

A Critical Review on Self-Regulated Learning in AI-supported EFL Education

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ABSTRACT

This review synthesizes theoretical frameworks, empirical findings, and methodological advancements in the domain of AI-driven self-regulated learning (SRL) within university-level English education. Grounded in social cognitive theory and extended through innovative models such as the "compound brain" paradigm, the integration of artificial intelligence (AI) technologies fosters dynamic human-machine collaboration to support multifaceted SRL processes, including goal-setting, strategy use, time management, self-evaluation, environment construction, and help-seeking. Empirical studies highlight robust measurement and classification techniques for SRL abilities, incorporating psychometric scales, latent profile analyses, and coding schemes based on learning analytics data. Generative AI tools like ChatGPT show promise in scaffolding autonomous English learning, particularly via writing assistance and adaptive feedback, though their efficacy is moderated by learner cognitive and meta-cognitive readiness. The interplay of motivation, positive psychology constructs, and meta-cognitive strategies emerges as a critical influence on SRL engagement and outcomes. Furthermore, the review delineates the process characteristics of SRL within hybrid and AI-supported online learning contexts, illuminating how peer collaboration and AI mediation interactively shape learning regulation. Despite notable progress, challenges persist in terms of conceptual clarity, theoretical diversification, methodological rigor, learner variability, and ethical considerations, notably regarding data privacy and educational equity. Future research trajectories advocate for integrative theoretical frameworks, expanded empirical samples, longitudinal designs, enriched meta-cognitive interventions, and systematic ethical analyses to deepen understanding and optimize AI-supported SRL in EFL contexts.

KEYWORDS

AI-supported learning; Self-regulated learning; EFL education; Learning analytics

1 Introduction

The relevance and significance of AI-driven self-regulated learning (SRL) in university English education have been increasingly highlighted, particularly through the application of learning analytics (LA) as a tool to support and evaluate SRL in online learning environments, where students are required to independently manage their learning processes to enhance academic performance and lifelong learning skills^[1]. Against this backdrop, theoretical advancements have been made, such as the construction of a theoretical framework for SRL in human-machine collaborative environments based on triadic reciprocal determinism theory, accompanied by the development of an assessment scale for SRL ability^[2]. Innovations in conceptualizing human-machine collaboration, including the "compound brain" approach—a new paradigm for SRL involving human and machine intelligence collaboration—encompass three levels ("data brain" for collaborative recording, "convergent brain" for collaborative analysis, and "intelligent brain" for collaborative decision-making) and three typical patterns of human-machine collaborative regulation (co-regulation, shared regulation, and compound regulation)^[3]. Empirically, explorations of undergraduates' SRL behaviors during interactions with ChatGPT, drawing on spontaneous conversational data and in-depth interviews, reveal that while generative AI offers significant advantages in facilitating autonomous learning, its effectiveness is contingent upon factors such as students' prior knowledge, cognitive abilities, and meta-cognitive awareness, which influence their learning readiness^[4].

2 Theoretical Foundations and Conceptual Frameworks of AI-Supported Self-Regulated Learning

2.1 Definitions and Dimensions of SRL in English as a Foreign Language Education

In the context of English as a foreign language (EFL) education, self-regulated learning (SRL) is conceptualized as a dynamic process involving cognitive, emotional, and behavioral components aimed at achieving personal learning goals. As defined through Zimmerman's (2002) framework discussed in relevant literature, SRL encompasses three interrelated stages: forethought (preparation), performance (behavioral execution), and reflection. The forethought stage involves planning and goal-setting, the performance stage focuses on the actual execution of learning behaviors, and the reflection stage entails evaluating outcomes and adjusting strategies. Notably, within EFL research, there is a tendency to prioritize the forethought and performance stages, with relatively limited attention given to the reflection stage.

