

Reconceptualizing Digital Drawing Skills in the Age of Artificial Intelligence: A Theoretical Perspective on Benefits, Risks, And Pedagogical Transformation

Menghua Zhao¹, Lee Hoi Yeh^{2*}, Lilong Yang³

¹Faculty of Art, Sustainability & Creative Industry, Universiti Pendidikan Sultan Idris (UPSI), 35900 Tanjong Malim, Perak, Malaysia.

²Faculty of Art, Sustainability and Creative Industry, Universiti Pendidikan Sultan Idris (UPSI), 35900 Tanjong Malim, Perak, Malaysia

³Faculty of Intelligent Film and Television Modern Industry College, 710130 Modern College of Northwest University, Xi'an, Shaanxi, China.

*Corresponding Author

DOI: <https://doi.org/10.47772/IJRISS.2026.1026EDU0376>

Received: 27 May 2026; Accepted: 01 June 2026; Published: 22 June 2026

ABSTRACT

The integration of artificial intelligence (AI) into art education is increasingly reshaping how digital drawing skills are conceptualized, developed, and assessed. Despite growing scholarly attention, existing studies tend to provide fragmented or largely descriptive accounts, often overlooking the underlying mechanisms through which AI systems influence learning processes. Addressing this gap, this paper adopts a conceptual and theoretical approach to examine the role of AI in digital drawing education.

Drawing on the Diffusion of Innovation (DOI) theory and synthesizing recent research on AI-supported learning, the paper reconceptualizes digital drawing skill development as a hybrid human–AI process mediated by three mechanisms: adaptive feedback, generative expansion, and cognitive offloading. These mechanisms illustrate how AI systems may restructure both technical skill acquisition and creative practice. At the same time, the theoretical analysis highlights critical tensions associated with AI integration, including over-reliance on automated systems, challenges to originality and authorship, and unequal access to advanced technologies.

Building on this mechanism-based analysis, the paper proposes a theoretical framework for AI-integrated digital drawing education. This study contributes to the literature by moving beyond descriptive accounts and offering a structured conceptualization of how AI reshapes creative skill development. It further identifies the pedagogical conditions under which AI can support meaningful, equitable, and sustainable innovation in art education. As a conceptual paper, this study does not present primary empirical data or systematic review findings; rather, it aims to provide theoretical clarity and a foundation for future empirical research.

Keywords: Artificial Intelligence; Digital Drawing Skills; Art Education; Conceptual Framework; Diffusion of Innovation

INTRODUCTION

Artificial intelligence (AI) can be understood as changing what it means to possess and develop digital drawing skills. Competency is shifting from manual proficiency and individual creativity toward hybrid human-machine cognition and co-creative workflows. Within art education, this shift challenges traditional models of skill acquisition, which have long emphasised perceptual judgment, deliberate practice, and autonomous creative decision-making. As AI-powered systems—ranging from real-time feedback tools to generative image models—become embedded in drawing instruction, learners no longer simply draw; they increasingly negotiate, evaluate,

and integrate machine-generated suggestions into their artistic processes. This transformation, we argue, demands a reconceptualization of digital drawing skills. Rather than simply describing AI's benefits, a mechanism-based understanding of how AI may mediate learning is needed

Recent reviews indicate that AI-powered systems—including generative models, intelligent tutoring systems, and adaptive learning platforms—are increasingly embedded in educational practices (Crompton & Burke, 2023; Tlili et al., 2023). Specifically, Dwivedi et al. (2023) argue that generative AI transforms knowledge production across creative domains, while Kasneci et al. (2023) provide evidence that large language models can support personalised learning through adaptive feedback. Furthermore, Uğraş et al. (2024) emphasise the role of AI-driven tools such as ChatGPT in promoting sustainable and scalable educational practices. The convergence of these findings suggests a shift beyond auxiliary use: Kasneci et al. (2023)'s controlled experiments suggest that large language models could adaptively respond to student inputs in real time, effectively functioning as an integral component of the learning loop rather than an external aid. Similarly, Uğraş et al. (2024) found that when ChatGPT was integrated into primary school curricula as a core pedagogical tool—not merely a supplementary resource—it significantly reduced teachers' routine task load and enabled more sustained student engagement. These observations suggest that AI may be moving from the periphery toward the core of educational practice.

In the context of art education, and particularly digital drawing, the integration of AI introduces new possibilities for creative production and skill acquisition. AI-powered tools enable functions such as real-time feedback, automated refinement, and text-to-image generation, thereby reshaping both the technical and cognitive dimensions of drawing. Mazzone & Elgammal (2019) question the evolving boundaries between human and machine-generated art, suggesting that authorship becomes distributed. Ivcevic & Grandinetti (2024) argue that AI functions as a co-creative tool, shifting the locus of creativity from the individual to human-AI collaboration—a finding directly relevant to digital drawing. In addition, Lampropoulos & Papadakis (2025) stress the importance of understanding AI not only as a tool but as an interactive agent capable of shaping learning experiences and pedagogical relationships. These studies indicate that digital drawing skills are gradually shifting from purely manual operations to being achieved through mediated methods. Specifically, Ivcevic & Grandinetti (2024) report that participants who used AI as a creative partner produced works whose technical execution was shaped by algorithmic suggestions. This finding implies that the skill of 'drawing' now includes the ability to curate and refine machine-generated outputs. Similarly, Lampropoulos & Papadakis (2025) documented through classroom observations that when AI systems functioned as interactive agents, learners' drawing processes shifted from solitary execution to iterative dialogue with the system—a pattern that cannot be captured by traditional manual-skill frameworks. Together, these findings indicate that digital drawing skills must be reconceptualised as hybrid processes that integrate human intention with algorithmic mediation.

However, despite the rapid proliferation of AI applications in art and design education, existing studies often provide descriptive accounts of technological benefits without sufficiently examining the underlying mechanisms through which AI influences learning processes. A number of studies emphasise outcomes such as efficiency, engagement, or creativity, yet fail to explain how these outcomes emerge within specific learning contexts. As noted in recent reviews, the field still lacks theoretically grounded frameworks that connect AI functionalities with pedagogical transformation and learner development (Crompton & Burke, 2023; Tlili et al., 2023). This gap is particularly evident in research on digital drawing, where the interaction between cognitive processes, technical skills, and AI mediation remains underexplored.

