Architectural Design Studio in Confluence

AI Integration at the schematic stage and its potential impact on final design

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This study explores the integration of artificial intelligence (AI) tools into architectural design education through an experimental studio. By engaging second-year students in a three-stage process combining conceptual modeling, AI-assisted design exploration, and design development, the study examines AI's impact on structural innovation, material articulation, and spatial organization. Findings reveal that AI tools, when critically and creatively employed, can enhance not only formal outcomes but also students' reflective and conceptual thinking, offering pedagogical value beyond mere visual generation.

Keywords: *AI-assisted architectural design, Design pedagogy, Computational design education*

INTRODUCTION

The advent of computer-aided design (CAD) programs has brought about a transformative shift in architectural practice. This technological evolution has not only revolutionized the production of design but has also redefined creativity within architectural education, giving rise to pedagogical approaches rooted in digital tools and computational design methodologies (Herr and Karakiewicz, 2007; Özkar, 2011, 2017; Tan, 2024). On one hand, digital design tools facilitate the documentation and construction of highly complex architectural forms with relative ease; on the other, they have enabled the development of algorithmic design strategies that make a vast array of design possibilities both computationally accessible and analytically assessable (Jabi, 2013; Terzidis, 2006; Woodbury, 2010). This dual impact has not only expanded the creative capacities of architects but also supported the integration of such competencies into architectural curricula.

Although there is continued debate regarding the impact of rapidly evolving technologies on the quality and originality of design, digital tools have become an indispensable part of contemporary architectural workflows—largely due to their widespread adoption and the increasing proficiency of practitioners in utilizing them.

Today, a comparable paradigm shift is unfolding with the rapid proliferation of artificial intelligence (AI) tools. These technologies, while introducing novel capabilities into design processes, have also provoked critical discourse regarding their advantages and potential drawbacks (Epstein et al., 2023). In the specific context of architectural design, the question of how AI tools can be employed to enhance creativity—without fostering standardization or compromising design originality—has emerged as a central area of scholarly and pedagogical investigation (Tong et al., 2023; Paananen, Oppenlaender and Visuri, 2024). Within this landscape, the development of a coherent pedagogical framework for AI-integrated architectural education has become a pressing concern.

The extent to which digital design supports creativity in architecture is contingent upon the ability to construct interactive design processes (Oxman, 2006). Likewise, it is believed that the potential of AI-assisted architectural design to foster creativity depends fundamentally on the capacity of pedagogical approaches to mediate a fluid and meaningful interaction between human cognition and AI-generated outputs. It is posited that such interaction can lead to more dynamic, innovative, and effective design processes.

In response to this emerging context, the present study proposes a model aimed at enhancing interactivity in AI-supported architectural design processes. The following section provides a review of existing literature on the integration of AI in architectural design and education, establishing the theoretical foundations of the study. This is subsequently followed by a detailed account of the methodology employed in developing the proposed model.

ARTIFICIAL INTELLIGENCE IN ARCHITECTURAL DESIGN EDUCATION

Within this research, a systematic review was conducted in the Scopus database using the keyword “AI in Architectural Design Education.” The retrieved publications were analyzed to identify interdisciplinary trends and examine the roles AI assumes in architectural processes. Findings show that AI tools significantly enhance the speed and efficiency of design workflows by transforming creative processes (El Moussaoui and Krois, 2025).

Bibliometric mapping using VosViewer revealed a notable cluster centered on the keyword "students," indicating a recent surge in studies on AI integration in architectural education (Figure 1). Most focus on generative AI systems, particularly text-to-image or image-to-image tools—used during the conceptual phase and their impact on students' creativity. A recurring theme is the capacity of these tools to support form generation and reshape students’ design thinking, while enhancing efficiency and creativity. However, the literature consistently stresses the need for educators to balance technological innovation with human-centered design approaches, emphasizing critical awareness of the limitations and biases of AI systems (Almaz et al., 2024; Chandrasekera et al., 2024; Elere, Ulme and De Paolis, 2024; Montenegro, 2024).

