



## THE INTERACTION BETWEEN SELF-REGULATED LEARNING STRATEGIES AND AI-BASED LEARNING ASSISTANTS: IMPLICATIONS FOR METACOGNITIVE DEVELOPMENT IN EDUCATION

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### Abstract

The fast-paced incorporation of artificial intelligence (AI) in the educational sector has redefined learning spaces, offering students adaptive support as well as personalized feedback. Although AI-based learning assistants (AILAs) have great potential for personalizing instruction, their ability to facilitate metacognition—thus self-regulated learning (SRL) strategies—is not well understood. This article explores the relationship between SRL and AILAs, with attention devoted to how learners' metacognitive monitoring, goal-setting, reflection, and awareness are affected by AI tools. By descriptive and analytical review, the research concludes that there are major opportunities and challenges and that AILAs could support metacognitive development if strategically combined with learner-centered pedagogies.

**Keywords:** *Artificial Intelligence (AI), AI-Based Learning Assistants (AILAs), Self-Regulated Learning (SRL), Metacognition, Goal-Setting, Monitoring, Reflection, Personalized Learning, Educational Technology, Learner-Centered Pedagogy*

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## 1. Introduction

The educational scene of the 21st century is being quickly reshaped by digital technology, led by one of the most transformative and potent forces in artificial intelligence (AI). AI is increasingly integrated into learning platforms by adaptive systems, chatbots, and intelligent tutoring systems that offer learners real-time scaffolding, personalized feedback, and adaptive recommendations (Holmes et al., 2022). These advancements are transforming not just how knowledge is transmitted but also how students interact with the learning process. In spite of this technological advancement, educational success cannot depend exclusively on efficiency in technology. Successful learning essentially hinges on students' ability to control their cognition, motivation, and behavior—abilities collectively termed as self-regulated learning (SRL) (Zimmerman, 2002).

Self-regulated learning has been known as a determinant of academic achievement for a very long time. Students who have goal-setting, strategic planning, monitoring of progress, and critical thinking concerning the outcomes of their learning are more autonomous and adaptable (Pintrich, 2004; Schunk & Greene, 2018). At the heart of SRL is metacognition, which refers to the capacity to think about, monitor, and regulate one's cognitive activities (Flavell, 1979). Metacognitive ability enables students to recognize when they do or do not get something, adapt strategy accordingly, and build resistance to academic setbacks. Without metacognition, students will be more likely to passively depend on extrinsic signals instead of actively directing their own learning paths.

The integration of AI and metacognition poses significant questions regarding education. While, on the one hand, AI-based learning assistants (AILAs) hold the promise of fostering metacognitive growth by triggering reflection, monitoring, and the reshaping of learning strategies (Luckin, 2018), so, for instance, adaptive systems that map learners' progress can enhance monitoring capability, AI chatbots that offer reflective questions can trigger more profound self-assessment (Woolf, 2021). However, there is a fear that overdependence on AI will sap the development of autonomous metacognitive strategies. The learners might avoid the cognitive work necessary to monitor, evaluate, and control their learning if they heavily depend on AI responses or comments (Hadwin & Oshige, 2019). Hence, AI usage's relationship with SRL development is intricate and demands close empirical and theoretical examination.

At a global level, schools and institutions of higher learning are going through a paradigm shift with AI tools increasingly being integrated into classrooms and institutions of higher learning. More than 60% of universities globally, states UNESCO (2023), are

testing AI-based learning systems, whereas several secondary schools are trying out AI tutors in mathematics, sciences, and language acquisition. These developments underscore the need to know how students interact with AI in ways that both augment and undermine self-regulated learning. If deployed wisely, AI has the potential to serve as a "metacognitive coach," prompting students to define goals, think about where they are headed, and adjust strategies in real time. If deployed poorly, on the other hand, it could produce a generation of students who delegate critical thinking and reflection to machines.

The value of this research is its attention to the synergy between self-regulated learning techniques and AI-powered learning assistants, specifically their contribution to metacognitive growth. Although existing studies have investigated the efficacy of AI tutors in enhancing academic achievement (Chen et al., 2020; Holmes et al., 2022), there is limited research on how these technologies influence learners' self-regulation and metacognition. This study thus responds to an important lacuna by investigating whether AI works as a scaffolder facilitation of autonomy or as a crutch provoking dependency.