Digital drawing skills themselves represent a complex integration of perceptual awareness, technical proficiency, and creative decision-making. Unlike traditional drawing, digital environments introduce layers of mediation through software interfaces, algorithmic constraints, and tool-specific affordances. The integration of AI further transforms this process by embedding automation and generative capabilities into artistic workflows. From this perspective, learning to draw digitally becomes a hybrid activity involving both human cognition and machine-supported processes. Such a view aligns with emerging discussions of AI as a co-creative partner rather than a passive tool (Ivcevic & Grandinetti, 2024).

To address this conceptual gap, this paper adopts a theoretical and analytical approach to examine how AI reshapes digital drawing skill development. Specifically, the study draws on the Diffusion of Innovation (DOI)

theory (Rogers & Quinlan, 2014) to interpret the adoption and pedagogical integration of AI technologies in educational contexts. DOI theory's constructs—such as relative advantage, complexity, and compatibility—are particularly useful for understanding how learners and educators adopt AI tools, and how these adoption patterns shape the mechanisms identified in this paper. Recent research further suggests that these factors are highly relevant in understanding the uptake of AI in education, particularly in relation to generative technologies and their perceived impact on learning outcomes (Alasadi & Baiz, 2023).

Rather than presenting empirical findings, this paper develops a conceptual synthesis of existing literature to identify key mechanisms through which AI mediates digital drawing skill development. These mechanisms include adaptive feedback, generative expansion of visual possibilities, and cognitive offloading of routine technical tasks. By shifting the focus from descriptive reporting to explanatory analysis, the study aims to provide a more rigorous and theoretically grounded understanding of AI in art education.

At the same time, the integration of AI into creative learning environments raises critical concerns. While AI tools can enhance efficiency and support experimentation, they may also contribute to over-reliance on automated systems, reduce deep cognitive engagement, and challenge traditional notions of originality and authorship. Holmes & Tuomi (2022) highlight the ethical and pedagogical implications of AI in education, emphasising the need for critical evaluation of its impact on learning processes. These concerns are particularly relevant in art education, where creativity, authenticity, and individual expression are central.

This study discusses how artificial intelligence as an emerging technology is reshaping the cognitive and technical demands of digital drawing, a form of digital literacy increasingly required in creative education. It examines the ethical tensions surrounding authorship, originality, and overreliance on automated systems, which resonates with AMLER's focus on responsible technology integration. Additionally, discussions of unequal access to advanced AI tools and the need for pedagogical mediation are consistent with the journal's commitment to equitable and sustainable educational practices. By reconceptualizing digital drawing skills through a mechanism-based perspective, this article aims to contribute to AMLER's readership by providing theoretical clarity on how to integrate artificial intelligence into creative learning environments without compromising underlying skills or learner autonomy.

This paper therefore aims to make three main contributions. First, it provides a structured conceptualisation of how AI reshapes digital drawing skills through identifiable learning mechanisms. Second, it critically examines the tensions and risks associated with AI integration in creative education. Third, it proposes a theoretical framework to guide future research and pedagogical practice in AI-supported digital drawing instruction. This is a conceptual paper; it does not present primary empirical data or systematic review findings. Instead, it aims to provide theoretical clarity and a foundation for future empirical research.

Overall, by moving beyond descriptive accounts toward a theoretically informed analysis of causal processes, this study contributes to a more coherent understanding of AI in art education. Such an approach is essential for ensuring that technological innovation supports genuine learning outcomes and long-term educational development.

THEORETICAL FRAMEWORK AND ANALYTICAL APPROACH

This study uses a conceptual methodology to examine how AI reshapes digital drawing skill development. It reports no primary data. It establishes theoretical foundations, conceptual definitions, and analytical logic for mechanism-based analysis. The section covers DOI theory, reconceptualization of digital drawing skills, mechanism identification procedure, and study positioning.

Diffusion of Innovation Theory as an Analytical Lens

This study draws on Diffusion of Innovation (DOI) theory (Rogers & Quinlan, 2014) to interpret AI adoption and integration in digital drawing education. The DOI theory explains how innovations spread in social systems through five attributes: relative advantage, compatibility, complexity, trialability, and observability. Perceived

higher relative advantage, compatibility with values and practices, low complexity, trial opportunities, and observable results increase adoption (Rogers & Quinlan, 2014).

Recent work applies DOI theory to AI adoption in education. Alasadi and Baiz (2023) show that DOI constructs help understand generative AI uptake in higher education, especially perceived usefulness and pedagogical fit. A systematic review by Raman et al. (2026) discusses how compatibility with existing curricula and perceived complexity may influence AI adoption.

For digital drawing education, the DOI theory provides a structured lens. Relative advantage includes efficiency gains and expanded creative possibilities. Compatibility concerns alignment with art curricula and values like individual expression. Complexity refers to ease of use without extensive training. Trialability is low-stakes experimentation. Observability is visible benefits to stakeholders.

DOI theory also stresses that adoption is social and pedagogical, not just technical. Perceptions, social networks, and institutional contexts shape implementation. This perspective matters for digital drawing, where human skill versus technological assistance is contested.

In the context of this study, each of the three learning mechanisms can be understood through DOI attributes. Adaptive feedback primarily influences perceived relative advantage (by accelerating skill acquisition) and observability (visible improvements). Generative expansion affects compatibility with artistic values such as originality and authorship, raising potential perceived risk. Cognitive offloading reduces complexity for novices and increases trialability (low-stakes experimentation). Pedagogical mediation, as a social system factor, shapes how these perceptions are communicated and institutionalised.

DOI theory was chosen over other technology acceptance models (e.g., TAM, UTAUT) because it explicitly addresses how the perceived attributes of an innovation influence adoption in social systems, including educational settings. TAM focuses primarily on perceived usefulness and ease of use, which correspond to the relative strengths and sophistication of DOIs, but DOIs also include compatibility, trialability, and observability—attributes that are particularly relevant to arts education, where values such as originality and authorship (compatibility) and visible creative output (observability) are core elements.

Conceptualising Digital Drawing Skills as Hybrid Cognitive–Technical Practices

Digital drawing skills in contemporary environments require reconceptualization. Traditional models emphasise perceptual awareness, motor control, practice, and creative decision-making (Ericsson, Krampe, & Tesch-Römer, 1993). Digital drawing adds software interfaces, algorithmic constraints, and tool-specific affordances.

This study reconceptualizes digital drawing skills as hybrid cognitive–technical practices informed by three developments. First, AI functions as a co-creative tool, shifting creativity from individuals to human–AI collaboration (Ivcevic & Grandinetti, 2024). Learners engage with AI that generates, modifies, and evaluates visual content.