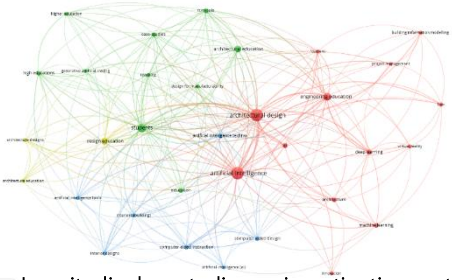

Figure 1
Bibliometric mapping reveals a prominent cluster in green around the keyword "students"

Longitudinal studies investigating the integration of generative AI tools into conceptual design reveal that such tools can stimulate more exploratory approaches among students, diversify early design ideas, offer heightened visual richness, and encourage broader formal experimentation (Cudzik, Nyka and Szczepanski, 2024; Gupta and Khan, 2024). Interviews conducted with students also affirm that many perceive significant creative potential in these tools (Samad et al., 2024; Weng, Lai and Yeh, 2024). Nevertheless, how architectural curricula should adapt to these technological shifts remains a critical and unresolved question.

One of the primary challenges in integrating AI into architectural education lies in the inherent limitations and potential biases of the technologies themselves. Generative AI systems are ultimately constrained by their training datasets and, as a result, may reproduce entrenched architectural preconceptions. Empirical studies have shown that when prompted with ambiguous or overly broad terms—such as “architecture”—AI models frequently generate generalized and biased imagery, typically favoring symmetrical compositions that blend classical and modern elements rendered in dramatic perspectives. In the absence of precise and contextually grounded prompts, these systems often neglect fundamental architectural principles, such as human scale, producing outputs that are disconnected from spatial and structural realities. Consequently, it is argued that AI tools should be integrated into design education as complementary—rather than substitutive—components, to preserve a spatially and materially grounded design pedagogy (Iranmanesh and Lotfabadi, 2024). When students—particularly those who have not yet developed robust architectural reasoning skills—engage with these tools uncritically, there is a risk that the algorithm's aesthetic biases and formal superficialities may shape and constrain their design thinking (Hedges, 2023). Comparative research has further demonstrated that traditional design approaches continue to better support the development of students' tactile, spatial, and structural reasoning skills, playing a more effective role in cultivating architectural awareness and coherent design logic (Wang et al., 2024).

Another challenge stems from the opacity of these systems' internal processes, invoking the "black box" metaphor—an idea contrary to the interactive and exploratory nature of computational design thinking. Reducing the designer's role to mere input-output manipulation, such systems pose a threat to pedagogies centered on human-machine interaction and iterative creative discovery (Calixto and Croffi, 2024). In response, several studies have explored interactive AI-assisted pedagogies that encourage students to engage with architectural form, space, and structure.

Recent research has increasingly shifted from prompt-based generative systems such as MidJourney and DALL·E toward more customizable, open-source platforms like Stable Diffusion and ComfyUI, which offer greater potential for interactive and iterative design workflows (Cao, Abdul Aziz and Mohd Arshard, 2024; Kim, 2024). These multimodal models hold considerable promise for AI-assisted design; however, their dependence on complex commands and coding introduces new barriers—including steep learning curves, reduced intuitive control, and difficulty integrating programming with design development. These factors may hinder critical thinking and foster overreliance on AI (Jin et al., 2024).

Concurrently, several studies have examined AI less as a tool for concept generation and more as a means of spatial configuration and schematic visualization. While AI systems demonstrate proficiency in layout visualization, they often struggle to generate coherent architectural plans (Yamada, Hayashi and Fujita, 2024). In the context of interior design, Shreya and Kumar (2024) highlighted the potential of AI-driven 3D modeling to enhance creativity, accuracy, and inclusivity. Similarly, Bank Stigsen et al. (2023) explored the translation of AI-generated images into 3D geometries to support students with limited modeling experience; however, this approach is constrained by low informational richness and software proficiency challenges. Agkathidis, Song and Symeonidou (2024) proposed an AI-driven studio model in which the morphogenetic phase is conducted through text-to-image synthesis. Yet, the resulting outputs frequently lack spatial logic and architectural coherence. In such cases, students often revert to conventional tools—such as floor plans and sectional drawings—during critical design decision-making (Vissers-Similon and Dounas, 2024). Ironically, this dependence on traditional methods may undermine the intended benefits of digital engagement.