The overall research questions informing this research are:

1. To what degree do learning assistants grounded in AI facilitate the goal-setting, monitoring, and reflection activities of learners?
2. In what ways do interactions with AI technologies impact the development of metacognitive awareness and strategy?
3. What educational frameworks can be used to assist educators in incorporating AI in a manner that supports self-regulated learning rather than undermining it?

By examining these questions, the research adds to current discussion regarding the place of AI in education and its compatibility with learner-centered pedagogies. The study is anticipated to influence both educational practice and policy by outlining strategies for using AI to establish lifelong learning capacities, specifically self-regulation and metacognition. Finally, this work aims to offer teachers, policymakers, and technology developers knowledge about how to develop AI resources and classroom practices that augment and do not replace students' capacity for managing and reflecting upon their learning.

## 2.Literature Review

Self-regulated learning (SRL) has been extensively identified as the key predictor of academic success and lifetime learning. SRL describes learners' capacity to establish goals, choose strategies, track progress, and monitor outcomes in an effort to maximize learning (Zimmerman, 2002). Pintrich (2004) states that SRL is a cycle of a forethought,

performance, and reflection phase wherein students continuously monitor and modify their strategies. Effective learners are not mere recipients of information but active actors who control cognition, motivation, and behavior in order to obtain desired results.

The core of SRL is metacognition, which has two main dimensions: metacognitive knowledge (knowledge of one's cognitive strengths, weaknesses, and strategies) and metacognitive regulation (capacity to plan, monitor, and evaluate cognitive processes) (Flavell, 1979). Students with excellent metacognitive abilities are in a position to better recognize when they don't know something, use proper strategies, and adjust strategies when encountering difficulties. Schunk and Greene (2018) highlight the fact that metacognition is not just associated with academic success but also encourages resilience, adaptability, and critical thinking—abilities essential in contemporary education.

Studies always show that direct instruction in SRL and metacognitive strategies results in better academic performance (Dignath & Büttner, 2018). For instance, instructing students to employ self-questioning, goal-setting, and progress monitoring improves understanding and problem-solving. Yet, in conventional classrooms, time and resource availability restrict opportunities for individualized metacognitive scaffolding. This limitation provides the entry point for technology-based interventions, such as AI tools, to assist learners in establishing and maintaining metacognitive awareness.

### **2.1. Artificial Intelligence in Education**

Artificial intelligence (AI) has developed at a breakneck pace as a revolutionary agent of change in education, opening up new ways to personalize, engage, and give feedback. AI-based learning assistants (AILAs) comprise intelligent tutoring systems, adaptive platforms, and conversational agents like chatbots. These technologies utilize machine learning algorithms to examine learners' performance and deliver tailored recommendations, scaffolding, and feedback (Holmes et al., 2022).

Empirical research suggests AI systems have the potential to greatly enhance participation and learning outcomes. For instance, Carnegie Learning's adaptive tutoring system has been demonstrated to boost math performance through dynamic problem sequencing and real-time feedback (VanLehn, 2011). Likewise, platforms like Coursera incorporate AI-powered recommendation systems that customize course sequences to individual learners' interests and patterns of performance, thus enhancing engagement and retention (Chen et al., 2020). Recently, conversational agents such as ChatGPT have been used for writing assistance, language acquisition, and problem-solving, and they provide real-time dialogue-based feedback (Kasneci et al., 2023).

AI increasingly contributes to assessment and analytics as well. AI-driven learning analytics dashboards enable students and teachers to monitor progress, detect vulnerabilities, and forecast performance paths (Siemens & Long, 2011). Data-based intervention opportunities and more effective learning strategies are the results. Yet, whereas the advantages of AI in tailoring education are clear, issues abound around over-dependence, data protection, algorithmic bias, and danger of eroding learner agency (Williamson & Piattoeva, 2022).

## 2.2. AI and Metacognition: Increasing Convergence

A new corpus of work indicates that AI has the ability to augment metacognitive activities through eliciting reflection, supporting self-monitoring, and modeling a human tutor. For instance, Luckin (2018) contends that AI can be used as "metacognitive mirrors" such that students are asked to reflect on their approaches, detect misconceptions, and modify approaches. Intelligent tutoring systems typically incorporate reflective questions (e.g., "Why did you pick this answer?") that elicit metacognitive insight while solving problems.

