INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 14, Issue 4, (2025) E-ISSN: 2226-6348

Generative Artificial Intelligence and Cognitive Load in Second Language Learning: A Narrative Review

Chenyu Li, Amelia Alias

Faculty of Education, Universiti Kebangsaan Malaysia, Malaysia

DOI Link: http://dx.doi.org/10.6007/IJARPED/v14-i4/27007

Published Online: 11 December 2025

Abstract

Generative artificial intelligence is rapidly reshaping the landscape of second language learning by offering immediate linguistic support, automated feedback, and opportunities for interactive practice. While research has documented its pedagogical potential and its influence on learner affect, far less attention has been paid to the cognitive mechanisms through which AI affects learning processes. This article adopts Cognitive Load Theory as an analytical framework to examine how generative AI modifies the distribution of intrinsic, extraneous, and germane cognitive load during L2 learning tasks. By synthesizing findings from studies on conversational AI, human–AI interaction, digital communication, and AI-enhanced learning environments, the review shows that AI can reduce unnecessary cognitive burden, make complex tasks more manageable, and facilitate deeper processing under appropriate conditions. At the same time, AI may introduce new sources of cognitive strain or encourage superficial engagement when learners rely uncritically on its output. The review further discusses the instructional implications of these patterns, emphasizing the roles of task design, teacher orchestration, and emotional factors in regulating cognitive load. It concludes by identifying key directions for future research, including longitudinal analyses, individual differences, and the integration of cognitive and social perspectives. Overall, the cognitive load lens provides a productive foundation for understanding both the opportunities and the constraints of generative AI in L2 learning.

Keywords: Generative Artificial Intelligence, Cognitive Load Theory, Second Language Learning, Conversational Ai, Instructional Design, Germane Load, Extraneous Load

Introduction

Generative artificial intelligence (AI) has become increasingly integrated into university-level language learning. Tools powered by large language models now assist learners with interpreting texts, refining written output, and clarifying linguistic structures. These developments have accelerated the adoption of conversational AI systems in L2 learning contexts, as evidenced by studies examining chatbots and AI-mediated interaction (Belda-Medina & Calvo-Ferrer, 2022; Ruan et al., 2021). At the same time, researchers have begun exploring the broader implications of AI on pedagogy, teacher roles, and the organization of

AI-enhanced learning environments (Holstein, McLaren & Aleven, 2019; Ji, Han & Ko, 2022; Semerikov, Striuk & Shalatska, 2021).

Despite the growing body of work on AI in language education, much of the existing research has focused on learner perceptions, classroom interaction, and affective or motivational outcomes. These lines of inquiry have provided valuable insights into anxiety, enjoyment, and digital communication (Horwitz, Horwitz & Cope, 1986; Dewaele & MacIntyre, 2014; Lee & Chiu, 2023). However, relatively little attention has been paid to the cognitive consequences of AI-assisted learning. Generative AI alters not only how learners access information but also how they allocate mental resources during tasks. This raises fundamental questions regarding cognitive load, working memory demands, and the processes underlying L2 learning.

Cognitive Load Theory (Sweller, van Merriënboer & Paas, 1998) provides a structured lens for examining these shifts. By distinguishing among intrinsic load, extraneous load, and germane load, this framework highlights how instructional conditions influence working-memory allocation. Applying this perspective to generative AI allows for a more precise analysis of how AI reduces, redistributes, or introduces cognitive demands during L2 learning. This review therefore synthesizes current evidence to examine how generative AI interacts with different types of cognitive load and discusses the instructional implications for AI-enhanced language learning.

Cognitive Load Theory and L2 Learning

Cognitive Load Theory posits that learning depends on how mental resources are distributed across intrinsic load, extraneous load, and germane load (Sweller et al., 1998). Intrinsic load refers to the inherent complexity of material, shaped by the number of interactive elements and the learner's prior knowledge. In L2 learning, intrinsic load often stems from syntactic complexity, lexical density, or unfamiliar discourse structures. Extraneous load arises from factors unrelated to learning goals, such as unclear instructions or unnecessary processing demands. Germane load is associated with cognitive effort devoted to constructing and refining linguistic knowledge structures.

These dimensions have been applied in prior work to understand how learners interact with instructional materials and digital tools. In AI-mediated environments, the distribution of cognitive load may shift due to automated feedback, adaptive explanations, or AI-generated input. Recent studies of conversational AI and chatbot systems indicate that learners rely on AI for linguistic clarification and procedural guidance (Belda-Medina & Calvo-Ferrer, 2022; Ji et al., 2022), which suggests potential reductions in extraneous load. However, evidence from AI-supported writing and digital communication also shows that learners experience cognitive strain when evaluating AI output or crafting effective prompts (Lee & Chiu, 2023; Semerikov et al., 2021).

