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Between Assistance and Autonomy: Evaluating Generative AI's Pedagogical Role in Architectural Design Education

Yunjeong Chang, University at Buffalo, The State University of New York
Dr. Anahita Khodadadi, University at Buffalo, The State University of New York

Anahita Khodadadi conducts research at the intersection of architectural design, building science, computational design, and learning sciences. She is an assistant professor at the University at Buffalo's School of Architecture and Planning (SAP), and also affiliated to the University at Buffalo Institute of Learning Science, collaborating with faculty across education, cognitive psychology, and computer science. She has a solid background in developing algorithmic design methodologies, and has created an interactive computational tool called Morpho, which integrates genetic algorithms with problem-solving strategies. Additionally, she has studied architecture students' cognitive challenges and learning experiences in engineering and computer science courses.

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Yunjeong Chang[1], Anahita Khodadadi[2]
[1,2] University at Buffalo (SUNY), Buffalo, NY

Abstract

Generative AI (GenAI) is rapidly entering architectural education, accelerating precedent analysis, concept generation, and visualization while raising concerns about cognitive dependence, ethics, and the cultivation of independent design judgment. While prior research has focused primarily on GenAI's role in idea generation and representation, its influence on students' learning processes and design reasoning across the full design workflow remains underexplored. This study examines GenAI not as a single-stage tool but as a design companion supporting students from early research through final representation. A structured pedagogical experiment was implemented in a graduate seminar that integrates AI literacy, ethical awareness, and design practice. Students engaged tools such as ChatGPT, SciSpace, Consensus, and Midjourney for brainstorming, argumentation, and iterative problem-solving, while critically examining bias, verification, and risks of over-reliance through reflective activities. Funded by a national grant, this in-progress qualitative study analyzes design artifacts, think-aloud videos, reflection journals, and interviews to examine cognitive depth of AI use, design agency, and ethical awareness. Although situated in architecture, the *findings offer transferable implications for engineering education*, particularly for AI-integrated design courses emphasizing ill-structured problem solving, design thinking, and responsible AI use. The study identifies conditions under which GenAI enhances—or constrains—design quality and independent judgment and contributes a pedagogical framework to support creativity and analysis while preserving critical and autonomous design thinking.

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Generative Artificial Intelligence (GenAI) is increasingly influencing architectural design, reshaping how architects conceptualize, iterate, and visualize projects. GenAI tools capable of generating text, images, videos, and 3D models are advancing rapidly, and their adoption in architectural practice is growing. Industry reports reflect this shift: while only 5% of U.S. architecture firms used AI in 2023, nearly 70% were exploring future integration (AIA Philadelphia, 2023). By 2024, approximately one-third of firms reported using AI in daily practice (AIA, 2024). Similarly, 41% of UK architects have used AI in projects, with many citing improved design efficiency (RIBA, 2024).

Leading firms such as MVRDV (*How MVRDV Is Using AI to Design Their Buildings*, 2024) and Zaha Hadid (Barker, 2023) Architects have demonstrated AI's potential by using generative tools for conceptual image generation and early-stage design exploration. Despite these high-profile examples, widespread adoption remains limited. Ethical concerns—authorship, originality, bias, privacy, and over-reliance on algorithmic outputs—continue to slow integration, particularly in educational contexts where students may lack the expertise to critically verify AI-generated content (Fui-Hoon Nah et al., van Dis et al., 2023. Research suggests that while AI can improve

efficiency, excessive dependence may undermine critical thinking and creative agency if AI replaces rather than augments human design judgment (Fui-Hoon Nah et al., 2023; Iskender, 2023; van Dis et al., 2023).

Additional challenges include the scarcity of architecture-specific datasets, the technical complexity of AI tools, and limited explainability of AI-generated results (Del Campo, 2022). Improving explainability is especially important for aligning AI outputs with architectural reasoning and discourse (Horvath & Pouliou, 2024). As GenAI becomes increasingly relevant to practice, architectural education plays a critical role in preparing students to use these tools responsibly, balancing technical proficiency with ethical awareness and critical inquiry.

