Dysregulated Learning with Advanced Learning Technologies

Roger Azevedo and Reza Feyzi-Behnagh

McGill University, Department of Educational and Counseling Psychology
Center for Metacognition and Advanced Learning Technologies
3700 McTavish Street, Montreal, Quebec, H3A 1Y2, Canada
{roger.azevedo@mcgill.ca}

Abstract

Successful learning with advanced learning technologies is based on the premise that learners adaptively regulate their cognitive and metacognitive behaviors during learning. However, there is abundant empirical evidence that suggests that learners typically do not adaptively modify their behavior, thus suggesting that they engage in what is called *dysregulated learning*. Dysregulated learning is a new term that is used to describe a class of behaviors that learners use that lead to minimal learning. Examples of dysregulated learning include failures to: (1) encode contextual demands, (2) deploy effective learning strategies, (3) modify and update internal standards, (4) deal with the dynamic nature of the task, (5) metacognitive monitor the use of strategies and repeatedly make accurate metacognitive judgments, and (6) intelligently adapt behavior during learning so as to maximize learning and understanding of the instructional material. Understanding behaviors associated with dysregulated learning is critical since it has implications for determining *what* they are, *when* they occur, *how* often they occur, and *how* they can be corrected during learning.

The Importance of Self-Regulated Learning

Successful learning with advanced learning technologies is based on the premise that learners adaptively regulate their cognitive and metacognitive behaviors during learning (Aleven et al. in press; Azevedo et al. in press a; Winne, in press). However, there is abundant empirical evidence that suggests that learners typically do not adaptively modify their behavior, thus suggesting that they engage in what is called *dysregulated learning*. Dysregulated learning is a new term that is used to describe a class of behaviors that learners use that lead to minimal learning. Examples of dysregulated learning include failures to: (1) encode contextual demands (e.g., retain an internal mental representation of the hierarchical structure of the instructional materials), (2) deploy effective learning strategies (e.g., note-taking and knowledge elaboration), (3) modify and update internal standards, (4) deal with the dynamic nature of the task (e.g., internalize and correct behavior based on the system's feedback and scaffolding), (5) metacognitive monitor the use of strategies and repeatedly make accurate metacognitive judgments, and (6) intelligently adapt behavior during learning so as to maximize learning and understanding of the instructional material. Understanding behaviors associated with dysregulated learning is critical since it has implications for determining *what* they are (i.e., detection and classification), *when* they occur (e.g., onset, duration, temporal dynamics, antecedents), *how* often they occur (e.g., patterns across time, maladaptivity), and *how* they can be corrected during learning (e.g., inference based on converging evidence, system intelligence, scaffolding, and feedback). The goal of this paper is to: (1) present MetaTutor, an adaptive intelligent multi-agent learning environments designed to train and foster students' SRL and content understanding; (2) present empirically-based examples of dysregulated and regulated learning; and, (3) present some challenging for future directions.

MetaTutor: An Adaptive Multi-Agent Hypermedia Learning Environment

MetaTutor is a hypermedia learning environment that is designed to detect, model, trace, and foster students' self-regulated learning about human body systems such as the circulatory, digestive, and nervous systems (Azevedo et al. 2009, 2010). Theoretically, it is based on a general premise of SRL as an event and on cognitive models of SRL (Pintrich 2000; Winne and Hadwin 2008; Zimmerman 2008). The underlying assumption of MetaTutor is that students should regulate key cognitive and metacognitive processes in order to learn about complex and challenging science topics. The design of MetaTutor is based on our extensive research (see Azevedo 2008; Azevedo et al. in press a; Azevedo and Witherspoon 2009) showing that providing adaptive human scaffolding that addresses both the domain knowledge and the processes of SRL enhances students' learning science topics with hypermedia. Overall, our research has identified key self-regulatory processes that are indicative of students' learning about these complex science topics (Azevedo and Witherspoon 2009). More specifically, they include several processes related to planning, metacognitive monitoring, learning strategies, and methods of handling task difficulties and demands.

Overall, there are several phases to using MetaTutor to train students on SRL processes and to learn about the various human body systems: (1) a facility that models key SRL processes; (2) a discrimination task where learners choose between good and poor use of these processes; (3) a detection task where learners watch video clips of human agents engaging in similar learning tasks, stop the video whenever they see an SRL process used, and select the relevant process from a list; and (4) the actual learning environment used to learn about the biological system.