As a result, two persistent challenges remain unresolved in literature: (1) the lack of meaningful interaction, which often leads to (2) the production of generic outputs. A promising strategy to address these issues involves repositioning AI tools away from early-stage concept generation and toward later phases of the design process, particularly material exploration and spatial organization. In one such study, students employed AI-assisted visualization engines to enrich their 3D massing models using architectural references derived from case studies. This approach enabled students to more effectively connect conceptual ideas with real-world precedents. The AI-generated visualizations provided immediate feedback, helping to clarify spatial dynamics, material characteristics, and overall design implications—thereby supporting rapid iteration and encouraging creative exploration. However, a notable drawback was AI's tendency to generate highly photorealistic imagery, which often led to homogenized and reductive design outcomes. Since abstraction plays a crucial role in fostering novel architectural possibilities, an overreliance on photorealism may constrain interpretive richness and limit imaginative thinking (Alymani, 2024).

Still, as demonstrated by Kavakoğlu et al. (2022) and Tong et al. (2023), AI-based interactive workflows often remain dependent on human-generated visual inputs. Consequently, when strategically guided, repositioning AI applications to the later stages of the design process retains the potential to enhance interactivity and cultivate a more dialogical and reflective design environment. Within this framework, the present study investigates whether—and in what ways—the integration of AI systems after the schematic phase of the architectural design process influences students' design decisions concerning materiality, spatial experience, and structural innovation. If such influence proves to be significant, the study aims to propose an interactive pedagogical framework for the integration of AI tools into architectural design education. The following section outlines the components of this pedagogical model and presents the key findings of the study.

AI INTEGRATION THROUGH A THREE-STAGE MODEL

This study is based on an experimental design studio conducted during the Fall semester of the 2024–2025 academic year with second-year architecture students. The studio was structured around the thematic focus "Patterns of Living for the Other," explored within the context of social housing design. Each participant was asked to design a housing complex comprising 5-6 residential units. The expected outcome was a proposal that moved beyond conventional housing solutions, prioritizing flexibility, ecological sensitivity, and collective living strategies. The integration of shared spaces, such as communal courtyards and gardens, was considered a core design criterion to promote social interaction and a sense of community.

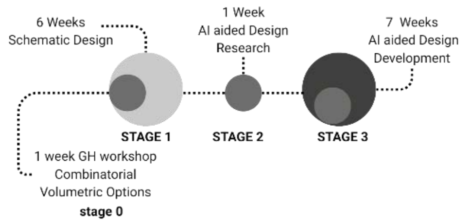

Figure 2
Three-stage model illustration for AI integration in architectural design

A total of 13 students participated in the studio, 10 of whom completed all requirements and received full credit. The remaining 3 students, although not awarded full credit, produced projects deemed successful in terms of design development and engagement with the process. The studio was organized into three main stages, each completed over a distinct period. The three-phase design process of the study is illustrated in Figure 2.

Stage 1 Schematic Design and Mass Modeling

In this initial phase, students began by analyzing the site and conducting in-depth research on the studio theme without using AI tools. Grounded in fundamental principles of social housing, they focused on spatial organization, formal coherence, and conceptual clarity. Drawing from the physical context and thematic framework, students generated design ideas, which were translated into abstract mass models to initiate formal exploration.

To support design variation, students used the Rhino–Grasshopper interface, developing custom scripts to produce mass models in different configurations. This digital workflow served as a tool for exploring and manipulating forms aligned with their design intentions (see Figure 3).

These early proposals encouraged structural reasoning and engagement with key architectural concepts such as volumetric composition, solid-void balance, and proportional relationships. Unlike the AI-assisted, image-driven exploration described in the previous section, this phase emphasized spatial awareness, abstract relational thinking, and three-dimensional representation.