Understanding these interactions requires integrating CLT with empirical findings from AI-enhanced L2 contexts. The following sections analyze how generative AI influences extraneous, intrinsic, and germane load, providing a conceptual foundation for instructional decisions in AI-supported language learning.

Generative AI as a Reducer of Extraneous Load

A growing body of research suggests that generative AI can reduce extraneous cognitive load by simplifying access to linguistic information and streamlining task procedures. Conversational AI systems and chatbot-based environments provide immediate explanations, reformulations, and clarifications that help learners navigate complex input with fewer unnecessary processing demands (Belda-Medina & Calvo-Ferrer, 2022; Ruan et al., 2021). Such support aligns with CLT principles, which emphasize reducing extraneous load to free working memory for essential processing (Sweller et al., 1998).

Studies on AI-mediated interaction indicate that when learners engage with AI systems for lexical clarification, syntactic explanation, or discourse exploration, they spend less cognitive effort locating information across multiple resources (Ji et al., 2022). Research in AI-enhanced classrooms further shows that integrated support tools can help manage procedural complexity, particularly during multi-step tasks (Holstein et al., 2019). By consolidating explanations, examples, and feedback within a single interface, generative AI minimizes navigation-related burdens that would otherwise contribute to extraneous load.

Nevertheless, reductions in extraneous load are not automatic. Learners may experience increased cognitive demands when interpreting lengthy AI-generated content, evaluating accuracy, or formulating prompts that elicit appropriate responses (Semerikov et al., 2021; Lee & Chiu, 2023). These conditions illustrate how AI can introduce new sources of extraneous load when system outputs exceed learners' processing capacity or when unfamiliar interaction patterns impose additional demands.

Overall, generative AI shows clear potential to reduce extraneous cognitive load by offering integrated and immediate linguistic support, although careful design and guidance are required to prevent unintended increases in cognitive burden.

Generative AI and the Redistribution of Intrinsic Load

Intrinsic cognitive load is determined by the inherent complexity of linguistic input and the learner's prior knowledge. Generative AI has the potential to reshape intrinsic load by modifying how learners interact with complex tasks. AI-generated scaffolding, such as simplified explanations or chunked input, may allow learners to engage with texts or tasks that would otherwise exceed their processing capacity (Belda-Medina & Calvo-Ferrer, 2022). In this way, AI contributes to a redistribution rather than a reduction of intrinsic load, making complex tasks more manageable without diminishing their essential cognitive demands.

At the same time, intrinsic load may increase when AI enables learners to attempt tasks of greater linguistic complexity. Research on AI-supported L2 communication highlights that lower-proficiency learners use AI to participate in interactions or written tasks beyond their independent ability (Ruan et al., 2021; Ji et al., 2022). This suggests that AI acts as a compensatory tool that expands learners' productive and receptive capacities while maintaining the underlying complexity of tasks.

However, overreliance on AI scaffolding can also mask intrinsic complexity. If learners rely heavily on automated reformulations or explanations, they may engage insufficiently with the linguistic structures that form the core of intrinsic load. Such patterns may limit opportunities

for internalizing structural complexity, a concern echoed in research on digital anxiety and cognitive strain in technology-mediated interactions (Lee & Chiu, 2023).

Thus, AI does not eliminate intrinsic load but redistributes it across different stages of task performance, allowing learners to engage with higher-complexity content while also posing risks to independent processing.

Generative AI and Germane Load: Deep Processing or Superficiality?

Germane load reflects the cognitive effort invested in constructing and refining linguistic knowledge structures. Generative AI has a nuanced relationship with this form of load. On one hand, AI can promote deeper processing by modeling reasoning, highlighting discourse patterns, and offering elaborated explanations that support schema development. Conversational interaction with AI systems can prompt learners to refine their understanding, revise their output, and attend to linguistic form, supporting the type of generative processing associated with germane load (Belda-Medina & Calvo-Ferrer, 2022; Ruan et al., 2021).

On the other hand, research on human–AI interaction reveals that users often respond to AI in a "mindless" manner, accepting system outputs without critical evaluation (Nass & Moon, 2000; Nass, Steuer & Tauber, 1994). Such responses may reduce learners' engagement with linguistic structures and weaken deep processing. When learners adopt a passive stance toward AI-generated content, they may bypass opportunities for elaboration, comparison, or hypothesis testing, resulting in insufficient germane cognitive activation.

Affective factors also interact with germane load. Studies on foreign language anxiety suggest that high anxiety can suppress deep processing and reduce engagement with complex linguistic structures (Horwitz et al., 1986; Dewaele & MacIntyre, 2014). If AI reduces anxiety by offering non-judgmental assistance, germane load may increase. Conversely, if AI introduces uncertainty or evaluation pressure, germane load may decline.

The relationship between AI and germane load therefore depends on how learners position themselves toward AI support, how they evaluate AI output, and how instructional designs encourage or discourage deeper engagement.