Second, hybrid intelligence describes human and artificial actors sharing cognitive processes (Akata et al., 2020). Cukurova (2024) advocates combining human cognition with AI capabilities, seeing AI as externalisation, internalisation, and extension of human cognition. Lampropoulos and Papadakis (2025) understand AI as an interactive agent shaping learning and pedagogy. This applies to digital drawing, where AI actively participates in creative workflows.

Third, AI integration aligns with evolving boundaries between human and machine art (Mazzone & Elgammal, 2019). Learners navigate technical skill acquisition and shifting frameworks of originality and authorship.

Digital drawing skills emerge from human intention, technological affordances, and algorithmic processes. Learners engage in hybrid activity involving internal cognition (perceptual judgment, creative ideation) and external AI support (real-time feedback, generative variation, technical execution).

Analytical Procedure for Mechanism Identification

This study uses conceptual synthesis, not systematic review. The interpretive, theory-driven process identifies mechanisms through which AI mediates digital drawing skill development. The procedure had three stages.

First, interpretive reading of peer-reviewed studies on AI in education and creative domains, focusing on recurring patterns in AI-learning interactions. This drew on systematic reviews (Crompton & Burke, 2023; Tlili et al., 2023; Zawacki-Richter et al., 2019) and studies on generative AI, intelligent tutoring systems, and adaptive platforms (Dwivedi et al., 2023; Kasneci et al., 2023). The focus was conceptual relationships, not quantitative aggregation.

Second, three candidate mechanisms consistently appeared: adaptive feedback, generative expansion of visual possibilities, and cognitive offloading of routine technical tasks. These are repeatedly discussed, theoretically grounded, and relevant to digital drawing as a hybrid practice.

Adaptive feedback is immediate, personalised, iterative responses to learner input. Real-time feedback supports skill acquisition by reducing the gap between action and evaluation (Kasneci et al., 2023; Alevén et al., 2023). In digital drawing, adaptive feedback analyzes stroke patterns, suggests corrections, or generates alternative pathways.

Generative expansion refers to AI (GANs, diffusion models) enabling multiple visual outputs from minimal input. This expands the creative search space and supports divergent thinking (Dwivedi et al., 2023). In digital drawing, this includes text-to-image generation, style transfer, or variation from a base sketch.

Cognitive offloading delegates cognitive or technical tasks to external systems, reducing cognitive load and freeing mental resources. In digital drawing, this includes automated shading, perspective correction, or composition suggestions. Offloading can lower entry barriers but may weaken foundational skills and reduce deep engagement (Wang, 2026). Emerging research suggests offloading beyond thresholds may paradoxically free resources for higher-order reflection (Wang & Zhang, 2026), but conditions in art education remain underexplored.

Third, we critically analysed each mechanism for its dual-edged nature, identifying both learning affordances and pedagogical tensions. This balanced view follows critiques calling for critical AI integration (Holmes & Tuomi, 2022; Bulathwela et al., 2024).

The three mechanisms are analytically useful constructs, not an exhaustive list. Future research may identify additional mechanisms.

Positioning the Study Within AI in Education Research

This study adopts a conceptual and theoretical orientation, not empirical data collection or systematic review following PRISMA protocols. It uses interpretive synthesis to theorise mechanisms of AI mediation. The field has many descriptive accounts but few theoretically grounded frameworks linking AI functionalities to pedagogical transformation (Crompton & Burke, 2023; Tlili et al., 2023). This study addresses that gap by developing such a framework. The three mechanisms—adaptive feedback, generative expansion, cognitive offloading—are building blocks for a theoretical model presented later. DOI theory and the reconceptualization of digital drawing as hybrid practice provide a coherent lens. Section 3 examines each mechanism in depth, identifying learning processes and critical tensions. Section 4 integrates these into a theoretical model of AI-mediated digital drawing skill development.

Mechanism-Based Theoretical Analysis

Using the framework from Section 2, this section analyzes three mechanisms through which AI reshapes digital drawing skill development: adaptive feedback, generative expansion, and cognitive offloading. Each mechanism is examined for educational affordances and pedagogical tensions.

Adaptive Feedback: Acceleration and the Risk of Over-Reliance

AI provides immediate, personalised feedback in digital drawing. AI-driven tools analyse user input in real time and generate suggestions, corrections, or enhancements. This creates a continuous feedback loop supporting rapid trial, error, and refinement, potentially accelerating technical skill acquisition (Kasneji et al., 2023). Adaptive feedback reduces the gap between action and evaluation, a condition favourable for skill development. Real-time feedback supports iterative skill acquisition by externalising evaluative judgments learners would otherwise generate internally (Aleven et al., 2023; Escalante, Pack, & Barrett, 2023).

A potential risk arises. Learners dependent on AI corrections may fail to develop internal evaluative judgment or self-regulated learning strategies. Frequent delegation of cognitive tasks to AI contributes to cognitive offloading, reduced mental effort, and diminished executive functions (Hou, Zhu, & Sudarshan, 2025). The risk is that learning to evaluate one's own drawing becomes externalised to AI. Misuse of generative AI weakens independent thinking, especially among students without strong foundations; those with the lowest critical thinking skills are most dependent on AI (Dong et al., 2025). Dong et al. (2025) reported that students who misused generative AI suggest weakened independent thinking and a lower sense of ownership over their work.

Thus, accelerated skill acquisition risks reducing learner autonomy. Over-personalised AI systems undermine autonomy and intrinsic motivation; students see AI tutors as authorities, leading to emotional outsourcing and reduced epistemic agency. AI feedback masks the learner's judgment with algorithmic precision, removing opportunities to develop self-evaluation as a competency.

From a DOI perspective, adaptive feedback enhances relative advantage and observability, which may accelerate adoption, but overreliance risks increasing perceived complexity if learners struggle without AI.

Generative Expansion: Exploration and the Erosion of Originality

Generative AI (text-to-image, style-transfer models) allows learners to produce multiple visual outputs from minimal input, expanding the creative search space (Dwivedi et al., 2023). Generative expansion supports divergent thinking and enables exploration of otherwise inaccessible artistic possibilities, especially for novices. A study by Hwang et al. (2026) suggests that GenAI-integrated instruction in design education may be associated with higher learning motivation, engagement, and creative performance. GenAI functions as external cognitive support, enhancing creative intelligence through motivational and instructional factors. However, as this is a preliminary finding, further research is needed. Hybrid intelligence systems involve human and artificial actors sharing cognitive processes (Akata et al., 2020). Cukurova (2024) argues that hybrid intelligence combines human cognition with AI capabilities, externalising, internalising, and extending human cognition in unprecedented ways.