The interface of the actual learning environment includes a window dedicated to declaring the learning goal, set by either the experimenter or teacher (See figure 1). For example, *Your task is to learn all you can about the circulatory system. Make sure you know about its components, how they work together, and how they support the healthy functioning of the human body*. This goal is associated with the sub-goals window where the learner can generate several sub-goals for the learning session. A list of topics and sub-topics is presented on the left side of the screen, while the actual science content (including the text, static and dynamic representations of information) is presented in the center of the interface. The main communication dialogue window (between the learner and the environment) is displayed directly below the content window. The pedagogical agents are displayed on the top right-hand corner of the interface. In this case, Mary the Monitor is available to assist the learners through the process of evaluating their understanding of the content. Below the agent window is a list of SRL processes that the learner can use throughout the session. Learners can choose to use any SRL process they would like to use at any point during learning by selecting it from the list. The purpose of having learners select the processes is to enhance metacognitive awareness of the processes used during learning and to facilitate the environment's ability to trace, model, and foster learning. In addition to learner-initiated self-regulation, the agent can prompt learners to engage in planning, monitoring, or strategy use under appropriate conditions traced by MetaTutor.

One objective of the MetaTutor project has been to examine the effectiveness of pedagogical agents as external regulatory agents to detect, trace, model, and foster students' self-regulatory processes. MetaTutor is in its infancy, so the algorithms to guide feedback to the student are developed but not yet fully tested. The broad scope of SRL appeals to educational researchers who seek to understand how students become adept and independent in their educational pursuits. Whether SRL is viewed as a set of skills that can be taught explicitly or as developmental processes that emerge with experience, pedagogical agents have the potential to provide students of all ages with information that will help them become strategic, motivated, and independent learners. However, several theoretical and empirical issues need further research before practical classroom applications can be put forth (Graesser et al. 2008; Greene, Moos, and Azevedo, in press). How do students regulate their own learning when using a computer-based learning environment (CBLE) to learn complex science topics? Which processes associated with self-regulation and co-regulation do students and pedagogical agents use during collaborative learning with a CBLE? How can pedagogical agents be designed and used in CBLEs to support SRL? How can pedagogical agents be used as external regulating agents that model specific self-regulatory processes and challenge students to use and develop their own?

The challenge will be to provide feedback on the relevance of the content, on the accuracy of responses to embedded questions, and on the appropriateness of the strategies used by the student. Current machine learning methods for detecting students' evolving mental models of the circulatory system are being tested and implemented (Rus et al., in press). In addition, we are testing specific macro- and micro-adaptive tutoring methods based on detailed system traces of learners' navigational paths through the MetaTutor system (Witherspoon, Azevedo, and Cai 2009).

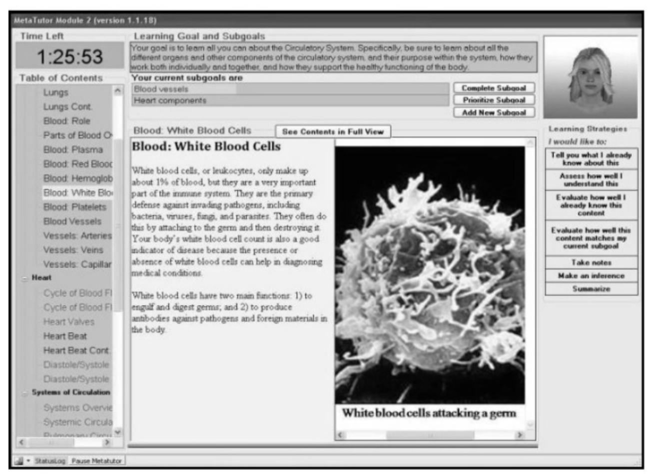

Figure 1. MetaTutor Screen Shot

Ideal Self-Regulated Learning

Self-regulation while learning (SRL) with non-linear, multi-representational, intelligent, open-ended learning environments like MetaTutor involves using different processes like planning, knowledge activation, metacognitive monitoring and control, strategy use and reflection (Azevedo at al. 2010). There is abundant interdisciplinary evidence that learners do not self-regulate by using these processes during learning and that they also do not adaptively modify their behavior, thus engaging in what we call *dysregulated learning*. Dysregulated learning is a new term that is used to describe a class of behaviors that learners use that lead to minimal learning.