Instructional Implications for AI-Enhanced L2 Learning

The cognitive load perspective highlights several implications for integrating generative AI into L2 instruction. First, teachers play a central role in regulating the balance between extraneous, intrinsic, and germane load. Research on AI-enhanced classrooms emphasizes the importance of teacher orchestration in coordinating AI tools with instructional objectives (Holstein et al., 2019). Clear guidance on when and how AI should be used can help ensure that cognitive demands remain aligned with learning goals.

Second, instructional design should leverage AI to reduce extraneous load without diminishing essential cognitive effort. Tasks can be structured so that AI provides only targeted support—such as clarification or linguistic explanation—while the learner retains responsibility for interpretation and production. Studies on conversational AI indicate that AI is most beneficial when used to scaffold rather than replace linguistic processing (Belda-Medina & Calvo-Ferrer, 2022; Ji et al., 2022).

Third, teachers can design activities that promote germane load by requiring learners to evaluate AI output, compare AI-generated and self-generated responses, or articulate reasons for accepting or rejecting AI suggestions. Such activities counteract tendencies toward mindless acceptance documented in human–computer interaction research (Nass & Moon, 2000). They also align with findings in positive psychology showing that emotional engagement and teacher-supported regulation enhance deeper processing and sustained effort (Dewaele & MacIntyre, 2014; Yan & Li, 2022).

Finally, because learners vary in digital proficiency, anxiety levels, and beliefs about AI, differentiated guidance may be required to ensure that AI use supports rather than inhibits cognitive engagement. Attention to these factors can help educators integrate AI in ways that optimize cognitive load distribution and sustain meaningful learning.

Directions for Future Research

Current research on generative AI and language learning has expanded rapidly, yet the cognitive mechanisms underlying AI-assisted learning remain insufficiently understood. Future work should adopt longitudinal and process-oriented approaches to examine how sustained engagement with AI reshapes the distribution of intrinsic, extraneous, and germane load over time. Much of the existing work on conversational AI focuses on general affordances, user perceptions, or teacher collaboration (Ji, Han & Ko, 2022; Semerikov, Striuk & Shalatska, 2021), while empirical evidence on cognitive load trajectories is limited.

Further studies should investigate individual differences that influence cognitive load in AI-mediated contexts. Emotional and psychological factors such as anxiety, enjoyment, and engagement are known to affect learners' cognitive processing (Horwitz, Horwitz & Cope, 1986; Dewaele & MacIntyre, 2014; Yan & Li, 2022), yet little is known about how these variables interact with AI-generated support. Digital communication anxiety and the challenges of interpreting AI output also merit closer examination, particularly for lower-proficiency learners (Lee & Chiu, 2023).

There is also a need for research that integrates CLT with theories of human–computer interaction. Work on mindless social responses to technology (Nass & Moon, 2000; Nass, Steuer & Tauber, 1994) suggests that learners may over-trust AI, which has direct implications for superficial processing and reduced germane load. Future studies could examine how prompts, feedback formats, or interaction designs influence learners' depth of processing.

Finally, collaborative learning environments involving AI require targeted exploration. Recent work grounded in social learning theories highlights the potential of generative AI to shape group interaction and collective meaning-making (Zhou & Schofield, 2023). Integrating social perspectives with cognitive load analysis may reveal new insights into how AI affects distributed cognition in group tasks. Overall, future research should conceptualize learners as active agents whose cognitive and emotional orientations mediate the influence of generative AI on L2 learning.

Conclusion

Generative AI has introduced new modes of interaction and support in second language learning, with significant implications for how learners allocate and regulate cognitive

resources. By applying Cognitive Load Theory, this review has examined how AI reduces unnecessary burdens, reshapes the complexity of learning tasks, and influences opportunities for deep processing. Evidence from AI-enhanced interaction, classroom orchestration studies, and human–AI communication research suggests that the cognitive consequences of generative AI are multifaceted rather than uniformly positive or negative.

AI offers meaningful support when it clarifies linguistic input, integrates feedback, and provides task-relevant scaffolding (Belda-Medina & Calvo-Ferrer, 2022; Ruan et al., 2021). Yet its benefits depend on how learners interpret and evaluate AI-generated output, as well as how instructors guide AI's integration into instructional designs (Holstein, McLaren & Aleven, 2019). Patterns of mindless acceptance documented in human–computer interaction research (Nass & Moon, 2000) remind us that AI may also lead to superficial engagement unless learners are encouraged to regulate their cognitive effort actively.

The central task for language educators is therefore to create environments in which AI reduces extraneous load while preserving intrinsic complexity and fostering germane processing. Achieving this balance requires attention to learners' cognitive, emotional, and digital competencies. When integrated thoughtfully, generative AI can support learners' engagement with linguistic complexity and contribute to more efficient and meaningful L2 learning.

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