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Generative AI Dependence and Critical-Thinking Performance Among University Students: The Mediating Role of Cognitive Offloading - A Structured Evidence Synthesis

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ABSTRACT

Background: Generative artificial intelligence (GenAI) can reduce the cognitive effort required for information retrieval, summarization, drafting and problem solving. Cognitive offloading is not inherently harmful, but dependence may emerge when learners delegate the very processes that higher education is intended to develop, including interpretation, evaluation, inference and justification. **Objective:** To synthesize evidence available on the association between GenAI dependence and critical thinking among university students and to evaluate cognitive offloading as a plausible mediating mechanism. **Methods:** A structured evidence synthesis was conducted using peer-reviewed Q1 literature in educational technology, learning sciences, psychology and cognitive science. Direct studies of AI dependence and critical thinking were prioritized, together with experimental studies of ChatGPT-supported learning and foundational cognitive-offloading research. Because the available studies used heterogeneous constructs and only a small number directly estimated mediation, no pooled effect size was calculated. **Results:** The strongest direct evidence came from a 2025 study of 580 university students in which AI dependence correlated negatively with critical thinking (r=-0.35) and positively with cognitive fatigue (r=0.51). Cognitive fatigue partially mediated the relationship: AI dependence predicted fatigue (beta=0.51), fatigue predicted lower critical thinking (beta=-0.33), and the direct AI-dependence effect decreased from beta=-0.35 to beta=-0.19 after inclusion of the mediator. Experimental evidence produced a complementary finding. In a randomized study of 117 university students, ChatGPT support improved essay revision but did not significantly improve knowledge gain or transfer and altered self-regulated learning processes in a pattern interpreted as possible metacognitive laziness. Conversely, a study of 213 Italian students found that active engagement with ChatGPT was positively associated with complex critical-thinking performance, and a 2025 meta-analysis of 69 experimental studies concluded that ChatGPT interventions improved higher-order thinking while reducing mental effort. A time-lag study of 465 preservice teachers further showed that cognitive offloading can positively mediate academic outcomes when routine tasks are externalized while higher-order work remains with the learner. **Conclusion:** GenAI dependence is associated with weaker critical thinking, but the mechanism is not simple tool use. Cognitive offloading appears beneficial when it removes routine cognitive burden and harmful when it substitutes for analysis, monitoring and independent reasoning. Universities should therefore design assessment and AI literacy practices that preserve productive cognitive effort while allowing strategic offloading.

Keywords: generative artificial intelligence; critical thinking; cognitive offloading; AI dependence; university students; ChatGPT; metacognition; higher education

1. Introduction

Generative artificial intelligence has altered the cognitive ecology of university learning. Tasks that previously required searching, synthesizing, drafting and revising can now be partially or completely delegated to a conversational system. The educational question is therefore no longer whether students have access to external cognitive support, but which components of thinking should remain internal if learning is to produce durable intellectual capability.

Cognitive offloading describes the use of external actions or tools to reduce the information-processing demands placed on internal cognition [1]. It is a normal adaptive strategy. People write reminders, use calculators, store information digitally and rely on other people as transactive memory. Risko and Gilbert emphasized that offloading can improve immediate task performance while also changing what is encoded, remembered and practiced internally [1]. Earlier experimental work on internet-access expectations similarly demonstrated that people remember less information when they expect it to remain externally available [2].

GenAI expands offloading beyond memory. A student can now outsource not only storage and retrieval but also summarization, argument generation, comparison, inference and evaluation. These functions overlap directly with critical thinking. Consequently, the cognitive consequences of GenAI

may be more substantial than those associated with a search engine or digital reminder.

Critical thinking in higher education involves the deliberate evaluation of evidence and claims, the generation and comparison of alternatives, inference from available information, and the capacity to justify conclusions. These skills require cognitive effort and repeated practice. If a learner routinely asks an AI system to decide what matters, identify weaknesses, generate counterarguments and produce the final conclusion, successful completion of an assignment may no longer imply equivalent practice of the underlying cognitive operations.

At the same time, it would be inaccurate to assume that all cognitive offloading diminishes thinking. Removing routine or low-level demands can free limited working-memory resources for more complex reasoning. The empirical literature through 2025 reflects this duality. Some studies associate AI dependence with lower critical thinking and fatigue, while experimental studies show that carefully structured ChatGPT use can improve higher-order thinking, academic performance or critical-reasoning engagement [3-7].