Stage 2 AI-Aided Design Research

In this phase, students conducted design research addressing key project dimensions, including materiality, spatial experience, and structural innovation. Prior to this, they were introduced to several AI tools in a dedicated session and asked to select one for their investigations. Among the text-to-image systems presented were Vizcom, Krea, and VisoidAI. Due to temporary Discord restrictions in Turkey, MidJourney was unavailable, and Stable Diffusion was excluded due to its complexity and steep learning curve. Most students chose Krea AI for its user-friendly interface and effective handling of architectural scale.

Students fed their selected AI tool with visual outputs from their original models alongside written prompts. They were encouraged to structure prompts clearly, articulating both what to enhance and how. To guide this process, four key criteria were established:

1. Upload a raw image derived from the student's own model.
2. Craft prompts intentionally to generate context-relevant design ideas.
3. Adjust the "AI Strength" parameter mindfully to control the balance between input fidelity and AI-generated output.
4. Use region highlighting to direct the AI's focus during generation.

Using this structured approach, students engaged in iterative experimentation, generating visual alternatives related to spatial configurations, materials, and structural strategies. Avoiding photorealistic outputs, they opted for sketch-like styles to keep the design process open-ended and exploratory. The resulting visuals informed new design directions, with students integrating AI-generated suggestions into their conceptual thinking, thus expanding their creative potential.

Stage 3 AI-Aided Design Development

In the final stage, students critically evaluated the AI-generated visuals and spatial suggestions to further develop and finalize their designs. Many aimed to incorporate insights related to spatial organization and material expression derived from the AI outputs.

While some continued to experiment with AI tools to refine their ideas, several reported difficulties in managing the design process due to the unpredictable transformations introduced by the tool—ultimately limiting its perceived usefulness at this stage. As a result, most final representations for project submission were produced using real-time rendering software, without direct reliance on AI. During this phase, students developed detailed proposals for materials and structural systems, reflecting on the feasibility and implementation potential of concepts explored during earlier AI-supported stages.

This study investigates the integration of AI into architectural design education, with a particular focus on its influence on students' final design, specifically in terms of structural innovation, material articulation, and spatial organization. All participants followed the structured studio process described earlier, and their final projects were evaluated by a jury of five expert reviewers. Most students fully engaged with the pedagogical framework and produced high-quality results.

A central aim of this research was to explore the relationship between the quality of student design outcomes and the influence of AI-generated inputs. Therefore, among the participants, four students received the highest evaluation scores from the jury and were selected as the "qualified design" sample group for detailed comparative analysis. AI-assisted visualizations served as control variables, while the students' final design proposals constituted the primary outputs for evaluation.

It is important to note that this research does not investigate the potential correlation between unsuccessful outcomes and AI integration—constituting a primary limitation of the study. Nevertheless, the success cases provide valuable insights into how AI support may enhance the development of architectural proposals. The following section presents the study's findings and offers a critical discussion of their implications.

OUTCOMES AND REFLECTIONS

The students' design processes and outcomes were examined through four distinct case studies, as outlined below:

Student A: In the initial stage, the student explored a spatial system derived from the combination of basic volumetric forms. Although abstract, the resulting configuration was coherent and well-articulated. In Stage 2, the AI-generated visuals helped clarify spatial relationships within the abstract masses but did not significantly alter their organization or usage. This limited transformation can be attributed to the student's use of low-light base images and a low AI strength parameter (approximately 20%). Nevertheless, the AI tool's sense of "lightness," conveyed through materiality and mass permeability, was further refined in Stage 3 through subtractive modeling and enhanced material transparency.

Student B: In Stage 1, the student adopted a modular and systematic approach to volumetric exploration. While balconies were considered, they did not emerge as a strong formal expression on the façade. In Stage 2, the AI tool significantly enriched the design by introducing features such as green surfaces, balconies, and layered façade elements. The student experimented with varying levels of AI strength to generate a wide range of spatial possibilities. In Stage 3, several AI-informed proposals were directly modeled; features like green roofs and layered façades were incorporated into the final design. The multiplicity of spatial configurations suggested by the AI found measurable expression in the final outcomes.