Ideally, learning about complex topics such as the human body systems with MetaTutor requires the use of various self-regulatory processes. Initially, a learner begins by understanding task demands and the dynamic components of the task at hand. For example, this may include understanding the task, setting relevant sub-goals, understanding the role of the pedagogical agents, developing an internal representation of the structure of the non-linear and multi-representations content, recall strategies about how to best to approach the task, etc. An ideal self-regulating learner is not necessarily someone who is aware or understands these issues beforehand, but he/she uses appropriate monitoring processes and learning strategies during learning to continually maintain a sense of progress throughout the learning task. For example, they will use effective learning strategies such as drawing, taking notes, and coordinating informational sources to comprehend the material and build an internal mental representation of the topic. During task performance, they will also decide when to generate new sub-goals, abandon previously set sub-goals, and determine when sub-goals have been met. Other strategies include circumventing working memory (WM) limitations by off-loading difficult task elements and make best use of resources he has at hand at the time of performing the task. Afterwards, the ideal self-regulating learner engages in planning or goal-setting. Goal setting takes place at the beginning of the learning task, and the learner might also turn back and modify or eliminate the sub-goals he/she had set at the beginning; hence, the process is a cyclical one. At this stage, he sets task-relevant, manageable, and specific goals and sub-goals and prioritizes them prior to learning. He avoids setting narrow or broad sub-goals, and ideally settles on well-specified goals. This stage of the learning task is very significant, and the learner can benefit from assistance or sub-goal suggestions made by agents in computer learning environments like MetaTutor to calibrate his goals toward the overall learning task. By receiving prompts from MetaTutor, the learner actively engages in goal-setting and thinks about what he intends to achieve in the allotted time (e.g., 2-hour learning session). By contrast, a poor learner, or a learner who doesn't self-regulate properly, tends to set either broad, narrow, or irrelevant sub-goals for the learning task, and thereby begin planning to focus his efforts on parts and material which is either irrelevant or does not lead to comprehensive learning.

Subsequent to setting goals and sub-goals, the ideal self-regulating learner takes into account the domain an topic of the learning task and activates prior knowledge and relates it to what he is going to learn (which may involve reading text and inspecting diagrams). Prior to the learning task, this may involve activating related schemata and mental models in the long-term memory and bringing them to the working memory, and during learning the material, this may involve actively connecting what is being read to relevant material in the working memory, and making it easier and more appropriate for storage and future retrieval. Several cognitive and metacognitive processes are involved such as feeling of knowing (FOK) which indicates to the learner that he/she has or has not seen or be familiar with the contentor domain, judgments of learning (JOL) are based on one's assessment of his/her emerging understanding, and content evaluation is a judgment to determine whether the multimedia hypermedia content is relevant (or irrelevant) to the current goal. These metacognitive judgments lead to the use of control processes that are behaviorally manifested as learning strategies. For example, a negative judgment of learning (JOL-) (e.g., not understanding the role of the pacemaker) may lead a learner to engage in goal-directed search for a specific page and/or medical illustration of the structure and location of the pacemaker. In dealing with computer-based learning environments like MetaTutor, the pedagogical agents prompt the learner to think about the topic and perhaps summarize whatever they already know about the topic. This way, the learner will delve into the task after receiving advice from one of the agents. By contrast, a poor learner tends not to relate the subject at hand to his prior knowledge of the topic and therefore the understanding he will create will be superficial and transitory, and may lead to a faulty or incomplete mental model of the biology system.

As the learner progresses through the hypermedia content, he keeps checking what he is reading with what he knows already, and this way he recognizes the relativity of the material to the intended sub-goal, and if the material is not related to the current sub-goal, he passes on. Actually, adaptive learning environments like MetaTutor are very effective in prompting the learner periodically to check if what he reads is relevant or not. This is a critical metacognitive judgment since many students persist reading irrelevant content. This is typical of poor self-regulating learners who persist reading and inspecting content that is irrelevant to the current sub-goal by not stopping periodically to ask themselves the relevancy of whether what they are reading and inspecting in MetaTutor.