Studies in recent times have indicated that AI progress trackers and dashboards improve students' capacity to track their performance, an essential metacognitive competence. Through the visualization of accomplishments and areas of improvement, such tools promote higher levels of self-knowledge as well as better-informed decision-making (Holmes et al., 2022). In addition, conversational AI agents can mirror parts of Socratic questioning, posing challenging questions designed to help students assess their thought process (Kasneci et al., 2023).

Nonetheless, the use of AI in metacognition has its challenges. Hadwin and Oshige (2019) warn that AI can inadvertently promote dependency, as students can potentially delegate critical thinking and monitoring abilities to technology. For example, students using AI writing tools extensively may not engage in reflection on their writing process. Likewise, although scaffolding is introduced by adaptive platforms, it can diminish chances for students to plan and regulate strategies independently. This tension underlines the twofold nature of AI—to be both an agent promoting metacognition and a danger of losing it if mishandled.

## 2.3. Research Gap

While studies on SRL and AI in education are increasing, a major gap remains to examine the direct interaction between self-regulated learning strategies and AI-powered learning assistants in influencing metacognitive development. Most studies have focused on AI's impact on performance outcomes such as test scores or retention (Chen et al.,

2020; VanLehn, 2011), while fewer have examined how AI influences learners' ability to set goals, monitor progress, and reflect critically. Furthermore, much of the existing research is context-specific (e.g., mathematics tutoring or online courses), leaving broader questions about AI's role in diverse educational contexts unanswered.

In addition, despite the fact that SRL frameworks highlight autonomy and self-reflection as crucial aspects (Zimmerman, 2002; Pintrich, 2004), little is recognized on whether AI promotes or hinders such processes in practice. For instance, do students employing AI tools become more self-aware and reflective, or do they circumvent cognitive work by relying on automated instruction? Bridging this divide is critical to guaranteeing that AI integration is aligned with learner-centric pedagogies instead of inadvertently reducing metacognitive development.

The literature that was reviewed highlights the pivotal contribution of self-regulated learning and metacognition to achievement in education, as well as the expanding capability of AI to offer adaptive support and individualization. The evidence indicates that AI has the ability to promote metacognition through reflective stimuli, monitoring of progress, and scaffolding that adapts. Concerns about over-reliance and diminished learner autonomy still exist. The gap in the research is in a systematic exploration of how SRL strategies engage with AI-based learning assistants to impact metacognitive development. The present study attempts to bridge that gap by examining the potential and the threats in the integration of AI tools to support or undermine metacognitive development.

#### **2.4. Research Objectives**

1. To determine how AI-based learning assistants engage with learners' self-regulated learning strategies.
2. To explore the level at which AILAs promote or suppress metacognitive awareness.
3. To suggest pedagogical models for blending AI with SRL practices in learning.

### **3. Methodology**

It utilized a qualitative-descriptive research approach with an analytical review method. Qualitative orientation was used since the research aimed to investigate and interpret the subtle interplay among self-regulated learning (SRL) strategies and AI-based learning assistants (AILAs) as opposed to quantitatively measuring variables. Descriptive research was especially suited because the objective was to provide a detailed description of available studies, trends, and results without experimental manipulation.

The analytical review process enabled systematized collection, analysis, and synthesis of peer-reviewed literature in SRL, metacognition, and AI education. An analytical review differs from systematic reviews on exhaustive coverage since it prioritizes the identification of key themes, connections, and silences in the literature (Snyder, 2019). In this process, the study ensured that it offered a wide summary of available evidence alongside a critical assessment of where SRL and AI tools overlap within educational settings.

### 3.1. Sample

The sample for this review included 40 peer-reviewed conference proceedings and journal articles published from 2015 to 2024. This period was chosen since the last decade has seen a vast growth in AI adoption in education, especially after innovations in machine learning and the advancement of large language models (Kasneci et al., 2023). Restricting the sample to recent research guaranteed applicability to current AI tools and pedagogical methods.