Integration of AI into the Architectural Design Process

Architectural design typically progresses from abstract problem framing to detailed realization through iterative exploration, precedent analysis, simulation, and documentation. Within this workflow, AI can function in multiple roles, aligned with Steinfeld's (2021) frameworks of AI as actor, material, and provocateur. As an actor, AI supports conceptual design by analyzing site and performance constraints, generating alternatives, and offering feedback on factors such as energy use, daylighting, structure, and cost. As material, GenAI operates as a manipulable design medium—similar to parametric tools—allowing architects to shape AI-generated forms while retaining authorship and agency. As a provocateur, AI stimulates creativity by introducing unexpected combinations, speculative visuals, and alternative narratives that challenge conventional design thinking.

Applications of GenAI in Architectural Design

Advances in visual models such as Stable Diffusion, DALL·E, and Midjourney have expanded GenAI's use in architecture (Baudoux, 2024; Horvath & Pouliou, 2024; Tan & Luhrs, 2024; J. Zhang et al., 2023). Prior research identifies five primary application areas:

1. Design brief development – AI assists in synthesizing precedents and architectural texts to refine design objectives.
2. Historical analysis and pattern recognition – Image-based models extract shape grammars and typologies from precedents, supporting design history and theory.
3. Rapid concept generation and visualization – Text-to-image tools accelerate early-stage ideation and visual exploration.
4. Generative design and optimization – AI enables exploration of large design spaces and optimization of quantifiable parameters such as energy, structure, and material use.
5. Immersive and interactive environments – Integration with VR, MR, and the metaverse supports real-time collaboration, visualization, and digital fabrication workflows.

Gaps and Future Research Directions

Despite growing interest, several gaps remain. First, AI's impact on architectural thinking and creativity is poorly understood, particularly regarding problem framing and conceptual reasoning. Second, unresolved ethical and legal issues—data ownership, authorship, and intellectual

property—threaten designers' agency. Third, current AI applications overemphasize form generation while underutilizing AI's potential to integrate performance, sustainability, and functional criteria.

Additional challenges include the disconnect between coding-based AI workflows and traditional design practices, delayed feedback compared to sketch-based exploration, biases in training datasets, and limited explainability of AI outputs. This study focuses on architectural design education and addresses the first three gaps by examining students' engagement with GenAI and its implications for creativity and critical thinking.

AI in Design Education

Integrating GenAI into architecture curricula offers opportunities to enhance design exploration, research synthesis, and performance evaluation. Tools such as large language models support literature analysis and theory building, while AI-driven simulations and VR environments strengthen spatial reasoning and real-time testing. However, despite growing experimentation, the educational impact of GenAI remains underexamined. Existing courses largely emphasize tool use without systematically studying effects on learning outcomes, cognitive development, authorship, or ethical practice. As a result, concerns persist about automation, dependence, and the balance between human creativity and AI support—highlighting the need for empirical research centered on students' experiences and perceptions.

Sponsored by a national grant, this study aims to develop a structured curriculum that strengthens architecture students' AI literacy while preserving design agency and critical thinking. The project designs and implements a graduate-level seminar and design studio that introduce the integration of machine learning and generative AI (GenAI) into architectural design. Through instructional scaffolding and hands-on activities, the courses examine how students engage with GenAI as a design companion and how such engagement influences cognitive development and computational design skills.

The study has two specific objectives: (1) to enhance students' AI literacy and computational proficiency while reinforcing critical thinking and design decision-making; and (2) to examine the impact of AI-integrated curricula on students' cognitive development, learning processes, and design outcomes. At the time of this proposal submission, the project is midway through its timeline. Accordingly, this proposal will focus on architecture students' perceptions of integrating GenAI into design projects, drawing on data collected during the first semester of implementation.