One of the other characteristics of a good learner who self-regulates successfully throughout the learning task is using effective strategies, like note-taking, making inferences, drawing, paraphrasing, and summarizing accurately and at appropriate times. This way he reduces extraneous cognitive load, keeps track of what he reads, reformulates what he has just learned by saying it in his own words or re-representing it to another form like a diagram or drawing or a summary. The role of a pedagogical agent is also significant here. In environments like MetaTutor, the agent prompts the learner to summarize, for instance, or elaborate on the material just read. This way the learner will engage in elaborating and summarizing and since the system keeps the summaries and notes, he can refer back to his notes and edit or rewrite them, or use them for improving his understanding. On the other hand, using ineffective strategies does not lead to deep understanding of the material. However, what are called 'ineffective' strategies can also be used adaptively given some circumstances, and can be useful for the learning of the material. In using learning strategies, poorly self-regulating learners either use ineffective strategies, or do not use effective strategies, or if they do, they do so for a very short period of time, and these lead to poor understanding and shallow processing of the material.

While using learning strategies, the ideal learner always monitors whether the strategy he has just was effective or ineffective toward completing the current sub-goal(s) or the goals set for the learning session. This step is critical in the development of self-efficacy and maintenance of motivation and interest, in a way that it keeps the learner progressing by giving him positive feedback and encouragement and enhancing his motivation (Moos and Azevedo 2009; Moos and Maroquin 2010). This stage is also prompted by agents in computer learning environments, and the learner is asked to check the effectiveness of strategies he employs. One of the other processes the agents prompt is judgment of learning (JOL). The learner is asked to take a step back and check if he has understood what he had just read or not. This also helps the learner to maintain his motivation and be aware of lack of understanding throughout his learning. Poor learners do not check the efficiency of the strategies they use, and do not monitor their understanding as they progress in the text.

An ideal learner who self-regulates efficiently always keeps track of time on task, and does not spend disproportionate and unreasonable amounts of time on different sections of the task, sub-goals, or strategies. In other words, if part of the text is irrelevant, a learner with existing prior knowledge (either from previous learning or accumulated learning during interactions with MetaTutor) skips it as soon as he understands this or recognizes that it is irrelevant, and spends more time multimedia content that is relevant to the sub-goal. To help us understand how learners spend their time throughout the task, in our studies using MetaTutor, we make use of eye-tracking technology, which gives us an insight into the patterns of eye movements on text and diagrams, and when combined with data about time spent on text and other sources, we can understand where and how learners spend their time while reading material (Johnson, Azevedo, and Hoff 2010). Moreover, intelligent learning environments like MetaTutor prompt the learners when they spend unreasonable time on one topic, sub-goal or page, thereby increasing the learner's metacognitive awareness and helping him (re-)direct his attention to more relevant material, and manage time more efficiently. A poor learner, on the other hand, does not keep track of time, and spends a long time on irrelevant pages, or just visiting many pages, and seems not to stay on any relevant page long enough to acquire a deep understanding of the material.

During the process of learning, a good self-regulator takes steps back to check if he is progressing well toward the sub-goals set at the outset or not, and if he understands what has just been read is not sufficient or relevant, he takes measures to compensate for it and actively engage in strategies to learn more, and learn more efficiently. Also during the learning task, the learner asks questions about what has just been read, and checks if can answer those questions having read the material, and if not, he refers back to the text or his notes to overcome any lack of understanding. These self-checks include self-questioning, summarizing, making inferences, and engaging in knowledge elaboration. It should be noted that these are considered high-level self-regulatory processes that are seldom used by learners. MetaTutor attempts to prompt and foster the use of these processes during learning by posing questions relevant to each section in the form of short quizzes from time to time during learning, to help him recognize if he has understood the material or not, and if he sees that he cannot respond to those questions, he can actively engage in other strategies, like re-reading or asking the pedagogical agent for help. Poor self-regulating learners do not ask themselves if they understood or not, and keep reading, this way they lose the chance to refer back to the text or diagrams or to use efficient strategies to improve their understanding.

