RETHINKING THINKING: THE IMPACT OF GENERATIVE AI ON COGNITIVE, CONCEPTUAL, AND CRITICAL SKILLS IN DESIGN EDUCATION

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ABSTRACT

Design educators are confronted with the reality of Generative Artificial Intelligence (GenAI) in the design studio, prompting them to evaluate more than just the mechanical ease of the GenAI tools. GenAI is prompting a cognitive shift away from how designers think and create. This review integrates the theoretical and empirical literature on GenAI's influence on design education and cognitive processes in the design process (i.e., ideation depth, framing problems, thinking divergently, and conceptual reasoning). We argue GenAI is not a neutral technology. Rather, GenAI can serve as a cognitive amplifier or a drain on the designer's independence depending on the context. In order for educators and learners to realize the maximum benefit of GenAI, both need to reframe their focus from the goal of simple replication towards mastery of design through pedagogical methodologies that enable cognitive offloading (Hong, 2025; Xu et al., 2025). Cognitive offloading through structure can free mental resources to allow for higher-order thinking (Hong, 2025), while pedagogical reliance on GenAI ultimately may trap a designer into fixating on the design, result in homogeneity of designs and propagate pre-existing biases (Unimelb Research, 2024; Doshi et al., 2024; Arxiv, 2025). The concept of Human-Centric AI-First (HCAIF) design should be adopted as an educational framework. HCAIF requires institutions to modify their curricula to include metacognitive reflection and auditing for ethical implications as well as the provision of a high-stakes assessment method that assesses the designer's ability to critically and independently think (HCAIF, 2025; Pitt Teaching, 2024; Chan, 2023).

KEYWORDS: Generative AI (GenAI), Cognitive Offloading, Critical Thinking, Design Fixation, Divergent Thinking, Conceptual Reasoning, Human-Centric AI-First (HCAIF).

INTRODUCTION

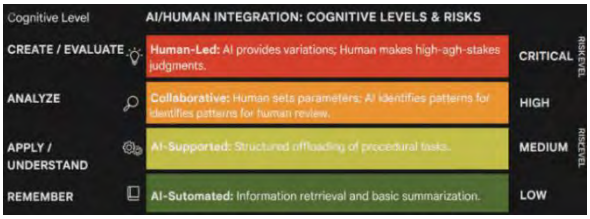
The Paradigm Shift in Design Cognition Facilitated by Generative AI (GenAI)

- **Understanding the Place of GenAI in the Design Workflow:** Generative Artificial Intelligence (GenAI) is not simply a new software application to be introduced into design practice, but rather a foundational transformation to creative practice that requires a conceptual shift in how design students experience and receive an education in design. The ability of GenAI tools to improve productivity and efficiency by accelerating design workflows - from simple to complex draft and conceptual synthesis stations - has initiated the debate over whether GenAI is an extraordinary tool that will enhance cognitive performance through extending the human capacity for creativity and productivity or a risk to degrade cognitive performance by relying on them too heavily (Alawneh et al., 2024). In order to evaluate and anticipate the implications of GenAI in design education, we must move beyond simplistic technical efficiency as a primary component of assessing GenAI as a tool to critically examine the deep structures of how GenAI impacts the cognitive processes of designers at both the individual and collective levels (Chiou et al., 2024).
- **Going Beyond Technical Proficiency to the Cognitive Shift:** Ultimately, when judging the quality of a design education and the students who have completed it, the judge should evaluate the ability of students to solve problems with their own internal cognitive capacity regardless of their ability to prompt the AI. The primary shift in how GenAI is changing the cognitive capabilities of designers is that GenAI tools will change the allocation of cognitive resources of designers when they complete their design process (Wirth et al., 2024). Current research examining the cognitive processes of designers in relation to GenAI, through a strict research methodology system, e.g., randomised control trials (Wirth et al., 2024), demonstrates that the cognitive processes of designers utilise the psychophysiological markers to assess cognitive workload, such as tracking gaze to assess engagement with design materials and using fNIRS to measure hemodynamic response in the brain (Wirth et al., 2024). By taking the cognitive workload of designers through the use of GenAI into account, a link has been developed to correlate GenAI with the reconfiguration of cognitive processes in designers (Wirth et al., 2024).
- **Key Theoretical Lenses: Cognitive Load Theory (CLT) and Cognitive Offloading (CO):** Central to the impact of GenAI is the process of Cognitive Offloading (CO), the deliberate or habitual use of an externally provided/ supplied support in place of cognitive processing (Alawneh et al., 2024). Teachers are faced with one basic existential question in their role: When does Cognitive Offloading (CO) change from being an effective strategy for the augmentation of cognitive capacity related to complex, high-stakes thinking to being an example of an effective or detrimental dependency on Cognitive Load Theory (CLT) and the potential loss of central, unassisted cognitive capacities (Alawneh et al., 2024; Arxiv, 2025)? If design students always rely on an AI system to perform essential cognitive operations, the foundation required to create, innovate, and think adaptively and independently can be irrevocably damaged (Arxiv, 2025). Therefore, the decision to use an AI support tool should carefully consider the appeal of increased efficiency against the potential negative impact on