The learner becomes a co-creator with AI; the locus of creativity becomes distributed. Originality becomes ambiguous when variations derive from shared training data, potentially homogenising style. Generative AI trains on vast datasets of existing artworks, absorbing formal vocabularies and stylistic signatures (Chen & He, 2026). It learns how art "looks" by metabolising artistic identities at scale, raising questions about authorship and attribution (Chen & He, 2026). When AI mimics distinct artistic styles, questions arise about credit for original artists (Singh, 2025). A systematic review by Slimi (2026) suggests that GenAI may enhance accessibility and productivity while also posing potential risks to originality, critical thinking, and epistemic justice.

Ease of generating multiple outputs may discourage sustained engagement with a single idea, central to deep artistic development. Students may become passive consumers rather than active creators.

Generative expansion offers exploration but risks diminishing authentic authorship and sustained effort.

Generative expansion raises compatibility concerns with traditional artistic values, potentially slowing adoption unless pedagogical mediation reframes its use.

Cognitive Offloading: Efficiency and the Risk of Superficial Learning

Cognitive offloading delegates technical or cognitive tasks to AI systems. In digital drawing, this includes automated shading, perspective correction, composition suggestions, or error correction. Reducing cognitive and technical burden lowers entry barriers and allows focus on higher-level creative decisions. This benefits early-stage learners overwhelmed by simultaneous demands of technique and ideation.

AI represents an unprecedented leap, actively replacing sophisticated cognitive functions such as analysis, reasoning, and creativity. Cognitive offloading frees mental resources but carries significant risks.

The tension is superficial learning. Learners may produce technically competent outputs without understanding underlying principles (e.g., how shading works). Excessive reliance weakens foundational skill acquisition. A systematic review by Zhai, Wibowo, & Li (2024) identified that over-reliance on AI dialogue systems can weaken students' critical thinking and analytical reasoning. This finding suggests that AI tools are most beneficial when their use is structured to prevent passive dependence and promote critical engagement. A meta-analysis by Lee (2026) discusses how ChatGPT use may reduce mental effort but could also contribute to cognitive offloading in the absence of intentional scaffolding. Özer, Tanberkan, & Perc (2025) suggest that when students offload key tasks to AI systems, their ability to think critically, question information, and evaluate sources may diminish over time—a pattern of overreliance that students may recognise intellectually but still develop in practice. The educational challenge is determining which tasks to offload and when, as uncritical offloading turns AI from a scaffold to a substitute, leading learners to skip the uncomfortable process of struggling, questioning, and refining. They become passive consumers. External tools bypass creating and strengthening memory traces, leading to “apparent understanding”—a false sense of ownership (Dong et al., 2025).

Cognitive offloading reduces complexity and increases trialability, which can encourage initial adoption, but may also reduce perceived long-term benefit if foundational skills are weakened.

Synthesis: The Dual-Edged Nature of AI Integration

To make the three mechanisms comparable, Table 1 summarises each mechanism, its description, theoretical affordance, and theoretical concern.

Table 1. Mechanisms of AI in Digital Drawing Education: Theoretical Affordances and Concerns

Mechanism	Description	Theoretical Affordance	Theoretical Concern
Adaptive Feedback	Real-time, personalized AI-generated feedback on drawing performance	Accelerates skill acquisition through rapid trial-refine cycles; externalises evaluative judgments (Kasneci et al., 2023; Alevén et al., 2023)	May reduce the development of internal evaluative judgment and self-regulation; risk of epistemic outsourcing (Dong et al., 2025)
Generative Expansion	AI-generated visual outputs enabling multiple design variations	Expands creative search space; supports divergent thinking; enhances creative performance (Dwivedi et al., 2023; Hwang et al., 2026)	Risks homogenisation of style, unclear authorship, reduced sustained engagement, and erosion of originality (Chen & He, 2026; Singh, 2025; Slimi, 2026)
Cognitive Offloading	Delegation of technical or cognitive tasks to AI systems	Lowers entry barriers; reduces cognitive load; allows focus on higher-level decisions.	May weaken foundational skill acquisition; risk of superficial learning and “apparent understanding” (Dong et al., 2025; Spector & Ma, 2019)

As Table 1 illustrates, each AI mechanism can be understood as bringing both potential benefits and risks. Efficiency and creative exploration come with pedagogical concerns built into the same processes. These challenges are not accidental or easily fixed with better technology; they arise from how AI systems interact with human cognition and creativity. AI may be positioned as a supportive cognitive partner rather than a replacement for human cognition, but effective integration requires strong pedagogical design, ethical governance, and active mediation by educators (Kumara et al., 2025).

Three Key Challenges in Ai-Integrated Learning

Beyond the risks tied to each mechanism, the interaction of adaptive feedback, generative expansion, and cognitive offloading creates three broad challenges that any AI integration must address.

1. Efficiency versus depth of learning. AI accelerates visible performance gains but may reduce deep cognitive engagement and durable skill retention. Frequent AI usage correlates negatively with critical thinking; regular users score lower on critical reasoning assessments (Gerlich, 2025). Younger individuals show higher AI dependence and lower critical thinking scores than older generations. However, when AI is used after independent work, neural connections increase significantly, suggesting that GenAI-supported re-engagement can induce high cognitive integration and memory reactivation (Dong et al., 2025). The timing of AI engagement mediates learning depth.
2. Creative expansion versus originality. Generative AI increases the quantity and variety of accessible visual ideas but may reduce authenticity and personal signature. While generative AI may suggest greater originality in some contexts, sensitivity analysis shows this is driven by a few studies with large effects; a meta-analysis finds “no empirical support suggesting that GenAI has surpassed humans in creative idea generation” (de Rooij & Biskjaer, 2025). Copyright frameworks cannot fully capture a phenomenon grounded in learning rather than reproduction (Getty Images v. Stability AI, 2025). Learners must navigate aesthetic choices and emerging norms of attribution.
3. Support versus dependency. Well-designed AI assistance fosters early progress, but without careful scaffolding it undermines long-term learner autonomy and self-efficacy. Excessive dependency weakens metacognitive awareness, impairs deep information processing, and fosters passive learning, especially among students and young adults (Hou, Zhu, & Sudarshan, 2025). Over-reliance leaves students unprepared for careers and daily life, eroding critical thinking (Gerlich, 2025).

Holmes & Tuomi (2022) argue that these issues must be critically examined. In art education, creativity, authorship, and individual expression are central disciplinary values.