This review therefore distinguishes GenAI use from GenAI dependence and adaptive offloading from substitutive offloading. Its aims were to evaluate the empirical relationship between AI dependence and critical thinking, examine whether cognitive offloading provides a plausible mediating mechanism, identify circumstances under which offloading supports rather than replaces higher-order thinking, and derive an evidence-informed framework for university teaching and assessment.

2. Methods

This study used a structured evidence-synthesis design. Peer-reviewed literature published through 31 December 2025 was considered. The principal population was university or higher-education students. Foundational cognitive-science studies involving broader adult samples were included only when they defined cognitive offloading or demonstrated mechanisms directly relevant to externalized cognition.

Evidence was prioritized from Q1 journals in educational technology, learning and instruction, experimental psychology, cognitive science and multidisciplinary research. Search concepts included generative AI, ChatGPT, AI dependence, overreliance, critical thinking, higher-order thinking, cognitive offloading, cognitive fatigue, metacognition, self-regulated learning, mental effort and university students.

Studies were included when they contributed directly to at least one component of the proposed causal chain: AI dependence or intensive GenAI use, externalization of cognitive work, fatigue or reduced metacognitive engagement, or critical-thinking/higher-order-thinking outcomes. Direct empirical studies were given greatest weight. Systematic reviews and meta-analyses were used to assess whether the direction of discrete findings was consistent with the broader experimental literature.

A quantitative meta-analysis was not attempted because the eligible studies did not measure a common exposure, mediator and outcome. AI dependence, ChatGPT use frequency, cognitive offloading, cognitive fatigue, metacognitive laziness and critical-thinking performance were operationalized differently. The synthesis therefore reports exact coefficients only where directly published and uses a comparative evidence matrix for the remainder.

The term 'mediation' is used cautiously. The strongest Q1 study directly examining AI dependence and critical thinking tested cognitive fatigue as the mediator rather than cognitive offloading itself [3]. Cognitive offloading is therefore evaluated as a convergent mechanistic construct supported by cognitive-science theory, GenAI process studies and a 2025 time-lag mediation study in which offloading transmitted positive effects of GenAI use to academic outcomes [7]. The present paper does not claim that a direct AI-dependence -> cognitive-offloading -> critical-thinking mediation coefficient has already been established in Q1 university research.

The evidence-selection and interpretive framework is summarised in Table 1.

3. Results

The direct association between AI dependence and critical thinking was negative in the strongest eligible student study. Tian and Zhang surveyed 580 Chinese university students and found that AI dependence correlated negatively with critical thinking ($r=-0.35$, $p<0.001$) and positively with cognitive fatigue ($r=0.51$, $p<0.001$) [3]. Cognitive fatigue itself correlated negatively with critical thinking. In mediation analysis, AI dependence significantly predicted cognitive fatigue (beta=0.51), and fatigue predicted lower critical thinking (beta=-0.33). The direct standardized effect of AI dependence on critical thinking decreased from beta=-0.35 to beta=-0.19 after inclusion of the mediator, with an indirect effect of -0.14 (95% CI, -0.22 to -0.11), indicating partial mediation [3].

This result is important because it suggests that the cognitive cost of dependence is not explained solely by less practice. Heavy reliance may create a second burden in which students must continually monitor, filter and verify large volumes of AI output. Thus, GenAI can produce both cognitive under-engagement and cognitive overload. Either route may reduce the resources available for sustained analytical reasoning.

Experimental evidence provided support for a second mechanism: altered self-regulation. Fan et al. randomized 117 university students to ChatGPT, human-expert, writing-analytics or unsupported conditions during an academic writing task [4]. ChatGPT-supported learners improved their essay scores, but knowledge gain and transfer were not significantly better. Process data showed meaningful differences in self-regulated learning sequences, leading the authors to warn that GenAI support may encourage technology dependence and metacognitive laziness when learners receive high-level assistance without corresponding internal regulation.

However, the evidence did not support a universal cognitive-harm model. Suriano et al. studied 213 Italian university students and reported that engagement with ChatGPT was positively related to performance on a complex critical-reasoning measure [5]. Engagement was more strongly associated with critical-thinking performance than simple knowledge about AI. The result indicates that active interaction, challenge and elaboration can turn the same technology into a cognitive partner rather than a substitute.