2.2 Theoretical Models Underpinning SRL and Their Extensions in AI Contexts

Foundational self-regulated learning (SRL) theories have been increasingly extended to integrate artificial intelligence (AI) technologies, giving rise to new theoretical models and frameworks for human-AI collaborative learning. For example, based on triadic reciprocal determinism theory, a theoretical framework for SRL in human-machine collaborative environments has been constructed, which identifies six dimensions of SRL ability—goal setting, task strategies, time management, self-evaluation, environment construction, and seeking help—and develops a corresponding assessment scale^[2]. In another line of research, Azavedo's framework, encompassing nine SRL processes, has been adopted to develop a coding scheme for analyzing students' interactions with ChatGPT in open learning environments; results show that ChatGPT supports SRL through goal-oriented search, knowledge expansion, and learning monitoring, though its effectiveness depends on students' prior knowledge, cognitive abilities, and meta-cognitive awareness^[4]. Additionally, the "compound brain" model has been proposed to underpin SRL in AI contexts, consisting of three levels: the "data brain" for collaborative recording with data support, the "convergent brain" for collaborative analysis with data correlation, and the "intelligent brain" for collaborative decision-making with data empowerment.

3 Empirical Research and Classification of SRL in AI-Supported English Learning

3.1 Measurement and Classification of SRL Abilities among University Students

Empirical studies on measuring and classifying university students' SRL abilities have employed diverse psychometric tools and analytical methods. Psychometric instruments include established questionnaires and newly developed scales. For instance, Shang^[5] utilized the Motivated Strategies for Learning Questionnaire (MSLQ) to assess SRL strategies, revealing that organizational and elaboration strategies, as well as meta-cognitive self-regulation strategies, were significantly correlated with English academic achievement ($r > 0.80$, $p < 0.001$), whereas rehearsal and critical thinking strategies showed no significant correlation; high-achieving students also used meta-cognitive self-regulation strategies more frequently than low-achieving counterparts. Ji Yu^[2] developed a SRL ability assessment scale specific to human-machine collaborative environments, comprising 6 dimensions and 21 items, which demonstrated high internal consistency (Cronbach's $\alpha = 0.905$) and good structural validity through validation; empirical application on 348 university students indicated their SRL ability reached a good level, influenced by factors such as age, student type, AI usage experience, and GenAI usage frequency. Beyond questionnaires, coding frameworks have been adopted: Gao Yu^[6] employed a SRL coding framework based on SRLMQ, covering pre-planning, behavioral performance, and self-reflection stages, noting that high-performance learners exhibit more self-assessment behaviors and in-depth self-reflection patterns, generating value identification and stimulating learning interest at the pre-planning stage, while low-performance learners' value identification is more delayed.

In terms of classification, latent profile analysis (LPA) and clustering methods have been widely applied. Deng Guomin^[7] used LPA to classify learners based on their online SRL strategy levels, identifying three latent profiles: high, medium, and low, with high-level self-regulated learners demonstrating more effective time management strategies and stronger overall planning skills.

3.2 Application of Generative AI Tools in English Autonomous Learning

Generative AI technologies, such as ChatGPT, have been explored for their application in supporting students' autonomous English learning. A study analyzing students' spontaneous conversations with ChatGPT found that the tool was primarily used for writing assistance, specific tool support, and facilitating self-regulated learning. Students leveraged ChatGPT to set learning goals, seek feedback, correct language errors, and generate creative topics, highlighting its potential in enhancing writing education. Additionally, nine specific self-regulated learning behaviors facilitated by ChatGPT were identified, including goal-oriented search, knowledge expansion, resource acquisition, and learning monitoring^[4]. The influence of generative AI tools on self-regulated learning aligns with the understanding that learning environment is a key factor affecting self-regulated learning, as noted in research discussing the development of self-regulated learning across different age groups, which also emphasizes the role of motivation and individual differences in academic performance and skill development^[9].

