), mixed-methods research (e.g., Cifarelli, Goodson-Espy, & Chae, 2010), and the incorporation of behavioral measures of SRL (e.g., Jeske, Backhaus, & Stamov Roßnagel, 2014), among others. While the use of more sophisticated methodologies and analyses is not in itself a guarantee of quality of research, these features of the more recent research papers do reveal an interest by researchers in collecting data at sufficient levels to allow for, and warrant, more sophisticated analyses. It would be strange if research into cross-cultural elements of SRL continued to be constrained by limited data and limited analyses.

Future Research

Several directions for future research emerge from this review. First, there is still a dearth of SRL research that is conducted across a wide range of cultural groups. Most of the studies examined still used mono-cultural research samples, which limits our ability to gain insights into the cross-cultural similarities and differences in SRL. Mono-cultural studies have inherent limitations. Henrich, Heine, and Norenzayan (2010) criticized psychologists for drawing ostensibly pan-cultural generalizations from a thin slice of the world's population. They argued that most of the published psychological studies drew samples from Western, educated, industrialized, rich, democratic (WEIRD) societies. However, studies show that culture strongly influences key psychological processes and generalizations drawn from WEIRD samples may not be truly pan-cultural. Therefore, large-scale cultural studies that recruit more diverse samples are needed to address the inherent limitations of mono-cultural data. There are encouraging signs in the literature reviewed that researchers are covering more sociocultural groups in recent years.

Second, none of the studies reviewed used a bottom-up emic approach (with one exception, Kaplan et al., 2011) to the study of SRL. All of the studies relied on a top-down imposed etic approach. The imposed etic approach assumes that SRL is a universal process and then proceeds to test it across diverse samples. While valuable, this approach precludes us from uncovering particular ways of being self-regulated espoused by different cultural groups which can only be documented by using bottom-up emic methods. More bottom-up, emic-based studies are still needed.

Third, cross-cultural researchers have advocated the use of more sophisticated methodologies that would enable researchers to examine whether key constructs hold the same meaning and factor structure for people from different groups or whether there are salient cross-cultural differences that need to be acknowledged. While there is an encouraging trend towards more sophisticated analyses in our review of the post-2011 SRL literature, more needs to be done on this front.

Educational Insights

Most of the articles proffered advice for future research as well as insights into the role of SRL in enhancing learning. Important among these was a focus on the importance of training teachers in the use of self-regulation strategies to enhance their professional development (e.g., Festas et al., 2015; Friedrich, Jonkmann, Nagengast, Schmitz, & Trautwein, 2013; Lau, 2011). A range of educational interventions focusing on developing SRL were found to be effective across various cultural groups and related to enhanced educational achievement (e.g., Brydges et al., 2015; Festas et al., 2015; Kos-tons et al., 2012; Tsai, Lee, & Shen, 2013). Schools should be encouraged to source good SRL programs for both teacher and student training.

As with most previous studies the strong relationship between mastery-approach goals and SRL behavior was further demonstrated, emphasizing the utility of a mastery-approach-oriented approach to teaching, and facilitating the use of SRL by students. An emerging theme was a focus on emotions and anxiety. Several researchers found that the use of learning strategies reduces learning anxiety and enhances positive emotions for learning (e.g., Kesici et al., 2011).

Teachers need to be aware of the complex dynamics of cognitive, emotional, and behavioral components of a SRL process (Cheung & Pomerantz, 2012; Kaplan et al., 2011). Self-regulation does not just happen in a vacuum. It is something which can be proactively developed and nurtured, and teachers play a key role in its ontogeny.

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