Implications for Balanced Integration

AI should not replace foundational training but complement it. Educators should: encourage critical engagement with AI outputs (evaluating, modifying, rejecting); promote reflective practice on when and why to use AI; ensure unassisted drawing remains in the curriculum; scaffold AI use so independent effort precedes AI support, preserving cognitive integration.

Generative AI should be a supportive cognitive partner, not a replacement. Effective integration requires strong pedagogical design, ethical governance, and active educator mediation (Kumara et al., 2025). A systematic review identified cognitive dependency, protective learning strategies, and psychological processes for positive AI-enhanced learning. AI benefits are contingent on pedagogical framing and critical engagement.

AI reshapes digital drawing education through adaptive feedback, generative expansion, and cognitive offloading—each enabling affordances and introducing tensions. Theorising these dynamics is necessary for sustainable, equitable AI practices in art education.

DISCUSSION

The preceding sections have identified three core mechanisms—adaptive feedback, generative expansion, and cognitive offloading—through which AI reshapes digital drawing skill development, and have analysed the pedagogical challenges inherent in each. This discussion section synthesises these mechanism-based insights into a comprehensive theoretical model of AI-mediated digital drawing skill development. It then examines how this model addresses existing gaps in the literature, particularly the predominance of descriptive accounts and the absence of theoretically grounded frameworks. Finally, it outlines specific implications for future empirical research and educational practice.

A Theoretical Model of AI-Mediated Digital Drawing Skill Development

Building on the mechanism-based analysis presented in Section 3, this study proposes a theoretical model of AI-mediated digital drawing skill development. The model conceptualises learning as a dynamic interaction between three core components: AI technological affordances (input level), learning mechanisms (process level), and educational outcomes (output level), all situated within a broader pedagogical context that mediates the relationship between mechanisms and outcomes.

The model is structured as a three-layer framework:

Input Layer: AI Technological Affordances. At the input level, AI technologies provide specific affordances that enable new forms of learning interaction. These affordances include real-time feedback systems capable of analysing learner input and generating personalised suggestions; generative image production systems that produce multiple visual variations from minimal input; and automated technical assistance features that reduce the cognitive burden of routine tasks. These affordances correspond directly to the three mechanisms identified in this study.

Process Layer: Learning Mechanisms. The input affordances activate three key mechanisms that transform how learners engage with digital drawing tasks. Adaptive feedback mechanisms accelerate skill acquisition through rapid trial-refine cycles but simultaneously risk reducing learner autonomy and self-regulated evaluation. The generative expansion mechanism expands the creative search space and supports divergent thinking but risks homogenization of style and erosion of authentic authorship. Cognitive offloading mechanisms lower entry barriers and allow focus on higher-level creative decisions but risk weakening foundational skill acquisition and producing superficial understanding. These mechanisms interact dynamically rather than operating independently. For instance, cognitive offloading may free mental resources for reinvestment into generative exploration. Meanwhile, adaptive feedback scaffolds the feedback loop that makes generative expansion pedagogically productive.

Output Layer: Educational Outcomes. At the outcome level, the model highlights two parallel dimensions of educational outcomes. On the one hand, AI integration can enhance learning efficiency, engagement, and creative exploration when appropriately scaffolded. Systematic reviews indicate that generative AI has the potential to improve learning achievement, creative thinking, engagement, and cultural understanding when integrated through structured pedagogical frameworks with intentional instructor design (Rong et al., 2025). On the other hand, AI integration may introduce risks such as reduced learner autonomy, weakened foundational skills, superficial understanding, and challenges to originality and authorship. These dual outcomes reflect the inherent tensions identified in Table 1 and suggest that the impact of AI is contingent upon pedagogical implementation rather than being determined by the technology alone.

Mediating Component: Pedagogical Intervention. A distinctive feature of the proposed model is the explicit inclusion of pedagogical mediation as a moderating factor. Educators and instructional designers act as critical agents who regulate how AI is introduced, used, and interpreted within learning environments. This includes designing tasks that scaffold AI use appropriately, determining the timing and extent of AI assistance (e.g., whether AI precedes or follows independent effort), fostering critical reflection on AI outputs, and maintaining space for unassisted drawing practice. Without such mediation, the benefits of AI may be overshadowed by its limitations.

The model can be represented schematically as follows:

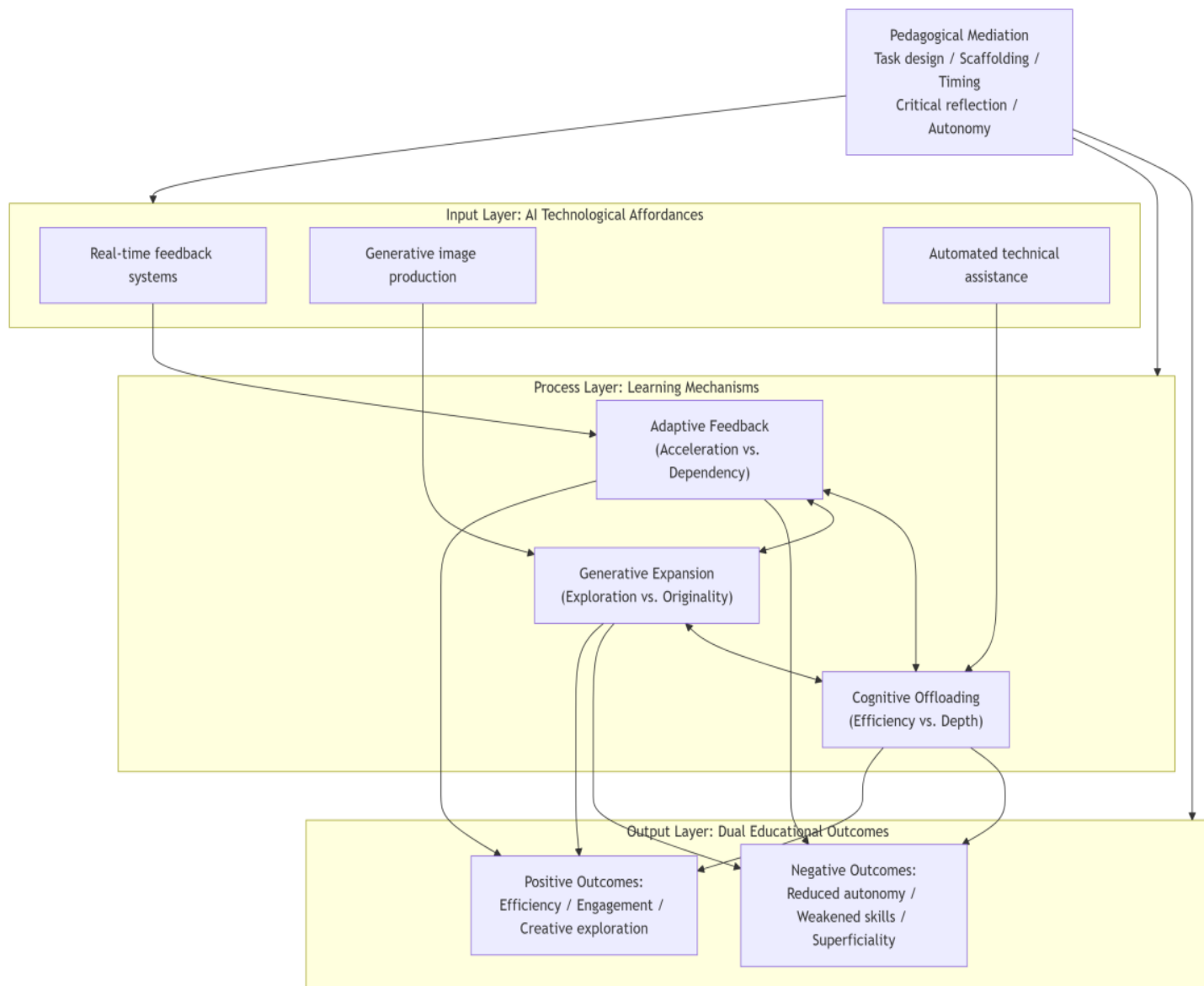


Figure 1. A Theoretical Model of AI-Mediated Digital Drawing Skill Development

Figure 1 presents the proposed theoretical model schematically. The model consists of three layers. The input layer (bottom) lists AI technological affordances: real-time feedback, generative image production, and automated technical assistance. These affordances activate the process layer (middle), which comprises the three core mechanisms: adaptive feedback, generative expansion, and cognitive offloading. These mechanisms are shown as interacting dynamically (indicated by bidirectional arrows). The output layer (top) shows two parallel outcome dimensions: positive outcomes (e.g., enhanced efficiency, engagement, creative exploration) and risks (e.g., reduced autonomy, weakened foundational skills, challenges to originality). Surrounding the entire model is the pedagogical mediation component, which moderates the relationship between mechanisms and outcomes. The diagram also indicates that the timing of AI engagement (e.g. Whether AI precedes or follows independent effort) is a key moderating factor.

Importantly, the model posits that the relationship between mechanisms and outcomes is not deterministic but contingent. The same mechanism—cognitive offloading, for instance—can produce either productive or counterproductive outcomes depending on the pedagogical context in which it is embedded. Recent research on pedagogical partnerships with generative AI provides preliminary support for this contingency perspective, suggesting that strategic cognitive offloading—when exceeding specific thresholds—can liberate mental resources for higher-order reflection, thereby enhancing transformative learning experiences (Wang & Zhang,

2026). This finding challenges the idea that delegation always harms learning depth. Instead, the effects depend on conditions such as whether offloading is strategic or passive, and whether it follows independent effort.

How the Model Addresses Existing Gaps in the Literature

The model addresses several gaps.

Moving beyond descriptive accounts. Existing studies often describe AI benefits without explaining underlying mechanisms (Crompton & Burke, 2023; Tlili et al., 2023). The model specifies how AI affordances translate into learning processes through adaptive feedback, generative expansion, and cognitive offloading, providing an explanatory rather than descriptive framework.

Distinctive contribution of a mechanism-based approach. A systematic review proposed a framework focusing on application contexts and outcomes, not cognitive processes (Rong et al., 2025). Liu & Chew (2025) proposed a TPACK-based framework for generative AI in art education, focusing on teacher knowledge rather than learner-centred mechanisms of skill acquisition. The present model complements these by offering a learner-centred perspective focused on how mechanisms operate on cognitive and pedagogical processes.

This section explicitly demonstrates how DOI theory serves as an active analytical lens rather than a mere framing device. Bridging AI functionalities with DOI theory constructs. The model is grounded in DOI theory (Rogers & Quinlan, 2014). Compatibility, complexity, and perceived usefulness significantly influence AI adoption intentions (Alzoun, Alshurideh, Al Kurdi, & Alzoubi, 2025). Perceived complexity and compatibility with existing practices are key adoption determinants (Wattanakasiwich, Kaewkhong, & Katwibun, 2025). Adaptive feedback influences perceived relative advantage and complexity. Generative expansion raises compatibility concerns about originality and authorship. Cognitive offloading intersects with complexity. The model links DOI adoption constructs to learning mechanisms, bridging technology-adoption and learning-process research. Thus, the proposed model explicitly links DOI adoption constructs (relative advantage, compatibility, complexity, trialability, observability) to the three learning mechanisms, providing a unified lens that connects technology-adoption research with learning-process research.

Integrating emerging findings on cognitive offloading. A large-scale mixed-methods study reports that pedagogical partnerships with generative AI activate both cognitive vigilance and cognitive offloading; strategic offloading beyond certain thresholds can paradoxically enhance transformative learning by freeing mental resources for higher-order reflection (Wang & Zhang, 2026). The model accommodates this complexity by conceptualising outcomes as contingent on pedagogical mediation.

Addressing the originality and authorship gap. Generative AI expands the creative search space but raises questions about authorship (He & Zhang, 2025). AI can lower creative confidence, and when AI floods ideas before a student's thinking forms, the result can be cognitive fixation (Luckin & Holmes, 2016). The model includes originality and authorship as outcome dimensions, positioning pedagogical mediation as essential for preserving an authentic artistic voice (Liu & Chew, 2025).

Implications for Future Research

The theoretical model proposed in this study opens several avenues for empirical investigation. While the present study is conceptual in nature, the mechanisms and contingent relationships identified suggest specific hypotheses that future research can test.