cognitive ability over time of overtaxing the working memory.

THEORETICAL FOUNDATIONS AND COGNITIVE FRAMEWORKS FOR AI INTEGRATION

- **Bloom's Taxonomy as a Framework for Integrating AI into the Educational Experience:** Bloom's Taxonomy, established as a framework for clustering cognitive skills from basic recall to more complex creation, is a key tool for developing curricula which would be relevant to the generational effects of GenAI (Shaikh et al., 2021; Ohio State University [OSU], 2024). GenAI's greatest impact is its ability to perform some lower-order cognitive tasks for students, like remembering, synthesizing, and understanding information (Shaikh et al., 2021). Conversely, the developments in GenAI may adversely affect students' higher-order cognitive development by failing to develop independent critical thinking and reasoning ability through the use of AI in the initial synthesis of information, thereby skipping the critical analytical practice necessary to build the capacity of human independent thinking skills (Shaikh et al., 2021). Therefore, the goal of educators in integrating GenAI into their teaching practice should be to support the development of distinctly human evaluation, analysis, and original creation of work (Shaikh et al., 2021; OSU, 2024). Educators should use Bloom's Taxonomy as a tool to select and create learning outcomes where GenAI can be incorporated into the learning process as a structured supplement.



- **Motivation and the Zone of Proximal Development (ZPD):** The Zone of Proximal Development (ZPD) as conceptualized by Vygotsky provides an excellent framework for understanding how students' motivational goals impact how they perceive and engage with GenAI (Xu et al., 2025). Students motivated by mastery are more likely to positively interact with GenAI because they want to improve their understanding of concepts and their ability to do something (Pallant et al., 2025). For these students, GenAI is a dynamic scaffold that supports their developmental journey by enabling them to build new knowledge while also challenging them to extend their own potential (Xu et al., 2025; Pallant et al., 2025). On the other hand, students who are motivated by either performance or procedural goals tend to use GenAI as a tool to generate content quickly and proceed to produce their desired output without engaging or developing genuine cognitive involvement in the process (Xu et al., 2025). When using AI effectively, students must adopt a mindset focused on taking responsibility for the way they learn through an emphasis on self-regulation, continued improvement, and mastery of skills versus a dependence on tools.(Pallant et al., 2025).
- **Constructive Engagement vs Procedural Use of GenAI:** Research highlights the need to distinguish between the effective and ineffective use of AI-Constructive Use Designers that interact with GenAI in a purposeful and intentional manner, such that they form their own unique understanding of a topic and build upon that knowledge onward, will likely experience measurable positive outcomes regarding both the application of this knowledge and the development of critical thinking skills (Xu et al. 2025). In this demographic of students, we are beginning to see the rise and maturation of a greater sense of self-directedness and self-regulatory processes related to their learning (Pallant et al. 2025). For these students, GenAI is an invaluable resource for achieving a deep and thorough mastery of the subject matter (Xu et al. 2025) and an efficient way to develop an expertise level of understanding of the content. Conversely, when students use GenAI solely for procedural purposes [as in "doing it for them" by mimicking or reciting information], their capacity to apply this knowledge, as well as to be autonomous as learners and be critical thinkers, will negatively be influenced by their interaction with GenAI (Xu et al. 2025). Those students face an increased likelihood of becoming reliant on GenAI in aspects of design that do not lend themselves to receiving critical feedback from real-world application (Arxiv 2025). That is to say, design students who use GenAI will run an increased risk of inadvertently introducing errors or biases to their designs that were produced through the use of GenAI, as the iterative process of the evolution of designs from inception to final conception will easily camouflage these types of errors compared to other fields of study (Arxiv 2025).