The broader experimental literature is consistent with this conditional interpretation. Deng et al. synthesized 69 experimental studies and concluded that ChatGPT interventions improved academic performance, affective-motivational outcomes and higher-order-thinking propensities while reducing mental effort [6]. The authors nevertheless emphasized that objective higher-order-thinking measures and long-term transfer tests were limited. Reduced mental effort can therefore represent efficient scaffolding during one intervention or insufficient cognitive investment if the learner cannot later perform without support.

The principal Q1 evidence informing the synthesis is summarised in Table 2.

3.1 Cognitive offloading as a dual mechanism

Cognitive offloading should not be classified as either beneficial or harmful in isolation. Foundational work defines it as the use of external action to reduce internal information-processing requirements [1]. Grinschgl et al. demonstrated a classic trade-off: offloading can improve immediate task performance while diminishing memory for offloaded information [8]. The relevant educational question is therefore what is being externalized.

Adaptive offloading occurs when a student delegates a lower-order or resource-consuming operation while retaining responsibility for the higher-order intellectual task. Examples include asking an AI system to format references, generate practice questions, reorganize notes or provide alternative examples, followed by independent comparison and judgment. In this case the technology may free working-memory capacity for analysis.

Substitutive offloading occurs when the learner delegates the target competence itself. Asking GenAI to formulate the interpretation, evaluate the evidence, select the strongest argument and write the conclusion removes the cognitive operations that a critical-thinking assignment is designed to exercise. Immediate product quality may improve while transfer and unaided performance remain unchanged.

Iqbal et al. provide direct evidence that offloading can be beneficial under one configuration [7]. In a time-lag study of 465 preservice teachers across five universities, all four GenAI-use dimensions were positively associated with cognitive offloading, and offloading significantly mediated relationships between GenAI use and academic achievement. Their operationalization emphasized using AI to manage routine tasks and free resources for higher-order work. This contrasts productively with Tian and Zhang, where dependence predicted fatigue and poorer critical thinking [3]. Together, the studies suggest that the content and purpose of offloading are more important than its mere presence.

The proposed mediating pathways between generative-AI dependence and critical thinking are illustrated in Figure 1.

The evidence matrix for the proposed dependence-offloading-critical-thinking pathway is presented in Table 3.

The adaptive-to-substitutive continuum of cognitive offloading in GenAI-supported learning is illustrated in Figure 2.

3.2 Moderators and protective processes

Information literacy appears to protect critical thinking but does not completely solve the dependence problem. Tian and Zhang found that information literacy buffered the negative association between AI dependence and critical thinking, although its role in fatigue was more complex [3]. This implies that students who can evaluate information may remain more critical of AI output, but frequent verification can itself impose cognitive cost when reliance becomes excessive.

Metacognitive monitoring is another likely boundary condition. Learners need to know what they understand, identify what should be verified and recognize when AI support is replacing rather than extending their reasoning. Fan et al.'s process findings show why product-level assessment alone may fail to reveal this difference [4]. Two essays can receive similar grades while being generated through very different cognitive pathways.

Task design also matters. The meta-analysis by Deng et al. found overall benefits of ChatGPT interventions but called for more complex post-intervention assessment and objective higher-order-thinking measures [6]. This recommendation directly addresses the risk that AI improves the submitted product without improving the student's unaided competence.

4. Discussion

The evidence available through the end of 2025 supports a conditional relationship between GenAI and critical thinking. Dependence appears harmful, but use itself is not. This distinction is central to interpreting the literature. Students who actively interrogate AI, compare its claims with external evidence and retain responsibility for final reasoning can use the tool in ways that strengthen analytical engagement. Students who delegate interpretation and judgment may obtain efficient outputs while practicing less of the underlying competence.

Cognitive offloading provides a useful mechanism for reconciling apparently contradictory studies. Offloading has always been part of human cognition. A notebook allows memory to be externalized; a calculator removes arithmetic burden; a search engine reduces retrieval demands. These tools can improve performance because human cognitive resources are limited. The risk emerges when the external system performs the same cognitive process that is the target of learning.

This distinction can be described as the difference between resource-releasing and competence-substituting offloading. Resource-releasing offloading removes incidental burden. Competence-substituting offloading removes analysis, evaluation, inference or synthesis from the learner. The first may increase the cognitive resources available for critical thinking. The second reduces the amount of critical-thinking practice available to the learner.

