Enabling or Negative - GenAI's Impact and Reconfiguration of Higher Order Thinking in College Students

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Abstract: This study systematically examines the double-edged sword effect of generative artificial intelligence on university students' higher-order thinking from an interdisciplinary perspective spanning educational technology and cognitive psychology. The educational technology lens focuses on design principles for technology integration and learning environment construction, while the psychological perspective analyses the underlying cognitive mechanisms and metacognitive processes. Findings indicate that GenAI may undermine the 'productive struggle' essential for critical and innovative thinking (Risko & Gilbert, 2016) by inducing 'cognitive offloading' and 'metacognitive neglect'. Concurrently, its algorithmic homogeneity risks triggering 'dialectical thinking atrophy' (Burke & Lueck, 2023). Building upon distributed cognition theory (Hutchins, 1995) and self-regulated learning models (Zimmerman, 2002), this paper constructs a 'human-machine collaborative thinking' educational framework. It proposes strategies such as 'metacognitive scaffolding,' 'critical embedding,' and 'cognitive resistance training' to transform GenAI from a 'substitute for thinking' into a 'whetstone for thinking,' providing theoretical and practical pathways for cultivating higher-order thinking in the intelligent era (Järvelä et al., 2020; Lin et al., 2025).

Keywords: GenAI; Educational technology; Cognitive psychology; Higher-order thinking; Human-machine collaboration

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1.Introduction: GenAI and the Crisis of Higher-Order Thinking from a Dual Perspective

This paper systematically examines the integration and challenges of Generative Artificial Intelligence (GenAI) in developing higher-order thinking skills among university students, adopting an interdisciplinary perspective that bridges educational technology and cognitive psychology. Since the Ministry of Education issued the Action Plan for Artificial Intelligence Innovation in Higher Education Institutions in 2018, GenAI applications within higher education have evolved from initial intelligent courseware generation to comprehensive educational services encompassing teaching effectiveness assessment, virtual assistant tutors, and daily learning management (Wenyuan et al., 2025). Within higher education settings, the integration of GenAI has deepened from the instrumental level to the cognitive practice level, constituting an entirely new 'cognitive environment.' A singular perspective struggles to comprehensively grasp its complex impacts. From an educational technology standpoint, we focus on designing optimal pathways for technological integration to enhance learning outcomes (Kozma, 2000); while psychology reveals shifts in individuals' cognitive architectures and thought processes following technological embedding. The intersection of these disciplines precisely diagnoses the core paradox in Gen AI's educational application: why might enhanced technological efficiency lead to cognitive decline? (Zawacki-Richter et al., 2019).

This study adopts an interdisciplinary perspective spanning educational technology and cognitive psychology, aiming to achieve two core objectives: Firstly, to conduct an in-depth analysis at the psychological mechanism level of the intrinsic drivers by which GenAI influences higher-order thinking, moving beyond mere phenomenological description to reveal the psychological essence of processes such as 'cognitive offloading,' 'metacognitive erosion,' and 'algorithmic homogenisation leading to diminished critical reasoning.' Secondly, from an educational technology perspective, to construct a teaching design framework grounded in cognitive principles, enabling theoretically grounded and actionable educational interventions (Mishra & Koehler, 2006). This paper not only addresses the questions 'What constitutes cognitive decline induced by technological advancement?' and 'Why does increased technological efficiency diminish cognitive abilities?', but also endeavours to resolve the core issue of 'How to mitigate the "negative cognitive impact" of educational technology amidst the inevitable rise of GenAI'. It provides theoretical underpinnings and practical guidance for higher education practitioners to safeguard deep learning in the era of artificial intelligence (Crompton & Burke, 2023); Hall, 2024.

2.Core Mechanism Analysis: The Psychological Pathways Through Which GenAI Influences Higher-Order Thinking

2.1 Cognitive Discharge and the Weakening of Executive Function

From a cognitive psychology perspective, GenAI offers an ideal opportunity for cognitive offloading—the process whereby individuals externalise cognitive tasks (Risko & Gilbert, 2016). This involves reducing mental processing load through physical actions or methods of recording information, thereby circumventing the limitations of our working memory. The executive functions underpinning critical and innovative thinking—including working memory, cognitive flexibility, and inhibitory control—function much like muscles, requiring active, strenuous thought processes to be exercised and maintained. GenAI's instant access to answers not only cognitively “outsources” memory but also “outsources” the entire thinking process. This effectively deprives the brain of crucial opportunities for executive function training, triggering a “cognitive energy-saving” mode. Consequently, students may become “cognitive misers” (Stanovich, 2018) with rigidised thinking habits. Preliminary neuroscience research indicates that individuals overly reliant on external cognitive aids exhibit abnormal activation patterns and reduced intensity in the prefrontal cortex (the core brain region for executive functions) when tackling complex problems (Zhai et al., 2021).