Student C: The initial volumetric proposals in Stage 1 were fragmented and lacked clear orientation. In Stage 2, the AI tool synthesized the scattered arrangement into a more cohesive design using vibrant colors and functional spatial elements. Notable outputs included child-centered configurations, integrated playgrounds, and public-use zones. Suggestions for material application on abstract masses were also obtained. In Stage 3, the concept of "community-centered living," emphasized in the AI outputs, was partially integrated into the project. However, the experimental and colorful character of the proposal was significantly toned down. The neutral material palette suggested by the AI was retained for the façades, reflecting a conscious effort to translate the creative potential of AI into a more refined and architecturally controlled language.

Figure 3
Comparative visual documentation of the three-stage design process for four student projects (A–D), illustrating the evolution from initial abstract massing (Stage 1), through AI-supported conceptual development (Stage 2), to final architectural proposals and presentations (Stage 3). The sequence highlights the varying degrees of AI integration and its impact on spatial configuration, formal articulation, and design refinement.

Student D: The massing strategy in Stage 1 reflected a minimal and contextually sensitive approach. In Stage 2, the AI tool introduced complexity to this simplicity by proposing multi-level terraces, varied façade treatments, and colorful material options. The student engaged with these possibilities, particularly by experimenting with spatial diversity and façade articulation. In Stage 3, the student returned to the original contextual strategy, but incorporated balconies and terraces inspired by the AI suggestions. The impact of AI was especially evident in material choices, with the final façade design largely reflecting the forms and strategies proposed by the AI-generated visuals.

Synthesis of Findings

The analysis of these cases reveals that the integration of AI tools into the architectural design process had varying degrees of influence on student outcomes. Most notably, during Stage 2, AI tools enabled students to question their intuitive massing decisions, explore alternative design strategies, and envision new spatial configurations. However, the extent and depth of these contributions were shaped not only by the capabilities of the tools themselves but by how each student interpreted and integrated AI-generated insights into their design thinking.

For instance, some students derived direct formal outcomes from AI suggestions. In Student A's project, massing was simplified, and the structural system reconfigured. In Student B's case, both structural logic and spatial programming were transformed—some spaces expanded, others redefined. Student D's project showed direct AI influence in material selection and façade articulation. Conversely, Student C engaged with AI more conceptually, selectively integrating ideas into the final proposal.

These findings suggest that AI can function not only as a visual production tool but also as a pedagogical catalyst within architectural education. Moreover, the quality of input images, the manipulation of parameters such as AI strength, and students' critical engagement with these variables significantly influenced the depth and relevance of AI-generated design suggestions. This supports the feasibility of an interactive, AI-assisted design process.

In this context, the integration of AI tools into architectural education—when paired with reflective design thinking—holds the potential to transform not only formal outcomes but also the intellectual and conceptual dimensions of the design process. To fully realize this potential, the use of carefully prepared visual inputs has proven especially effective in enhancing human–AI interaction.

CONCLUSION

The findings demonstrate that incorporating AI-based visual generation tools into students' design processes yielded varying degrees of contribution across key dimensions, including structural innovation, material articulation, and spatial organization. Although students' interpretations of visual qualities—such as color, texture, reflection, and atmosphere—can differ significantly, and their decisions may have been influenced by additional factors beyond the scope of this study, a comparison of final outcomes reveals noticeable alignments between certain design decisions and the characteristics of AI-generated visuals. In many cases, students employed AI tools to test and refine conceptual models, using the generated images as references for further design development. While some students directly integrated AI outputs into formal decisions, others utilized the visual diversity produced by AI as a catalyst for conceptual exploration.

Accordingly, the study suggests that AI-assisted design pedagogy holds the potential to support not only formal experimentation but also the development of critical thinking, intuitive decision-making, and reflective design skills. However, realizing this potential hinge on the mindful integration of AI tools, a clear understanding of their technical limitations, and the deliberate construction of a pedagogical framework rooted in critical awareness.

In conclusion, for AI tools to assume a creative, generative, and intellectually enriching role in architectural education, their integration must be structured to complement—rather than replace—traditional design pedagogies. These tools should foster dialogue, support flexible modes of interaction, and function as extensions of established educational models. When approached with this sensibility, AI-supported frameworks can offer not only technological enhancement but also meaningful pedagogical value for the future of architectural education.

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