3.3 Influence of Motivation, Positive Psychology, and meta-cognitive Strategies on SRL

Motivational beliefs significantly impact the use of SRL strategies among English learners.^[11] revealed that motivational beliefs, such as task value, intrinsic goal orientation, and self-efficacy, can effectively predict cognitive, meta-cognitive, motivational regulation, and social behavior regulation strategies. This is supported by^[12], where significant

differences were observed among high, medium, and low groups in internal goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and meta-cognitive self-regulation, indicating the close association between motivational factors and SRL strategy application.

Positive psychological traits also contribute to SRL strategy use. found that positive psychological factors, specifically growth mindset and persistent effort, have significant positive predictive effects on the four dimensions of SRL strategies, whereas consistent interest shows relatively weaker predictive power.

In terms of meta-cognitive strategies, ^[13] identified planning ability, execution ability, and reflection ability as primary indicators of SRL evaluation, with weights of 0.2862, 0.5038, and 0.2100 respectively, and noted that the online self-regulated learning ability of normal university students is at a moderate level, highlighting the fundamental role of these meta-cognitive components in SRL.

4 Key Findings on the Dynamics and Mechanisms of SRL in AI-Driven Environments

4.1 Process Characteristics of SRL Behavior in Hybrid and Online Learning Contexts

In AI-supported hybrid and online English learning environments, the process characteristics of SRL behavior involve distinct phases and behavioral dimensions. The compound brain, which supports SRL through three levels—"data brain" (collaborative recording with data support), "convergent brain" (collaborative analysis with data correlation), and "intelligent brain" (collaborative decision-making with data empowerment)—drives a three-stage process: collaborative judgment, collaborative adjustment, and collaborative decision, shaped by the interaction between the internal and external brain ^[3]. Concurrently, a theoretical framework based on triadic reciprocal determinism identifies six behavioral dimensions of SRL in human-machine collaborative environments: goal setting, task strategies, time management, self-evaluation, environment construction, and seeking help. These dimensions, assessed via a scale with good structural validity (factor loadings 0.476–0.819), characterize students' behavioral patterns, and university students' SRL ability (found to be at a good level) is influenced by factors such as age, student type, AI usage experience, and GenAI usage frequency, though not by gender or major ^[2].

4.2 Interactions between SRL and Peer Collaboration under AI Mediation

In AI-mediated collaborative English learning environments, the interplay between self-regulated learning (SRL) and peer interaction dynamics is underpinned by structured frameworks supporting collaborative SRL. The compound brain model, consisting of three levels—"data brain" for collaborative recording with data support, "convergent brain" for collaborative analysis with data correlation, and "intelligent brain" for collaborative decision-making with data empowerment—provides a foundation for understanding how SRL is facilitated in peer collaboration, alongside three identified human-machine collaborative regulation patterns (co-regulation, shared regulation, and compound regulation) that reflect varying degrees of decision-making autonomy between internal (learner) and external (AI) brains; notably, compound regulation emphasizes the internal brain's leadership in guiding the learning process and scheduling external tools, potentially shaping peer interaction dynamics by structuring how learners engage with AI and each other ^[3]. Empirically, specific SRL behaviors and monitoring processes observed in AI-augmented settings further illustrate this interaction.

4.3 Empirical Evidence Linking SRL Strategies with Academic Achievement and Learning Outcomes

Empirical evidence from a study by Ji Yu. ^[2] in an AI-driven context revealed that university students demonstrated a good level of self-regulated learning ability, with average scores across all dimensions ranging between 3 and 4 on a five-point Likert scale. Specifically, among the SRL strategies measured, the dimension of seeking help obtained the highest score (3.72), indicating that students frequently sought assistance from peers, teachers, and experts to optimize their learning process. In contrast, the dimension of environment construction scored the lowest (3.17), suggesting that students paid less attention to establishing an undisturbed human-machine collaborative environment.