2.2 Metacognitive Neglect and the Generation of Learning Illusions

More insidiously, GenAI erodes metacognition. According to Flavell's metacognitive model, complete metacognition encompasses metacognitive knowledge, metacognitive experience, and metacognitive monitoring (Flavell, 1979). GenAI's intervention first blurs students' boundaries between the “known” and “unknown”, distorting metacognitive knowledge and creating illusions of understanding. Students misinterpret the reading fluency of AI-generated content as their own knowledge mastery (Ehrlinger et al., 2008). Secondly, it circumvents the core components of metacognitive monitoring and metacognitive experience, depriving students of authentic encounters with perceived learning difficulties and thereby destabilising strategy adjustment. When AI directly provides optimised solutions, students lose the opportunity to evaluate the shortcomings of their initial plans and adjust their learning strategies accordingly, leading to the atrophy of metacognitive skills through lack of practice (Lodge et al., 2018). Research by Järvelä et al. (2020) emphasises that these shared regulatory processes are crucial for learning success in collaborative settings, yet often remain ‘invisible’; inappropriate AI usage may further exacerbate this metacognitive invisibility. Recent research indicates that embedding metacognitive feedback within educational chatbot interactions effectively reduces negative emotions and enhances motivation, indirectly confirming the existence of metacognitive neglect and the potential for intervention (Yin et al., 2024).

2.3 ‘Algorithmic Homogenisation’ and the Atrophy of Dialectical Thinking

From the perspective of the “cultural script” theory in socio-cultural psychology, GenAI is trained on existing human data, and its outputs essentially reinforce a form of “mainstream cultural script” (Burke & Lueck, 2023). Within innovation and entrepreneurship education, this may lead to students developing a homogenised understanding of business opportunities and models, hindering their ability to identify genuinely disruptive “outliers”. This suppresses the diversity heuristic cognitive strategy in psychology, which lies at the core of innovative thinking (Gürkan et al., 2023). Students immersed within algorithmically constructed “filters” may experience diminished motivation and capacity to engage with divergent viewpoints or challenge their own beliefs, thereby eroding the cognitive tension essential for dialectical thinking (Warschauer & Grimes, 2008). Hall (2024) argues from a critical pedagogy perspective that GenAI may be reshaping a technologically constrained vision of social possibility. This is far from a neutral process, but one laden with inherent biases and assumptions. This algorithmic homogenisation poses a unique threat to innovation and entrepreneurship education, which demands diverse perspectives and critical thinking.

3.Reconstructing Educational Pathways: Technology Integration Design Based on Cognitive Psychology

Based on the aforementioned psychological mechanisms, the task of educational technology is to design learning environments that capitalise on strengths and mitigate weaknesses (Mishra & Koehler, 2006). We propose the following integrative design principles:

Table1: An Educational Technology Design Framework Based on Cognitive Psychology

Psychological mechanisms	Educational risk	Principles of Instructional Technology Design	Specific teaching strategies
Cognitive Offloading and Executive Function Impairment (Risko & Gilbert, 2016)	Mental inertia, lack of analytical depth	Principle of Cognitive Impedance	Designing core task modules without AI (Huang et al., 2023); requiring students to reverse-engineer AI outputs to trace their reasoning chains.
Cognitive Offloading and Executive Dysfunction (Risko & Gilbert, 2016)	Inaccurate self-assessment, ineffective learning regulation	Principle of Metacognitive Manifestation	Embedding "metacognitive prompts" within the AI usage process (Järvelä et al., 2021); implementing an "explanatory scoring" system that prioritises assessing students' critical evaluation and reflection on AI-generated answers.
Algorithmic Homogenisation and the Atrophy of Dialectical Thinking (Burke & Lueck, 2023)	Convergence of views, constrained innovation	Principle of Cognitive Diversity	Mandatory requirement for AI to generate opposing viewpoints; Configure AI as collaborative critics; Conduct 'perspective ecosystem' analysis to compare variations in outputs across different AI models.