During learning, an ideal self-regulating learner develops an accurate and sophisticated internal mental representation of the content (e.g., sophisticated mental model of the circulatory system; Azevedo et al. 2008; Chi et al. 2004), and keeps comparing what he has just read to that model, and actively adds or modifies the representation as he progresses through the task. The development of an accurate and sophisticated mental model is the ultimate goal. However, under normal circumstances (e.g., in the absence of adaptive scaffolding) most learners do not develop sophisticated mental models. This is most often attributed to their lack of use of key SRL cognitive and metacognitive processes (see Azevedo et al., in press a,b). In contrast, there is data that supports the notion the adaptive scaffolding on SRL and content does improve the quality of learners' mental models. As such, we and other have addressed this issue, by using artificial agents as external-regulating agents designed to detect, rack, model, and foster learners' SRL and content understanding (e.g., Azevedo et al. 2010; Biswas et al. 2005; Graesser et al. 2008; McQuiggan and Lester 2009; White et al. 2009). In MetaTutor, there are four different agents, each with specific roles that have been designed to detect *which* specific SRL processes are used, *when* they are used and under what circumstances, are they used *appropriately* used given the circumstances, and were they *effective* in fostering learning.

In sum, learners do not typically regulate key aspects of the learning. More specifically, they tend to engage in dysregulated learning. Our focus is on identifying the nature of dysregulated learning and then using advanced learning technologies such as intelligent, adaptive multi-agent systems like MetaTutor to detect, track, model, and foster students' self-regulated learning. There are many scientific, technological, and computational challenges that lie ahead. However, recent advances along interdisciplinary lines are leading the way to solving some of these challenges as we design advanced learning technologies to support students' life-long learning (e.g., see Aleven et al., in press; Azevedo and Chauncey, 2010; Kinnebrew, Biswas, and Sulcer, 2010; Biswas McQuiggan & Lester, 2009; Calco & D'Mello, in press; Graesser et al., 2008; White et al., 2009).

Future Challenges

Intelligent multi-agent learning environments, like MetaTutor, represent a great leap forward in transforming how we support students' self-regulated learning. There are several multi-agent, adaptive and intelligent environments including Biswas and colleagues' Betty's Brain, Lester and colleagues' Crystal Island, White and colleagues' Inquiry Island, that have been developed to support students' SRL. Our focus has been almost exclusively on the detection, tracking, modeling, and fostering cognitive and metacognitive processes. There however, to other areas that have largely ignored by researchers—motivation and affect. A comprehensive model of SRL must include cognitive, metacognitive, affective, and motivational processes. For example, one of the significant challenges recently raised by Moos and Marroquin (2010) is the neglected area of studying motivation in multimedia, hypertext and hypermedia learning environments. According to them, there is a paucity of research understanding the role motivational processes mainly due to the complex construct of motivation and interest, and the difficulty in measuring and linking it to learning outcomes. Lastly, they caution researchers to take the appropriate steps in interpreting outcomes of studies using motivational constructs. But a more certain point is that the use of nonlinear media like in hypermedia and hypertext can cater to the diversity of learners, including those with varied interests. As Moos and Marroquin (2010) also mention, future studies in this field require consideration of more process data, like think-aloud protocols, eye-tracking data, and data from online trace methodologies (e.g., Azevedo et al., in press a,b). These data will provide insights into the processes of learning taking place in using hypermedia and hypertext environments, and the role of motivation, interest and similar factors on degree of learning. And finally, the question needs to be investigated whether the use of all sophisticated and expensive hypermedia environment benefits the learners significantly or not, and whether it boosts their motivation, interest and learning.

The role of affect has to be taken into consideration when examining the role of self-regulated learning with advanced learning technologies. Recent work has focused on the role of affect on students' learning in science and math and been instrumental in detecting and classifying various emotions during learning (e.g., Azevedo and Chauncey, in press; Calvo and D'Mello, in press; McQuiggan, Robison, and Lester 2010). Further work on affect should focus on understanding how affect may influence cognitive and metacognitive processes and either (temporarily) impeded learning and foster learning with advanced learning technologies. Similarly, work on affect regulation is needed to determine how learners monitor and control their emotions during learning about complex and challenging topics and domains. These are a few of the critical issues that need to be investigated so that we can advance the field of SRL and build learning technologies that are truly capable of supporting students' cognitive, metacognitive, motivational and affective self-regulatory process.

Acknowledgements

The research presented in this paper has been supported by funding from the National Science Foundation (Early Career Grant DRL 0133346, DRL 0633918, DRL 0731828, HCC 0841835) awarded to the first author. The authors would also like to thank A. Johnson, A. Chauncey, C. Burkett, A. Fike, M. Lintean, Z. Cai, V. Rus, A. Graesser, and D. McNamara for the design and development of MetaTutor.