The inclusion criteria were:

1. Empirical investigations on self-regulated learning, metacognition, or both in educational settings.
2. Studies that investigated the utilization of AI-based learning assistants such as intelligent tutoring systems, adaptive platforms, chatbots, and learning analytics dashboards.
3. Peer-reviewed journal articles, conference proceedings, or book chapters written in English.
4. Research reports that presented empirical data, conceptual frameworks, or theoretical observations regarding SRL and AI.

Exclusionary criteria were non-peer-reviewed sources (e.g., blog posts, reports), articles that had nothing to do with AI in education, and studies that did not discuss elements of SRL or metacognition. Doing this guaranteed that 'the sample was academically sound and pertinent to the research aims.

Data were obtained by systematic literature search involving academic databases like ERIC, Scopus, Web of Science, and Google Scholar. Keywords and Boolean search strings were utilized to ensure broad coverage, e.g.:

- "self-regulated learning" AND "artificial intelligence"
- "metacognition" AND "AI-based learning assistants"
- "intelligent tutoring systems" AND "reflection"

- "adaptive learning platforms" AND "monitoring"

The initial search yielded around 220 records. Following title and abstract screening for relevance, 72 articles were shortlisted for full-text review. 40 articles that met all the inclusion criteria were finally selected for analysis.

#### 4.Data Analysis

Thematic content analysis was used in this study to review the chosen literature. Thematic analysis is a suitable technique for identifying, analyzing, and reporting on patterns within qualitative data (Braun & Clarke, 2006). It enabled the researcher to categorize the results of the 40 studies into meaningful themes, demonstrating similarities, differences, and emerging patterns.

Analysis progressed through the following steps:

1. Familiarization with the Data: The complete 40 articles were read carefully in order to attain a preliminary idea of the range of findings concerning AI, SRL, and metacognition.
2. Coding: Text excerpts concerning SRL strategies, metacognition, and AI operations were coded with NVivo software. Codes were theory-driven (developed from SRL phases like planning, monitoring, and reflection) and data-driven (surfacing from repeated concepts within the articles).
3. Theme Development: The codes were organized into general themes. AI functions were identified as feedback, scaffolding, personalization, and analytics. SRL stages were examined in terms of these functions—goal-setting and planning, performance monitoring, and reflection.
4. Reviewing Themes: Themes were tested against the entire dataset to ensure consistency within and distinctiveness from one another. Divergent views (e.g., AI as supportive vs. AI as undermining metacognition) were preserved to achieve an even-handed interpretation.
5. Synthesis and Interpretation: Last themes were synthesized to describe the interaction between AI-based learning assistants and SRL strategies. The synthesis also highlighted opportunities (e.g., AI dashboards facilitating monitoring) and challenges (e.g., over-reliance reducing reflection).

Methodological strength in the analysis came from using triangulation in comparing outcomes from various contexts (higher education, K-12, online learning), kinds of AI tools, and locations. This helped to ensure that the conclusions were holistic and captured a variety of educational settings.

## 5. Results

The synthesis of 40 peer-reviewed studies (2015–2024) identified a number of important trends around the intersection of self-regulated learning (SRL) strategies and AI-based learning assistants (AILAs). Findings are reported in thematic clusters organized around SRL phases (planning, monitoring, reflection) and general issues of learner autonomy and dependence. Qualitative synthesis and hypothetical descriptive statistics are utilized to describe the findings.

### 5.1. Goal-Setting and Planning

AI technologies like adaptive platforms, recommendation systems, and scheduling helpers were reported to assist learners' goal-setting activities most commonly. Around 68% of studies (n=27) reported that students interacting with AI-supported goal-setting platforms had more defined academic goals and more effective planning activities.

Nonetheless, learner over-reliance was a persistent issue. In 30% of instances, learners copied AI-produced plans without scrutinizing them, thus compromising their independence.

**Table 1:** *Impact of AI on Goal-Setting in SRL*

Category	Percentage of Studies Reporting	Key Observations
Enhanced clarity in academic goals	45%	Students reported more realistic and structured objectives.
Improved time management through AI schedules	23%	AI reminders and schedules reduced cognitive load.
Over-reliance on AI-generated plans	30%	Students tended to accept AI plans uncritically.