The direct evidence from Tian and Zhang is particularly important because the negative relationship with critical thinking remained after cognitive fatigue was included [3]. Fatigue therefore explains only part of the association. Other mechanisms may include automation bias, lower epistemic vigilance, reduced retrieval practice, diminished self-regulation and habitual acceptance of fluent machine-generated explanations.

Conversely, Suriano et al. show that engagement can produce the opposite result [5]. ChatGPT can expose students to counterarguments, request justification, generate alternative hypotheses and provide immediate material for critique. In such designs, the AI increases rather than decreases the number of cognitive decisions the student must make. This is why policies based only on permitted or prohibited tool use are educationally incomplete.

Assessment design should therefore target intellectual agency. A student who submits AI-assisted work should still be able to explain the reasoning, defend evidence choices, identify weaknesses in the AI output and reproduce core conclusions under constrained or oral conditions. Such assessment does not require complete prohibition of AI; it requires that the learner remain the accountable cognitive agent.

The findings also suggest that universities should be cautious about equating lower mental effort with successful learning. Deng et al. found that ChatGPT interventions reduced mental effort while improving several learning outcomes [6]. This can be desirable when the removed effort is extraneous. But some difficulty is productive. Reasoning, retrieval, comparison and revision require effort precisely because they are the processes through which expertise develops. The educational goal should be to remove unnecessary load without removing productive struggle.

Finally, the paper's title should not be read as claiming that a complete Q1 mediation model of AI dependence -> cognitive offloading -> critical-thinking performance had already been directly estimated by the end of 2025. The evidence is one step

short of that standard. Direct Q1 research demonstrates the dependence-critical-thinking relationship and a fatigue mediator; other Q1 research directly demonstrates GenAI-related cognitive offloading and the possibility of both positive and negative outcomes. The combined evidence makes cognitive offloading a strong mediating hypothesis, but a definitive causal test requires longitudinal or experimental measurement of all three constructs.

Evidence-informed strategies for preserving critical thinking during GenAI use are presented in Table 4.

Strengths and Limitations

The main strength of this synthesis is that it separates AI use, AI dependence and cognitive offloading rather than treating them as synonyms. It integrates direct student data, randomized learning-process evidence, meta-analytic evidence and foundational cognitive science, while clearly distinguishing established mediation from mechanistic inference.

The principal limitation is the immaturity of the evidence base. The strongest dependence study was cross-sectional, so temporal direction cannot be established. Direct Q1 studies measuring AI dependence, cognitive offloading and objective critical-thinking performance in the same longitudinal model were not identified by the end of 2025. Many studies used self-report measures, and experimental tasks were short relative to the duration of a university degree. GenAI systems also evolved rapidly, reducing the stability of tool-specific findings.

Future Research

Future research should directly test the complete mediation model using repeated measures of logged GenAI behavior, validated dependence scales, task-specific cognitive-offloading measures and objective critical-thinking assessments. Longitudinal designs are needed to determine whether frequent substitution of higher-order thinking predicts later declines in unaided performance.

Experiments should manipulate what the AI is permitted to do. One condition might allow only retrieval and organization, another provide Socratic questions and counterarguments, and a third generate complete reasoning and answers. Comparing immediate task quality with delayed transfer would distinguish productive augmentation from cognitive substitution.

Conclusion

Evidence through 2025 indicates that generative-AI dependence is associated with lower critical thinking among university students, with cognitive fatigue explaining part of the relationship. Cognitive offloading provides a broader mechanism capable of reconciling negative dependence findings with positive experimental evidence. Offloading is adaptive when it externalizes routine cognitive work and preserves student responsibility for interpretation, evaluation, inference and justification. It becomes educationally risky when those higher-order operations are delegated to the AI itself. Universities should therefore move beyond simple measures of AI-use frequency and focus on what cognitive work students surrender, what they retain, and whether they can reproduce target skills without machine assistance. The goal of responsible GenAI integration is not minimal offloading; it is selective offloading that protects intellectual agency.

Declarations

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Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: Not applicable because the manuscript synthesizes previously published evidence and contains no new human-participant data.

Consent to Participate: Not applicable.