Hypothesis 1: Feedback timing and skill retention. Based on the adaptive feedback mechanism, it is hypothesised that the timing of AI feedback relative to learner effort moderates its effect on long-term skill retention. When AI feedback is provided immediately following learners' independent effort (i.e., after initial attempts), it may support skill acquisition without undermining self-regulated evaluation. Conversely, when AI feedback precedes or substitutes for learners' independent effort, it may reduce retention and autonomy. This hypothesis draws on the desirable difficulties principle from cognitive psychology, which suggests that productive struggle—the cognitive friction experienced when grappling with a task without immediate assistance—supports durable memory formation. Recent research on ChatGPT as a study aid provides empirical support for this concern: in

a randomised controlled trial, students who used ChatGPT scored significantly lower on a knowledge retention test 45 days after learning compared to those who studied traditionally (Barcaui, 2025). Future research should examine whether similar effects obtain in digital drawing contexts, where procedural and perceptual skills may be differently affected than declarative knowledge. A randomised controlled trial comparing immediate versus delayed feedback conditions, with retention measured weeks after instruction, would provide evidence to test this hypothesis.

Hypothesis 2: Generative expansion and creative originality. It is hypothesised that the effect of generative AI on creative originality follows an inverted-U pattern: moderate use of generative tools may support idea generation and creative exploration, but excessive or premature use may lead to cognitive fixation and reduced originality. Recent experimental work on divergent thinking provides initial evidence for this pattern. Researchers found that when undergraduates used ChatGPT to complete a divergent thinking exercise, their scores increased on the fluency and elaboration dimensions, but qualitative data revealed that students reported that “the computer literally does everything for you” and that after using AI, they struggled to generate additional ideas on their own—a phenomenon suggesting cognitive fixation (Luckin & Holmes, 2016). The researchers concluded that human creativity is needed to begin and end the creative act (Luckin & Holmes, 2016). Future research should investigate threshold effects of generative AI in digital drawing, examining how the frequency and timing of generative tool use interact with learners’ prior skill levels and creative self-efficacy. A longitudinal design tracking creative output quality, idea generation fluency, and self-reported creative confidence across repeated drawing tasks with varying levels of AI support would help establish causal relationships.

Hypothesis 3: Strategic versus passive cognitive offloading. Based on the cognitive offloading mechanism, it is hypothesised that strategic offloading—where learners consciously delegate routine technical tasks to AI while retaining cognitive engagement with higher-level creative decisions—produces different learning outcomes than passive offloading, where learners delegate tasks indiscriminately without reflective awareness. The distinction between strategic and passive offloading has emerged as a critical variable in recent research. A study on pedagogical partnerships with generative AI found that strategic cognitive offloading, when exceeding specific thresholds, can liberate mental resources for higher-order reflection, thereby enhancing transformative learning experiences (Wang & Zhang, 2026). This finding suggests that offloading is not inherently detrimental; rather, its effects depend on whether learners maintain active, reflective engagement with the offloaded tasks. Future research should develop instruments to measure offloading orientation (strategic vs. passive) and examine how this orientation mediates the relationship between AI use and skill development outcomes in digital drawing. A mixed-methods study combining survey-based measurement of offloading orientation with qualitative analysis of learners’ reflective journals and assessments of drawing skill development would provide valuable evidence.

Hypothesis 4: Moderating role of pedagogical scaffolding. Finally, it is hypothesised that the effects of the three mechanisms are moderated by the presence and quality of pedagogical scaffolding. Specifically, AI integration may positively predict learning outcomes when accompanied by structured guidance regarding when and how to use AI tools, critical reflection activities that encourage evaluation of AI outputs, and phased withdrawal of AI support as learner competence increases. This hypothesis aligns with systematic review findings indicating that generative AI’s positive outcomes on learning achievement, creative thinking, and engagement are contingent on integration through structured pedagogical frameworks with intentional instructor design (Rong et al., 2025). Future research should compare learning outcomes across conditions that vary the amount and type of scaffolding provided alongside identical AI tools. A factorial experiment manipulating the presence of reflection prompts, scaffolding for independent practice, and explicit instruction on AI use strategies would help isolate the active ingredients of effective pedagogical mediation.

Beyond these specific hypotheses, future research should also address several broader questions. These include the long-term impact of AI-mediated digital drawing instruction on foundational drawing skills (e.g., hand-eye coordination, perspective rendering, and tonal control); the transferability of skills acquired with AI assistance to unassisted drawing contexts; and the differential effects of AI tools across learner populations with varying prior skill levels, creative self-efficacy, and socioeconomic backgrounds. Given that art education has historically served as a domain for developing individual aesthetic voices, future research should also investigate how AI integration affects learners’ sense of ownership, authorship, and artistic identity over time.

Implications for Educational Practice

The analysis of mechanisms and the theoretical model also have important implications for educators and curriculum designers. Rather than adopting AI tools uncritically or rejecting them altogether, educators should take a strategic, reflective approach to their integration—one that aligns technological affordances with pedagogical goals and actively manages the tensions identified in this study.

First, AI should be used as a scaffold, not a substitute. The analysis of the cognitive offloading mechanism suggests that when AI tools replace core learning activities entirely—such as when learners delegate all shading, composition, or perspective decisions to AI without understanding the underlying principles—the risk of superficial learning and weakened foundational skills becomes acute. However, research indicates that strategic cognitive offloading, when it follows independent effort, can paradoxically support deeper learning by freeing cognitive resources for higher-order reflection (Wang & Zhang, 2026). A practical implication is that AI tools should be introduced in ways that scaffold rather than supplant. For example, adaptive feedback systems can provide real-time corrections during early-stage learning, but instructors should gradually reduce this support as learner competence develops, encouraging students to internalise evaluative judgment. This aligns with the gradual release of responsibility model, where the teacher initially models and scaffolds, then gradually transfers responsibility to the learner. One practical strategy is to implement a two-stage workflow: learners first complete a drawing task without AI assistance to establish a baseline understanding and engage in productive struggle; then, after this independent effort, they use AI tools for refinement, variation generation, or feedback. This sequencing preserves opportunities for cognitive engagement while still leveraging AI's affordances for skill acceleration. This approach is supported by research showing that students often turn to AI before engaging in productive struggle. Yet that struggle—working through a difficult problem—is essential for learning (Luckin & Holmes, 2016).

Second, teaching strategies should emphasise critical engagement with AI outputs. The analysis of the generative expansion mechanism highlighted concerns about originality, authorship, and cognitive fixation. To address these concerns, educators should design activities that encourage learners to analyse, question, and refine AI-generated outputs rather than passively accepting them. A classroom activity integrating generative AI image tools suggests how critical engagement can be operationalized: students were guided through theoretical framing, image selection, AI experimentation, and group analysis, with explicit emphasis on how prompt design shapes visual outputs and on the broader implications of generative systems (Källström, 2025). In digital drawing education, similar approaches might include asking learners to compare AI-generated variations against their own sketches, to articulate why they accept or reject specific AI suggestions, and to reflect on how their creative decision-making was shaped by—or remained independent from—AI inputs. Educators might also require that AI-generated elements in student work be clearly identified and that students provide written justification for their creative choices, thereby preserving accountability and promoting metacognitive awareness.