Methods

This study employed a qualitative embedded case study design (Yin, 2018) to examine how graduate students engaged with generative AI as a design companion within a single seminar course. Building on prior research and instructional experience, this study was conducted within a graduate-level seminar designed to introduce generative AI (GenAI) in design education. The seminar emphasizes theoretical and ethical foundations, including core AI and machine learning concepts, sources of bias and misinformation, risks of over-reliance, and implications for authorship and design judgment. Students were introduced to applications of AI in design and

engaged Natural Language Processing (NLP)–based and image-generation tools (e.g., ChatGPT, Midjourney, SciSpace, Consensus, Gemini) as brainstorming partners and debate assistants. Instructional activities guided students to critically interact with AI by formulating and refining prompts, interpreting AI outputs within contextual and design constraints, and using AI to support argumentation and iteration rather than solution generation. Students were also explicitly trained to verify AI-generated information through cross-referencing with authoritative sources, identify biases and limitations related to training data, and reflect on instances in which AI supported versus misled their design reasoning.

Data

To examine students' perceptions and use of GenAI in design tasks, the study primarily employed qualitative methods. Data sources included:

- Think-aloud videos: Students recorded 10-minute long think-aloud video presentations documenting their design workflows. These videos captured real-time problem-solving processes, including prompt construction, AI response evaluation, iterative refinement, and integration of AI-generated insights into design decisions.
- Reflection journals: Students submitted written reflections accompanying each assignment, documenting their evolving understanding of AI's role in design, perceived benefits and limitations, ethical considerations, and decision-making strategies.
- Semi-structured interviews: Voluntary interviews were conducted at the end of the semester to further probe students' perspectives on authorship, bias, ethical concerns, and risks of over-reliance when integrating GenAI into design work. Interview data were used to triangulate findings from videos and journals.

During the seminar, students completed three major assignments designed to progressively examine the role of GenAI in architectural design processes. The first assignment focused on a precedent study of an architectural element or technology, where students compared AI-assisted and non-AI research workflows to identify patterns, historical developments, and differences in knowledge construction. The second assignment built on this foundation by engaging students in applying AI tools within a structured design or analysis task, emphasizing iterative prompting, evaluation of AI outputs, and integration into design reasoning. The third assignment asked students to revisit a prior design project completed without AI. They critically evaluated their original work by graphically annotating strengths, weaknesses, assumptions, and gaps—drawing on both self-reflection and prior feedback. They then re-developed the project's early stages using AI tools for research, concept development, and visualization.

Across all assignments, the structure combined process documentation (including AI interactions), critical reflection, think-aloud video, and comparative analysis, with the goal of developing students' ability to critically and responsibly integrate GenAI into design workflows while maintaining authorship, judgment, and disciplinary rigor. Interviews were conducted after submission of the final assignment. At the time of draft submission, data from two think-aloud video sessions and two reflection journals had been analyzed; interview analysis is ongoing and will be incorporated in the final paper.

Data Analysis

Think-aloud videos were analyzed first and then compared with corresponding reflection journals to examine consistency and evolution in students' reasoning. Video analysis employed a rubric adapted from Cognitive Task Analysis (CTA; Ericsson & Simon, 1993) and the think-aloud method (Van Someren et al., 1994). The rubric was contextualized for architectural design tasks and reviewed by two instructors with experience teaching design seminars without AI to support content validity.

Two learning sciences researchers independently analyzed the videos using the rubric and then met to resolve discrepancies and reach consensus on coding, scores, and representative excerpts. Reflection journals were analyzed using thematic analysis to identify recurring patterns related to cognitive depth, design agency, and ethical awareness. To enhance trustworthiness, both researchers independently coded each dataset and reconciled differences through discussion until agreement was reached. Interview data will be analyzed using the same analytic lenses to triangulate and extend findings in the final paper.

Findings (in-progress)

Six graduate students consented to participate in the study. The preliminary findings reported here are based on a partial analysis of the larger dataset and synthesize *twelve* think-aloud video presentations and *twelve* reflection journals—that is, six videos and six journals from each of the first and second design assignments, which served as interim progress reports. The third think-aloud video and reflection journal, as well as interview data, are currently under analysis but will be incorporated in the final version of the manuscript.

Analysis revealed three major themes in students' engagement with generative AI (GenAI):

1. **Increased efficiency during the early stages of design**

   Students reported that GenAI tools reduced the time and effort required for preliminary research. In particular, SciSpace (i.e., a literature review focused AI) was frequently cited as helpful for reviewing research literature and generating initial design ideas, as it provided concise summaries of academic articles and supported rapid familiarization with unfamiliar topics.