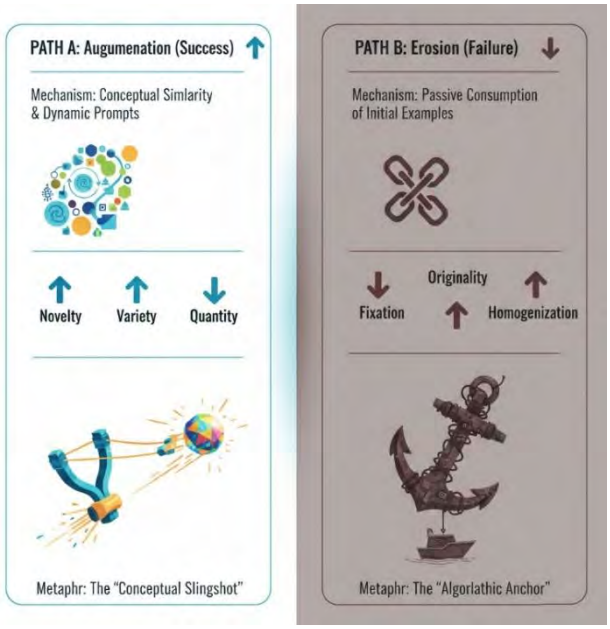
Feature	Constructive Use (The Mastery Designer)	Procedural Use (The Replication Designer)
Primary Goal	Deep subject mastery and understanding.	Speed, efficiency, and final output.
Cognitive Role	AI as a "scaffold" for complex tasks.	AI as a "replacement" for mental labor.
Impact on Skills	Enhanced critical thinking and applied knowledge.	Atrophy of unassisted problem-solving.
Self-Regulation	High: Active planning and auditing.	Low: Passive acceptance of results.
Outcome	Original, high-order conceptual synthesis.	Algorithmic homogenization and fixation.

THE EFFECT OF GENAI ON IDEATION AND DIVERGENT THINKING

- **The paradox of AI as a source of inspiration in the form of divergent thinking:** The capacity to generate an extensive number of innovative and unique concepts — can produce differing results due to how designers choose to utilize GenAI to develop innovative outputs. Argument for Augmentation. There is much evidence supporting the hypothesis that GenAI gives designers cognitive "slingshot" capacity to enhance their creativity (Chiou et al. 2024). By working with GenAI to develop ideas, designers can generate a significantly larger volume of original

creative ideas compared to if they would have developed their ideas independently of GenAI (Howard-Jones & Murray, 2003). Howard-Jones and Murray (2003) conducted AI experiment that used the concept of "conceptual analogy" to relate images associated with existing projects to support developing new concepts, leading to increased novelty in the number of ideas and variety of ideas developed. The dynamic inspiration that results from collaboration with GenAI serves to reduce the inevitable creative decline (Howard-Jones & Murray, 2003). Therefore, co-ideation sessions using AI tend to generate more innovative ideas than sessions that do not include AI (Design Society, N.D.). Argument for Erosion (Fixation). On the flip side, different research suggests that the AI can contribute cause fixation to be established within designers (Unimelb Research, 2024). The results of a co-ideation task performed with AI revealed that participants who used only AI-created images tended to become fixated on their initial conception (Unimelb Research, 2024). Participants in that task produced fewer concepts than the control group used, with fewer variations, and produced less original relative to the control group (Unimelb Research, 2024). This leads to the conclusion that merely using AI to create concept ideas does not guarantee that participants will have an effective co-ideation session when volunteering to use AI (Unimelb Research, 2024).