Third, curricula should maintain space for unassisted practice and foundational skill development. While AI can enhance productivity and creative exploration, foundational drawing skills—such as hand-eye coordination, perspective rendering, proportion judgment, and tonal gradation—remain essential both as transferable competencies and as the basis for informed creative judgment. The model suggests that unassisted drawing practice should not be eliminated from curricula but rather strategically interleaved with AI-supported activities. For instance, instructors might alternate between AI-supported sessions that focus on conceptual exploration and iteration and unassisted sessions that require students to execute drawings without algorithmic assistance, thereby consolidating and testing foundational skills. This balanced approach is supported by systematic review findings indicating that positive outcomes from generative AI integration occur when technologies are implemented through structured pedagogical frameworks with intentional instructor design (Rong et al., 2025) and when teachers maintain a focus on preserving human distinctiveness in concept formation, judgment, and meaning-making (Yang & Chou, 2025). Among the emerging themes in AI-powered design education identified in a recent systematic review, none suggest that foundational skills become irrelevant; rather, AI is positioned as a transformative force changing how we learn, update curricula, and assess knowledge rather than replacing the need for human creative judgment (Yang & Chou, 2025).

Fourth, equity and access considerations should be addressed explicitly. Not all learners have equal access to advanced AI tools. Some AI-powered drawing tools require paid subscriptions, high-performance computing hardware, or reliable internet connectivity—resources that may be unevenly distributed across institutions and student populations. Research on AI in primary education has found that generative AI tools such as ChatGPT offer significant potential for sustainable educational practices, but only when implementation accounts for existing resource disparities (Uğraş et al., 2024). Similarly, a systematic review of generative AI art applications in higher education found that barriers such as limited faculty training and unclear evaluation standards may hinder equitable access and long-term integration (Rong et al., 2025). Educators and administrators should therefore consider: (a) selecting AI tools that are freely available or institutionally subsidised; (b) providing technical support and training to ensure all students can access and use AI tools effectively; (c) designing assessments that do not disadvantage students who lack access to advanced AI technologies; and (d) offering alternative pathways for learners who choose not to use AI tools. In this regard, future research should continue to explore human-AI collaboration and learner adaptation to AI-enabled design education (Yang & Chou, 2025).

Fifth, AI literacy should be integrated as a learning objective in its own right. Beyond using AI as a tool for drawing instruction, educators should help learners develop critical understanding of how AI systems operate—including their training data biases, probabilistic rather than semantic basis, and limitations regarding originality and contextual understanding. The GIFT-AI classroom activity exemplifies this integration: by combining theoretical framing with hands-on engagement, students explored how AI-generated images are produced and analysed the aesthetic and epistemological dimensions of machine-generated media (Källström, 2025). In digital drawing education, this might include lessons on how style transfer models learn from existing artworks, the implications of training data bias for cultural representation, and the limits of AI in understanding aesthetic quality or artistic intention. Such AI literacy both prepares students for an AI-mediated professional landscape and encourages the critical reflection needed to reduce risks of overreliance and loss of originality.

This analysis provides some actionable insights that bridge theory and practice. The first section on mechanism-based frameworks provides educators and researchers with a vocabulary to critically evaluate AI tools based on their learning capabilities and risks. Directly supports AMLER's focus on evidence-based technology adoption. The second point, the emphasis on instructional intermediaries as moderators, highlights that technology alone does not determine learning outcomes; rather, instructional design, the timing of AI assistance, and opportunities for unassisted practice are crucial. This echoes AMLER's commitment to understanding how mobile and emerging technologies can be effectively integrated into different educational settings. Third, this article's discussion of cognitive offloading and the risks of superficial learning relates to the broader debate about digital literacy, arguing that students need not only technical skills but also a critical awareness of when and why to rely on artificial intelligence. Finally, an explicit focus on equity recognizes unequal access to advanced AI tools and calls for institutional policies and instructional strategies to prevent AI integration from exacerbating existing inequalities. These topics are consistent with AMLER's mission to advance research that is theoretically rigorous and practically relevant to mobile and technology-enhanced learning.

In summary, the effective integration of AI in digital drawing education depends not on the technology itself but on how it is pedagogically framed and critically engaged with. The proposed theoretical model provides a conceptual tool for educators, curriculum designers, and researchers to systematically consider the mechanisms through which AI reshapes learning, the tensions that arise, and the pedagogical conditions under which AI can support responsible and sustainable innovation in art education.

CONCLUSION

This conceptual study has argued that AI may reshape digital drawing skill development through three mechanisms: adaptive feedback, generative expansion, and cognitive offloading. Each mechanism offers learning affordances but also introduces pedagogical tensions—efficiency versus depth, exploration versus originality, and support versus dependency. The proposed theoretical model integrates these mechanisms, positioning pedagogical mediation as the critical factor determining whether AI enhances or undermines learning.

The model addresses gaps in the literature by moving beyond descriptive accounts, bridging AI functionalities with DOI theory, and incorporating evidence that strategic cognitive offloading can enhance transformative

learning. Future research should test hypotheses on feedback timing, originality thresholds, and scaffolding roles. For practice, educators should use AI as a scaffold, not a replacement, and combine it with unassisted practice, critical reflection, and AI literacy training.

Several limitations should be acknowledged. First, as a conceptual study, the analysis is based on interpretive synthesis of existing literature rather than a systematic review following PRISMA guidelines. The three mechanisms identified are analytically useful but not exhaustive; other mechanisms (e.g., motivational or affective dimensions) may also be relevant. Second, the proposed theoretical model has not yet been empirically validated; future research should test the hypotheses outlined in Section 4.3 through controlled experiments or longitudinal studies. Third, the model does not differentiate across learner populations (e.g., novice vs. advanced artists, different age groups, or varying socioeconomic backgrounds). The effects of AI mediation may differ significantly depending on prior skill levels, access to technology, and instructional contexts. Fourth, the framework primarily addresses digital drawing in formal education settings; its applicability to informal learning or professional practice requires further investigation. Acknowledging these limitations enhances the transparency of this conceptual contribution. AI can help or harm learning in art education, depending on how and when it is used. The goal is to use AI strategically, not excessively, while keeping human creativity central. This framework offers a conceptual tool for researchers and educators aiming for responsible and sustainable AI integration in creative learning.

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