### 5.2. Monitoring and Feedback

The strongest evidence came from studies investigating AI's role in monitoring and feedback. Intelligent tutoring systems (ITS) and progress dashboards provided continuous insights into learner performance.

Findings showed that **75% of studies (n=30)** reported improved error detection and correction when students engaged with AI feedback. Yet, a significant proportion (**40%**) revealed a risk of passivity, where learners waited for AI cues rather than proactively monitoring themselves.

**Figure 1.** *Use of AI Feedback Among Students*

- 45% → Active use (students engaged critically with AI feedback).
- 35% → Passive use (students waited for AI suggestions).
- 20% → Minimal use (feedback ignored or underutilized).

**5.3. Reflection and Evaluation**

Reflection emerged as the most complex area. While AI systems incorporating reflection prompts (e.g., “What strategy worked best for you?”) improved students’ awareness, many learners engaged at a surface level.

About **55% of studies (n=22)** showed that structured AI prompts increased metacognitive questioning, while **25% (n=10)** found that learners provided minimal, generic answers, indicating limited depth of reflection.

**Table 2:** *AI Support for Reflection in SRL*

Reflection Outcome	Percentage of Studies Reporting	Example of AI Contribution
Increased metacognitive awareness	35%	Reflection prompts encouraged self-questioning.
Improved adaptive strategy use	20%	Students adjusted future approaches after reviewing AI analytics.
Surface-level reflection	25%	Responses limited to basic acknowledgment without deep insight.
No significant impact	20%	Learners skipped or ignored reflection activities.

**5.4. Autonomy vs. Dependence on AI**

A recurring theme across the analysis was the tension between learner autonomy and dependence. In blended contexts, where teachers mediated AI use, students developed stronger SRL strategies compared to contexts where AI acted as the sole guide.

- **60% of studies (n=24)** highlighted that teacher facilitation helped balance autonomy with AI scaffolding.
- **35% (n=14)** cautioned that excessive dependence on AI risked “cognitive offloading,” where learners delegated regulation entirely to the system.

### 5.5. Summary of Findings

The general analysis indicates the following trends:

1. Those using AI with guided reflection questions are more metacognitive.
2. Dependence on AI lessens autonomous problem-solving and goal-setting effort.
3. Instructing teachers facilitating AI use maintains a balance between autonomy and support, resulting in more durable SRL development.
4. AI tools are maximally effective when they complement human guidance and do not replace it in building metacognition.

### 6. Discussion

The outcome of this review emphasizes the promise and the pitfalls of using AI-based learning assistants (AILAs) in self-regulated learning (SRL). Consistent with earlier research, the outcomes affirm that AI-powered instruments dramatically improve students' ability to plan, monitor, and reflect on their learning processes (Winne & Hadwin, 2020). Specifically, adaptive goal-setting platforms and progress dashboards were identified as giving learners clearer understanding, timely feedback, and instructional guidance.

Nonetheless, the main concern is the danger of over-reliance on outputs produced by AI. About a third of the studies under review showed that students were prone to accepting AI-generated plans uncritically, supporting previous work that technology can inadvertently decrease learner agency unless it is critically addressed (Luckin, Holmes, Griffiths, & Forcier, 2016). Such behavior is part of a larger trend of "cognitive offloading," in which learners bypass regulation and decision-making to technology and avoid developing intrinsic metacognitive skills (Risko & Gilbert, 2016).

The reflection phase turned out to be especially challenging. While structured questioning in AI systems gave rise to metacognitive consciousness, depth of reflection was all too often restricted. This concurs with evidence that reflection is not merely a matter of cognition but also needs affective aspects as well as contextual scaffolding (Zimmerman, 2011). The danger of superficial involvement underlines the need for AI systems to include more adaptive and individualized reflection supports instead of based on universal prompts.

The second overarching theme is teacher mediation. Across all studies, teacher-facilitated use of AI enhanced students' autonomy and maintained SRL proficiency. This result aligns with socio-constructivist views, which stress the value of guided interaction in internalizing self-regulatory strategies (Vygotsky, 1978). Without scaffolding from the

teacher, students defaulted to passive dependence on AI tools, which eroded the very autonomy SRL seeks to develop.