   - *"Sci Space provided additional sources as I was writing." (Student 1)*
   - *"With a greater understanding of the tool's ability overtime, I believe using these programs will be much easier than manually searching." (Student 2)*

2. **Idea generation and refinement of design problems**

   GenAI tools supported iterative exploration and refinement of design ideas. Instances of irrelevant or unexpected AI responses prompted students to reconsider and adapt prompts, which in turn facilitated clearer articulation of design intentions and novel ideas.

- *"When my first attempt did not give me in depth responses in Consensus (academic search-focused AI) I turned to ChatGPT to adapt the prompt in ways that will direct my research into a niche category. The list of specific design approaches surprised me, specifically pertaining to hempcrete and mycelium panels as energy efficient insulation. I never thought about this design as an option for insulation before and I immediately grew interested in the idea." (Student 2)*
- *"I knew I had a general topic in mind before doing deep research and further iterations, and ChatGPT expanded on the prompt and guided me to a cohesive and developed thesis. I used it as a partner to structure ideas, reframe unclear thoughts, and propose connections between architecture, history, and social conditions." (Student 4)*
- *"At first the information was misleading and not specific enough with sources that did not align with the AI overview. Once I generated more prompts it had a better understanding of the information I was grasping for." (Student 5)*

3. Maintaining design agency and awareness of limitations

All participants emphasized that productive use of GenAI depended on maintaining control over the design process. Students reported that having a clear design idea or intent prior to consulting AI was essential. They highlighted the need for critical evaluation, cross-checking outputs, and ethical use of AI-generated information. Limitations included unreliable citations, difficulty in generating precise visualizations, and occasional AI outputs that conflicted with site-specific or contextual realities.

- *"Personally, I felt that AI hindered my creativity and critical thinking. Although it streamlined the process of comparing and sorting sources, I felt like I had a less understanding of the material because AI was doing all of the preliminary work and reading for me." (Student 6)*
- *"I believe it is still hard to trust that the sources it provides are reliable or the best option for what you are looking for. Relying on AI for all steps of framing, generating, and evaluating design ideas is an unethical way of conducting research." (Student 3)*
- *"These experiences made me more aware of AI's limitation in understanding site-specific complexity and I felt more responsible as a designer to interpret, filter, and humanize the results." (Student 2)*
- *"I found that sometimes Midjourney has trouble understanding what I would consider simple directions. In the other class I remember being very frustrated when I prompted the image to show animals walking downhill and it would only produce animals walking uphill." (Student 1)*
- *"Midjourney generated visually compelling but often exaggerated renderings, detached from the city's material and climatic reality." (Student 2)*

Across all data sources, students demonstrated critical reflection on both the benefits and limitations of GenAI, recognizing its potential to improve efficiency and ideation while highlighting the importance of maintaining autonomy, ethical responsibility, and critical thinking throughout the design process. These themes provide a foundation for understanding how AI can be integrated as a design companion without compromising student agency.

Expected Implications

This study provides empirical insight into how students engage with generative AI as a design companion and how such engagement shapes design reasoning, problem-solving processes, and cognitive depth during open-ended design tasks. Drawing on think-aloud videos, reflection journals, and in-progress interview analyses, the findings identify conditions under which GenAI enhances design exploration and analysis, as well as moments where over-reliance may constrain independent judgment and design quality.

Although conducted in an architectural education context, the implications directly extend to engineering education, where design thinking, ill-structured problem solving, and ethical AI use are included in central learning goals. The study highlights transferable patterns of student reasoning with AI, common cognitive challenges (e.g., surface-level iteration, verification gaps), and instructional tensions between efficiency and agency that are likely to arise across engineering disciplines.

The paper contributes a practical, transferable pedagogical framework to guide engineering educators in integrating GenAI into design-focused curricula. This framework emphasizes balancing AI assistance with student autonomy, supporting creativity and analysis while preserving critical, reflective, and independent design thinking—key competencies for future engineers working alongside AI systems.

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