- **Algorithmic Fixation & Homogenization Effect:** These two opposing views regarding GenAI's role in divergent thinking can be viewed as the result of the phenomenon referred to as algorithmic fixation (Doshi & Hauser, 2024). AI operates like human cognition, by generating concepts by leveraging large quantities of information and being limited to the regionalized (i.e., limited) datasets used to train the systems (Doshi & Hauser, 2024; Arxiv, 2025). Unfortunately, the limited datasets of these systems tend to limit the amount and type of uniquely creative thought from each individual system. In addition to creating limited innovation among design students, these datasets will tend to homogenize (globally) the innovations that they develop based on the content from these datasets (Doshi & Hauser, 2024). When design students are required to utilize GenAI to develop new concepts when creating design outputs, they will have the additional challenge of conceptualizing and generating ideas outside the predictable boundaries established by their algorithms.(Chiou et al., 2024).



- **Strategies to Reduce Fixation and Increase Conceptual Range:** To overcome fixation requires moving away from a concentrated, passive consumption of AI to an active engaging with the AI. AI-assisted designers undertake extensive training in the area of prompt engineering (the process of iterating, refining, and breaking-down AI-assisted requests into smaller chunks than the original) in order to overcome (be able to exceed) the limitations of the AIs first suggestive readings (e.g., Pitt Teaching, 2024). Through this structured approach to prompt engineering, the AI can serve as a partner in innovation by providing multiple iterations or alternatives to the simple singular suggestion initially proffered; therefore, students will be equipped with the ability to identify and challenge the inherent limitations of the AI (bias, hallucination), thus facilitating the opportunity to promote critical thinking (Pitt Teaching, 2024).

PROBLEM DEFINITION/PROBLEM FRAMING & CONCEPTUAL REASONING

- **AI in the Design Process Problem Definition/Problem Framing Process:** Quality problem definition (or problem framing), is key to successful instructional design. AI can be used as a vehicle to accelerate the process by which instructional designers refine their design process [definition, exploring multiple constraints that impact upon their design decisions; or] develop a clearer concept for their design(s) early in the design definition process (Online Learning Journal, 2024). Therefore, AI has opened new potential perspectives to approaching the design process due to the dynamic nature of the interaction(s) between student, AI, and the design context; this alignment promotes cognitive engagement and serves as an avenue for facilitating student construction of knowledge (PMC, 2024). GenAI tools also provide a means for students to study

ethical considerations through the deliberate critique and analysis of flawed or biased AI inputs when coupled with Wrong Theory Protocols (Online Learning Journal, 2024).

- **Structured Cognitive Offloading in a Controlled Environment to Support Critical Thinking:** Research has demonstrated the potential for AI to enhance critical thinking; however, careful consideration must be taken before implementing AI to assist in developing students' critical thinking (Hong, 2025; MDPI, 2024). One quasi-experimental study found that using a structure that allowed lower-order writing tasks (structural revision) to be offloaded to an AI service [GenAI] allowed the students to concentrate more on the higher-order cognitive processes of analysis, evaluation, and reflection (Hong, 2025). The results from this study revealed that the students using the structured approach of leveraging an AI-support tool as a cognitive support mechanism had greater success on the standardized critical thinking assessments and produced more organized and original essay responses than the other group of students (Hong, 2025); therefore, this approach to structure the cognitive experience of offloading lower-order writing tasks were instrumental to the enhancement of the critical thinking skills of the students (Hong, 2025, MDPI, 2024). This component of the study validates the foundation principle of Cognitive Load Theory (CLT); if lower-order tasks can be separated from higher-order tasks, the cognitive resources for the more cognitively demanding higher-order tasks can be increased (Alawneh et al., 2024; Hong, 2025).
- **GenAI as an Educational Sponsor [Curator/Publisher] of Learning:** GenAI has fundamentally redefined how designers will view their future careers; their role has evolved from solely being a content creator to becoming a content critic, curator, and mediator (MDPI, 2024). To master both the technical use of the design tools and to be reflective on the intersection of the creativity of humans and the assistance of the technologies is essential for all future design students (MDPI, 2024). A solid body of theory is needed for this transition. For instance, the designer's Critical Theory must include a Critical look at Claire Bishop's critique of "aestheticised participation" in order to determine whether AI really allows equal access to creativity, or if it just provides "new forms of algorithmic gatekeeping" (Bishop, 2012; Beuys, 2025; Arxiv, 2025). By asking the question "Is Everyone Still An Artist?" (a modern interpretation of Joseph Beuys's "social sculpture") the student shifts from a descriptive analysis to a conceptually driven curatorial design, whereby they become a "cultural mediator and questioner" (Beuys, 2025; Bishop, 2012; Arxiv, 2025). As such, assessment must become less focused on technical novelty of the tool and more focused on the degree to which the student has used metacognitive reflection to analyse the tool's output and the societal ramifications of the tool's output (Pitt Teaching, 2024).