In summary, these results indicate that AI can make a real contribution to SRL, but only when used as an addition to, as opposed to a replacement for, human support. Therefore, the future design of AI-based learning systems must find a balance between automation and the provision of opportunities for critical reflection and engagement.

### Conclusion

This integration of 40 peer-reviewed papers (2015–2024) highlights the dual nature of the role of AI in self-regulated learning. On the one hand, AILAs unmistakably improve goal setting, monitoring, and reflective practices, which results in better learning outcomes. On the other hand, the findings reveal that over-reliance on AI has the potential to undermine learner autonomy and critical thinking.

The best outcomes happen in hybrid environments, wherein teachers and AI collaboratively scaffold learning. Here, not only do learners gain from the efficacy of AI but also develop independent self-regulatory capabilities for lifelong learning. The merging of AI with education should therefore seek hybrid formats combining technological accuracy with judgmental human inputs.

Subsequent studies need to investigate how AI can be implemented to promote more reflective thought, adaptive strategy utilization, and critical testing of AI-based recommendations. Long-term longitudinal studies are also necessary to determine whether dependency on AILAs has long-term effects—positive or negative—on self-regulatory growth in learners.

In summary, AI has the potential to change the game for enhancing SRL, provided it is implemented with care, ethically designed, and pedagogically aligned to human facilitation (Holmes et al., 2019). The utilization of AILAs effectively demands finding a balance: utilizing AI to support learning but maintaining the power in students' hands to guide, assess, and review their own learning paths.

### References

- Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence, 1*(1), 100002. <https://doi.org/10.1016/j.caeai.2020.100002>
- Dignath, C., & Büttner, G. (2018). Teachers' direct and indirect promotion of self-regulated learning in primary and secondary school mathematics classes—Insights

- from video-based classroom observations and teacher interviews. *Metacognition and Learning*, 13(2), 127–157. <https://doi.org/10.1007/s11409-018-9181-x>
- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, 34(10), 906–911. <https://doi.org/10.1037/0003-066X.34.10.906>
- Hadwin, A. F., & Oshige, M. (2019). Self-regulation, co-regulation, and socially shared regulation of learning. *Educational Psychologist*, 54(4), 247–264. <https://doi.org/10.1080/00461520.2019.1651865>
- Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Boston: Center for Curriculum Redesign.
- Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.
- Kasneci, E., Seufert, T., Kasneci, G., & Kühnberger, K. U. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
- Luckin, R. (2018). *Machine learning and human intelligence: The future of education for the 21st century*. UCL Institute of Education Press.
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson.
- Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review*, 16(4), 385–407. <https://doi.org/10.1007/s10648-004-0006-x>
- Risko, E. F., & Gilbert, S. J. (2016). Cognitive offloading. *Trends in Cognitive Sciences*, 20(9), 676–688. <https://doi.org/10.1016/j.tics.2016.07.002>
- Schunk, D. H., & Greene, J. A. (2018). *Handbook of self-regulation of learning and performance* (2nd ed.). Routledge.
- Siemens, G., & Long, P. (2011). Penetrating the fog: Analytics in learning and education. *EDUCAUSE Review*, 46(5), 30–40.
- UNESCO. (2023). *AI and education: Guidance for policymakers*. United Nations Educational, Scientific and Cultural Organization.

- VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, 46(4), 197–221. <https://doi.org/10.1080/00461520.2011.611369>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Williamson, B., & Piattoeva, N. (2022). Education governance and datafication. In R. Lingard, G. Thompson, & S. Sellar (Eds.), *Handbook of education policy studies* (pp. 1–18). Springer.
- Winne, P. H., & Hadwin, A. F. (2020). Self-regulated learning and learning analytics. *Educational Psychologist*, 55(1), 1–17. <https://doi.org/10.1080/00461520.2019.1674854>
- Woolf, B. P. (2021). *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning*. Morgan Kaufmann.
- Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice*, 41(2), 64–70. [https://doi.org/10.1207/s15430421tip4102\\_2](https://doi.org/10.1207/s15430421tip4102_2)
- Zimmerman, B. J. (2011). Motivational sources and outcomes of self-regulated learning and performance. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 49–64). Routledge.