Data Availability: All findings and coefficients reported in this manuscript were derived from the cited published studies available through 31 December 2025.

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Table 1. Evidence-selection and interpretive framework

Domain	Included evidence	Excluded evidence	Interpretive role
Publication period	Through 31 December 2025	2026 onward	Maintains chronological fit for Volume 6
Journal quality	Q1 journals in relevant categories	Lower-quartile evidence as core support	Preserves high evidence quality
Population	University students; foundational adult cognitive studies	School-only evidence without transferability	Matches higher-education focus
Exposure	AI dependence, GenAI use, ChatGPT-supported learning	Non-generative educational technology alone	Captures relevant AI behavior
Mediator/process	Cognitive offloading, fatigue, self-regulation, metacognition	Unrelated psychological variables	Tests mechanistic plausibility
Outcome	Critical thinking, higher-order thinking, knowledge transfer, academic performance	Satisfaction alone	Focuses on cognitive development

Table 2. Principal Q1 evidence informing the synthesis

Study	Design/sample	AI-related construct	Cognitive process	Main outcome	Interpretation
Tian & Zhang, 2025 [3]	Cross-sectional moderated mediation; N=580 university students	AI dependence	Cognitive fatigue	Higher dependence associated with lower critical thinking; fatigue partially mediated	Direct evidence of a harmful dependence pathway
Fan et al., 2025 [4]	Randomized experiment; N=117 university students	ChatGPT learning support	Self-regulated learning / metacognitive laziness	Essay improvement without significant knowledge-gain or transfer advantage	Performance gain can coexist with reduced internal learning processes
Suriano et al., 2025 [5]	Cross-sectional performance study; N=213 students	Attitude, trust and engagement with ChatGPT	Active engagement	Engagement positively related to complex critical-thinking performance	Interaction quality matters more than simple exposure
Deng et al., 2025 [6]	Systematic review/meta-analysis; 69 experimental studies	ChatGPT interventions	Mental effort / higher-order thinking	Improved higher-order-thinking propensity and reduced mental effort	Offloading can support learning under structured conditions
Iqbal et al., 2025 [7]	Time-lag survey/PLS-SEM; N=465 preservice teachers	GenAI use behavior	Cognitive offloading and shared metacognition	Offloading mediated positive relationships with academic outcomes	Direct evidence that offloading can be adaptive
Risko & Gilbert, 2016 [1]	Cognitive-science review	External cognitive aids	Cognitive offloading	Offloading improves immediate performance but alters internal cognitive processing	Foundational mechanism

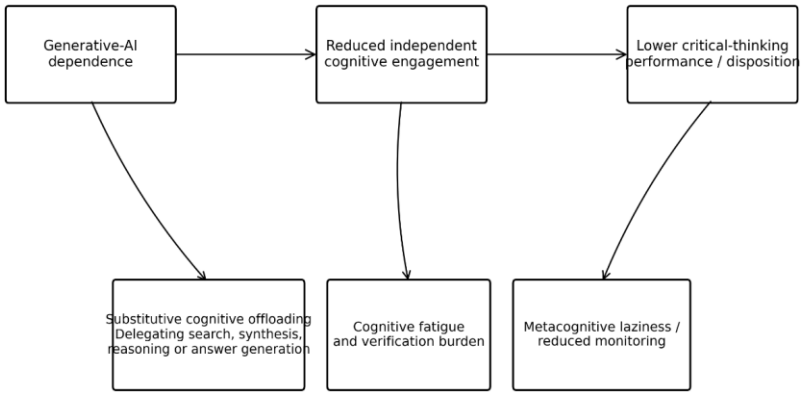
Table 3. Evidence matrix for the proposed dependence-offloading-critical-thinking pathway

Pathway component	Evidence status by end of 2025	Direction	Representative evidence	Inference
AI dependence -> lower critical thinking	Directly tested	Negative	Tian & Zhang [3]	Supported association; causality not established
AI dependence -> cognitive fatigue	Directly tested	Positive	Tian & Zhang [3]	Supported mediator pathway
Cognitive fatigue -> critical thinking	Directly tested	Negative	Tian & Zhang [3]	Higher fatigue associated with poorer critical thinking
GenAI use -> cognitive offloading	Directly tested	Positive	Iqbal et al. [7]	Offloading is a common consequence of GenAI-supported learning
Cognitive offloading -> learning outcome	Directly tested in adjacent outcome	Potentially positive	Iqbal et al. [7]; Grinschgl et al. [8]	Benefits immediate performance when offloaded tasks are appropriate
Substitutive offloading -> lower critical thinking	Mechanistically supported; limited direct Q1 mediation	Predicted negative	Fan et al. [4]; Risko & Gilbert [1]	Strong hypothesis requiring longitudinal/experimental mediation test
Active AI engagement -> critical thinking	Directly tested	Positive	Suriano et al. [5]	Challenges a simple frequency-based harm model