5 Limitations and Future Directions

Current research on AI-driven self-regulated learning (SRL) in college English teaching presents several limitations and future avenues. Conceptually, gaps exist in second language acquisition SRL research, including unclear conceptual definitions and confusion between terms like self-regulation, metacognition, and autonomous learning. Theoretically, overreliance on social cognitive theory necessitates expansion into diverse frameworks such as sociocultural theory,

positive psychology, and complex dynamic systems theory^[14]. Methodologically, limitations include sample bias, such as studies drawing from a single university with overrepresented humanities/social sciences students and female students, limiting generalizability, and small-scale, short-term learning analytics studies involving few students, with insufficient evidence for improving learning outcomes (20%) or support levels (22%). Learner-related constraints are significant: GenAI's effectiveness in facilitating autonomous learning is contingent on students' prior knowledge, cognitive abilities, and meta-cognitive awareness, and limited meta-cognitive knowledge and regulatory capacity can lead to fragmented AI tool use, hindering learning initiative and flexibility^[4].

Future directions should address these areas. Conceptual and theoretical advancement requires integrating diverse theoretical perspectives and conducting longitudinal and experimental studies with multiple process-oriented data collection methods. Methodologically, expanding sample diversity and balancing demographics, alongside scaling up LA studies to include more students over longer durations, can enhance generalizability and evidence. Addressing learner limitations involves enhancing meta-cognitive knowledge and regulatory capacity to optimize AI tool utilization. Finally, systematic analysis of educational equity, ethics, and responsibility in human-AI collaboration, along with increased attention to ethical and privacy concerns in LA research, is critical.

6 Conclusion

The synthesis of current research elucidates a multifaceted and evolving landscape of AI-driven self-regulated learning (SRL) within university English education. Conceptually, SRL is framed as an integrative process encompassing cognitive, emotional, and behavioral dimensions, yet empirical investigations reveal a predominant research focus on forethought and performance stages, with reflective processes remaining underexplored. The infusion of artificial intelligence, particularly through generative AI tools such as ChatGPT, has introduced novel paradigms of human-machine collaboration, encapsulated by models like the "compound brain" framework, which delineates layered cognitive functions and distinct regulatory patterns (co-regulation, shared regulation, compound regulation). These theoretical advancements redefine SRL as a dynamic interplay between internal learner agency and external AI facilitation, fostering conditions for enhanced learning monitoring, decision-making, and collaborative regulation.

Empirical findings demonstrate that university students generally exhibit moderate to high levels of SRL abilities in AI-mediated contexts, with measurable variances influenced by factors including age, prior AI experience, and frequency of generative AI tool use. Psychometric assessments and behavioral coding schemes underscore that meta-cognitive self-regulation and help-seeking behaviors serve as critical determinants linked to academic achievement, while areas such as environment construction warrant greater learner attention.

Motivational constructs and positive psychological traits emerge as significant antecedents shaping SRL strategy adoption, indicating that intrinsic goal orientation, task value, self-efficacy, growth mindset, and persistence collectively contribute to higher regulatory competence. The empirical interface between SRL and generative AI tools further highlights that the effective utilization of AI for autonomous English learning is contingent upon learners' existing cognitive and meta-cognitive readiness, emphasizing the necessity for scaffolding that enhances regulatory knowledge and flexible tool engagement.

Despite these advances, research limitations persist, including restricted theoretical diversity, sample representativeness issues, methodological constraints of small-scale and short-term learning analytics, and insufficient exploration of ethical, privacy, and equity dimensions within AI-supported SRL frameworks. Recognizing these gaps, future investigations are urged to pursue multidimensional theoretical integration, expand methodological rigor through longitudinal and large-scale studies, augment learner meta-cognitive development, and address complex ethical considerations inherent to human-AI educational collaboration.

Collectively, these insights substantiate that AI-driven SRL constitutes a promising yet complex domain requiring nuanced understanding of its dynamic mechanisms, learner variability, and sociotechnical contexts to effectively inform university English teaching practices and to optimize autonomous language learning outcomes.

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