References

Aleven, V., McLaren, B., Roll, I., and Koedinger, K. (in press). Automated, unobtrusive, action-by-action assessment of self-regulation during learning with an intelligent tutoring system. *Educational Psychologist*

Azevedo, R., and Chauncey, A.D. (in press). Integrating cognition, metacognition, and affect during learning with multimedia. In R.A. Calvo and S. D'Mello (Eds.), *Affective prospecting: New perspectives on affect and learning technologies*. Springer: Amsterdam.

Azevedo, R., Johnson, A., Chauncey, A. and Graesser, A. (in press a). Use of hypermedia to convey and assess self-regulated learning. In B. Zimmerman and D. Schunk (Eds.), *Handbook of self-regulation of learning and performance*. New York: Routledge.

Azevedo, R., Johnson, A., Chauncey, A., and Burkett, C. 2010. Self-regulated learning with MetaTutor: Advancing the science of learning with MetaCognitive tools. In M. Khine and I. Saleh (Eds.), *New science of learning: Computers, cognition, and collaboration in education* (pp. 225-247). Amsterdam: Springer.

Azevedo, R., Moos, D., Witherspoon, A., and Chauncey, A. (in press b). Measuring cognitive and metacognitive regulatory processes used during hypermedia learning: Issues and challenges. *Educational Psychologist*

Azevedo, R., and Witherspoon, A. M. 2009. Self-regulated learning with hypermedia. In D. J. Hacker, J. Dunlosky, and A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 319-339). Mahwah, NJ: Routledge.

Biswas, G., Leelawong, K., Schwartz, D., and the Teachable Agents Group at Vanderbilt. 2005. Learning by teaching: A new agent paradigm for educational software. *Applied Artificial Intelligence*, *19*, 363–392.

Calvo, R. A. and D'Mello, S. K. (in press). Affect detection: An interdisciplinary review of models, methods, and their applications. IEEE Transactions on Affective Computing.

Chi, M. T. H., Siler, S. A., & Jeong, H. 2004. Can tutors monitor students' understanding accurately? *Cognition and Instruction*, *22*, 363–387.

Graesser, A. C., Jeon, M., and Dufty, D. 2008. Agent technologies designed to facilitate interactive knowledge construction. *Discourse Processes*, *45*, 298–322.

Greene, J. A., Moos, D.C., and Azevedo, R. (in press). Learning with hypermedia. *New Directions in Teaching and Learning.*

Kinnebrew, J., Biswas, G.,and Sulcer, B. 2010. *Modeling and measuring self-regulated learning in teachable agent environments*. Proceedings of the AAAI 2010 Fall Symposium on MCES. Arlington, VA: AAAI.

McQuiggan, S., and Lester, J. 2009. Modeling affect expression and recognition in an interactive learning environment. *International Journal of Learning Technology, 4*, 216-233.

McQuiggan, S., Robinson, J., and Lester, J. 2010. Affective transitions in narrative-centered learning environments. *Educational Technology and Society, 13*, 40-53, 2010.

Moos, D. C., and Azevedo, R. 2009. Learning with computer-based learning environments: A literature review of computer self-efficacy. *Review of Educational Research, 79*, 576-600.

Pintrich, P. R. 2000. The role of goal orientation in self-regulated learning. In M. Boekaerts, P. Pintrich, and M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451–502). San Diego, CA: Academic Press.

Rus, V., Lintean, M. Cai, Z., Johnson, A, Graesser, A., & Azevedo. R. (in press). Computational aspects of the intelligent tutoring systems MetaTutor. In P. McCarthy & C. Boonthum (Eds.), *Applied natural language processing and content analysis: Identification, investigation, and resolution*. Hershey, PA: IGI Global.

White, B., Frederiksen, J., and Collins, A. 2009. The interplay of scientific inquiry and metacognition: More than a marriage of convenience. In D. J. Hacker, J. Dunlosky, and A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 175–205). New York: Routledge.

Winne, P., and Hadwin, A. 2008. The weave of motivation and self-regulated learning. In D. Schunk and B. Zimmerman (Eds.), *Motivation and self-regulated learning: Theory*, *research*, *and applications* (pp. 297–314). Mahwah, NJ: Erlbaum.

Zimmerman, B. 2008. Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*(1), 166–183.