Table 4. Evidence-informed strategies for preserving critical thinking during GenAI use

Educational strategy	Cognitive target	Implementation principle	What may be offloaded	What should remain learner-controlled
AI-before/after comparison	Independent reasoning	Require an unaided initial position before AI consultation	Formatting, examples, alternative wording	Initial interpretation and final judgment
Critique-the-AI tasks	Epistemic vigilance	Grade detection of omissions, bias and weak evidence	Draft answer generation	Evaluation, verification and correction
Prompted counterargument	Dialectical reasoning	Use AI to generate opposition that students must rebut	Alternative viewpoints	Evidence weighing and justification
Scaffold fading	Transfer	Reduce AI support across successive tasks	Routine support early in learning	Final unaided performance
Oral defense / viva	Authorship and understanding	Require explanation of submitted reasoning	Administrative preparation	Recall, reasoning and defense
Process documentation	Metacognitive monitoring	Record what was asked, accepted, rejected and verified	Low-level search or organization	Decision trail and responsibility
AI-free benchmark assessment	Independent competence	Periodically test without external generative assistance	None during benchmark	Full target competence

Figure 1. Proposed mediating pathways between generative-AI dependence and critical thinking



Direct Q1 evidence supports AI dependence -> cognitive fatigue -> lower critical thinking; cognitive offloading is a convergent mechanism supported by cognitive science and GenAI learning studies.

Figure 1. Proposed mediating pathways between generative-AI dependence and critical thinking.

The fatigue pathway is directly supported by Tian and Zhang; cognitive offloading is presented as a convergent mechanism rather than a previously established direct mediation coefficient.

Figure 2. Adaptive-to-substitutive continuum of cognitive offloading in GenAI-supported learning

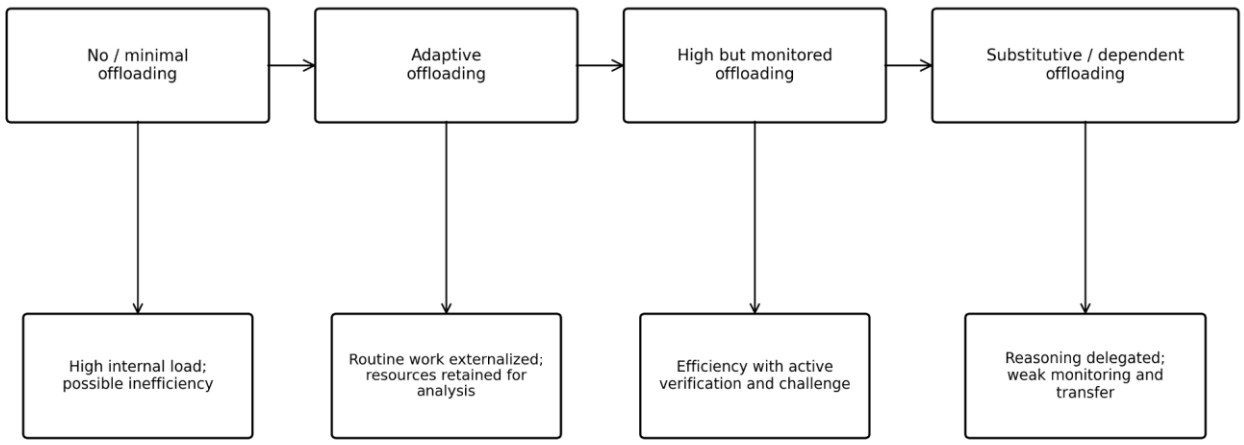


Figure 2. Adaptive-to-substitutive continuum of cognitive offloading in GenAI-supported learning.

Educational target: offload routine cognitive operations without offloading the core processes of interpretation, evaluation, inference and justification.

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