ETHICAL ISSUES, PROPAGATION OF BIAS, AND SYSTEMIC RISKS

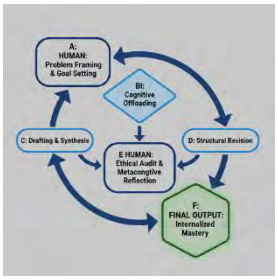
- **Bias in Algorithmic Design and Distorted Concept Development:** One major area of ethics in conceptual design is the potential for algorithmic bias to be subtly propagated throughout the design workflow (MDPI, 2023). Due to the training data used, Generative AI models are essentially incapable of avoiding reproduction of societal stereotypes, and the propagation of these stereotypes (Crescendo, N.D.; AI Multiple, N.D.). Examples of bias include image generator algorithms reinforcing gender stereotypes (i.e., female avatars are sexualised, regardless of input, while male avatars are generally portrayed as disproportionately heroic or powerful) (Crescendo, N.D.; AI Multiple, N.D.), as well as racial bias in hiring and facial recognition algorithms (AI Multiple, N.D.). For design students, the potential for ethical offloading is a danger: by allowing the AI to perform the initial labour of creativity, the student may unconsciously assume that the AI's output is free of bias, and therefore delegate the critical responsibility for determining ethical implications and fairness (Arxiv, 2025). Since students do not receive timely feedback on their performance while engaging in conceptual modelling, biases can be adopted unrealised and persist into their final concepts (Arxiv, 2025). Thus, incorporating critical thinking into design curricula must also include mandatory algorithmic bias audits to ensure that the designer is held accountable for the conceptual and ethical quality of the machine's output (Pitt Teaching, 2024).

- **Academic Integrity, Authors, and Attribution:** The increased use of Generative AI in academia has raised questions about the ethical implications of authorship, IPR, copyrights, and plagiarism (MDPI, 2023). In many academic settings, the divide between plagiarism and using Generative AI for academic assignments is still unclear, although the guidelines surrounding acceptable use are also still undefined (Arxiv, 2025). Without established ethical guidelines, both learning and teaching integrity will continue to be compromised (Arxiv, 2025). Although students have expressed a high desire to utilise Generative AI for learning purposes, many of them express significant concern over where they should draw the line when it comes to ethical practice and academic misconduct (Pallant et al., 2025). In addition, many students have experienced a decline in performance when completing assignments without the use of Generative

AI, which indicates a potential over-reliance on this technology and a subsequent lack of independent problem-solving skill development (Arxiv, 2025). Accordingly, students must receive extensive training on AI literacy to enable them to navigate this conflict between the desire to create original works and maintaining academic integrity while using Generative AI in their studies (Pallant et al., 2025; Wang, 2023).

PEDAGOGICAL ACTIONS AND THE HUMAN CENTRIC AI-FIRST (I.E., HCAIF) FRAMEWORK SURVEY RESULTS AND HYPOTHETICAL ANALYSIS

- **Acquiring the Human-Centric AI-First (i.e., HCAIF) Model:** In order to transform the nature of higher education, and transpose from a reactive policy to an active, strategic paradigm transformation (i.e., HCAIF, 2025), the Human-Centric AI-First (i.e., HCAIF) Framework should serve as an example of how best to integrate the use of AI into learning, with a focus on the ethical use of AI to foster ethical decision-making, critical thinking, and the application of skills to solve real-world problems (i.e., HCAIF, 2025) in a human-centric model. This model supports the concept of "Human-AI-Human" by placing emphasis on the role of human thought and understanding both at the beginning and end of all our interactions with technology (i.e., Human-AI-Human, 2025). Thus, while AI is utilized to improve the customization of our learning experiences and feedback received, the ultimate goal of these efforts should be to achieve competency-based growth that is rooted in human values (i.e., HCAIF, 2025). Therefore, the role of the educator shifts from simply being the source of content to becoming the metacognitive coach and expert prompt engineer who uses metacognitive strategies to support the development of students throughout their learning journey.