3.1 Constructing metacognitive scaffolding to achieve 'monitored collaboration'

The core of instructional design lies in constructing metacognitive scaffolding for student-AI interactions. This does not entail prohibition, but rather structured, scientific, and standardised guidance in usage. For instance, before requiring students to employ GenAI for market analysis within innovation and entrepreneurship plans, they must first independently complete an 'Analysis Planning Sheet' to clarify their initial hypotheses, knowledge gaps, and the specific deficiencies they expect AI to address. Following utilisation, students must complete an 'AI Output Evaluation Form', discerning the robustness and weaknesses of its reasoning, and reflecting on 'How did the AI's analysis alter or reinforce my existing understanding?' This process externalises and systematises what were previously implicit metacognitive processes, ensuring students' metacognitive monitoring systems remain activated while employing technology (Järvelä et al., 2021; Azevedo et al., 2022). Järvelä et al. (2020) indicate that through advanced technologies, signal processing, and machine learning, we are on the cusp of 'seeing' these complex cognitive and emotional phenomena, opening new possibilities for constructing refined metacognitive scaffolding.

3.2 Implementing Critical Embedding: From Passive Consumption to Critical Co-creation

Educational technology must drive students' transition from passive consumers of AI-generated content to active evaluators and co-creators. Course assessments should directly reward critical behaviour. For instance, within business plan grading criteria, a dedicated score for 'critical integration of AI content' could be established. This would recognise student work that not only utilises AI-generated material but also precisely identifies its limitations, supplements missing data, or proposes superior solutions based on it (Tondeur et al., 2017). This effectively positions critical thinking itself as a core learning outcome, guiding student behaviour through the feedback loop of the assessment system. Such embedded criticality also resonates with the self-regulated learning model (Zimmerman, 2002), which emphasises learners' need for active, systematic monitoring and adjustment of their cognition, motivation, and behaviour.

3.3 Incorporating cognitive diversity stimuli to counter algorithmic narrowing

To counter algorithmic homogeneity, instructional design should consciously incorporate cognitive diversity. Activities such as "multi-agent debates" may be devised, where students simultaneously instruct multiple distinct AI models (or assign different role-based commands to the same model) to debate a commercial issue, with students acting as "judges" to evaluate their arguments. This activity directly simulates the dialectical thought process, exposing students to diverse and even opposing viewpoints. It effectively hones their integrated abilities to synthesise information, evaluate arguments, and construct personal positions (Gürkan et al., 2023). This design also embodies the principles of distributed cognition theory (Hutchins, 1995), which posits that cognition resides not solely within individual minds but is distributed across individuals, tools, and the mediating environment. Here, AI functions as a component within the cognitive system, while students undertake the final critical integration and decision-making.

4.Discussion and Outlook: Towards Mind-Friendly Intelligent Education

From an interdisciplinary perspective spanning educational technology and psychology, the core challenge for the future lies in designing "cognitively friendly" intelligent educational environments—where technological integration aligns with and facilitates the principles of human cognitive development rather than contradicting them (Sweller et al., 2011). This constitutes not merely a technical issue, but a profound matter of educational ethics (Luppicini, 2005).

Future research should further employ precise cognitive experiments (such as eye-tracking and electroencephalography) to quantify the impact of GenAI on distinct cognitive processes, thereby providing more accurate empirical evidence for design (Zhai et al., 2021). Concurrently, longitudinal tracking studies are crucial as they can reveal the long-term effects of these influences (Crompton & Burke, 2023). At the practical level, developing learning analytics dashboards embedded within learning systems—capable of real-time monitoring of students' cognitive engagement and metacognitive activities—will enable educators to implement immediate interventions (Järvelä et al., 2021). As envisaged by Järvelä et al. (2020), multidisciplinary collaboration integrating learning science, affective computing, and machine learning will enhance our capacity to understand and facilitate complex learning processes.

5.Conclusion

For higher education, GenAI is by no means a mere efficiency tool; it is a potent cognitive shaper. Through interdisciplinary analysis of educational technology and cognitive psychology, we gain insight into its underlying mechanisms affecting higher-order thinking: weakening memory executive functions via cognitive offloading (Risko & Gilbert, 2016), creating illusions of learning through metacognitive neglect (Lodge et al., 2018), and suppressing dialectical thinking through algorithmic homogenisation (Burke & Lueck, 2023). The solution lies in establishing an educational paradigm centred on 'human-machine collaborative thinking'. This involves implementing defence-oriented designs grounded in cognitive principles—such as metacognitive scaffolding (Järvelä et al., 2021), critical embedding (Tondeur et al., 2017), and diversity stimulation (Gürkan et al., 2023)—to consciously mitigate technological risks. This transforms GenAI from a potential 'substitute for thought' into a potent 'grinding stone for thought,' ultimately safeguarding education's intrinsic value in the intelligent era: cultivating mature minds endowed with deep thinking abilities and independent spirit (Mishra & Koehler, 2006; Zawacki-Richter et al., 2019).

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