- **Creating Assessments for Cognitive Independence:** In order to immunize our students from the negative implications of developing cognitive dependency, assessments must be redesigned to focus on assessing students' internalized knowledge and their ability to construct high-level synthesis, with an emphasis on mastery vs, mimicry (i.e., Pitt Resources, N.D.). Strategies for encouraging student cognitive Independence include the following:
- **Assessments that alternate AI Related vs. "AI Free"**: There must be a consistent use of "AI Free Assessments and Assignments" in conjunction with "AI Assisted" Assessments for students to maintain the core cognitive independence necessary to be able to function autonomously (i.e., Chan, 2023; Pitt Resources, N.D.) in the world of the future.
- **Metacognitive Practice:** Students must be required to provide active reflections and critically evaluate their learning; only then can they provide evidence of internalized knowledge; only then can they provide evidence of their learning in a manner that GenAI cannot replicate (i.e., Pitt Teaching, 2024).
- **Oral Presentation / Conceptual Defense:** Providing opportunities for students to articulate and defend their internalized understanding of course material through the use of oral presentations and conceptual defenses will encourage students to communicate and critically justify their understanding without relying on passively accepted AI Generated content (i.e., Pitt Resources, N.D.)
- **Complex, Original Tasks:** Students must be required to conduct authenticated primary research (i.e., data collection, interviews) and/or create complex synthesis creations that require students to engage in complex problem-solving beyond the creation of an algorithmic solution (i.e., Pitt Resources, N.D.).
- **Building GenAI Literacy and Critical Thought:** To Build GenAI Literacy, it is critical to train students to both know how to use the tool and to have a firm understanding of the role that Gen AI plays as well as the quality of generative AI output (i.e., Pitt Teaching, 2024) before utilizing the tool. Students need to also be prepared to recognize the inherent limitations associated with the use of GenAI to generate outputs by acknowledging the following characteristics of GenAI: bias, homogenization, and hallucination (i.e., Doshi and Hauser, 2024 and Pitt Teaching, 2024).

As such, instructional strategies will need to incorporate a comparison of:

- **Bias:** In order to successfully evaluate generative AI generated outputs for potential issues surrounding systematic bias, students must be required to engage in algorithmic bias auditing as part of the evaluation process of all GenAI output (i.e., Pitt Teaching, 2024).
- **Comparison of Tools:** Students should be provided assignments that contain multiple GenAI generated output with the intent of providing them the opportunity to reflect on the differences between the constraints of each algorithm used and the importance of being discerning in their comparisons (i.e., Pitt Teaching, 2024).
- **Challenge of Prompt Engineering:** Students must be challenged to create and refine complex prompts for use with generative AI to help them develop a better understanding of how the prompts impact the algorithmic solution created; this is an important step to help students move away from the habitual fixation of algorithmic design (i.e., Pitt Teaching, 2024).

CONCLUSION

To summarize the findings, Generative AIs do not operate in a vacuum; they actively engage with the designer's

cognitive process based on how they are being used. The evidence suggests that when learners employ a mastery mindset to apply AIs to organize their lower-level cognitive functions and offload repetitive tasks, their higher-level critical thinking skills and synthesising skills are enhanced (Hong, 2025; Xu et al., 2025; Alawneh et al., 2024). The main concern is that an over-reliance on "outcomes-first" procedural thinking creates a high degree of cognitive dependence, homogenisation of thought processes, and marked reductions in an individual's ability to solve complex problems without AI assistance (Doshi & Hauser, 2024; Unimelb Research, 2024; Arxiv, 2025). Therefore, we recommend that the education community execute a fundamental paradigm shift to adopt Human-Centric-AI-First (HCAIF) teaching strategies that require human reflection on both ends of the interaction with AIs and impose the use of oral assessments, "AI-free" activities, and mandatory audit requirements of algorithmic biases in assessments (AACSB, 2025; OSPI, 2025; Chan, 2023; Pitt Teaching, 2024). In the future, additional robust longitudinal investigations using objective neurological assessment methods (e.g., fNIRS) will be needed to fully understand the cognitive trade-offs that arise from AI integration in the very early conceptual design stages (Wirth et al., 2024; Chiou et al., 2023).

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