E-ISSN: 2829-6257
P-ISSN: 2962-5629


# Generative Artificial Intelligence to Enhance Architecture Education to Develop Digital Literacy and Holistic Competency

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**Article Info**

***Article history:***

Received December 9th, 2023
Revised December 18th, 2023
Accepted December 18th, 2023

***Keywords:***

Generative AI
Architecture Education
Holistic Competency
Design Studio
Signature Pedagogy

**ABSTRACT**

This research investigates the impact of Generative Artificial Intelligence (GenAI) on digital literacy development and holistic competencies in Architecture education. The research design focuses on applying GenAI tools such as ChatGPT, Midjourney, BricsCAD BIM, and VR/AR software and their influence on architectural students' overall competencies. This paper uses a mixed research approach combining a case study of Architecture students' progress in a residential revisitation project, using Midjourney, BricsCAD BIM, and VR/AR software, with an online questionnaire survey administered to 350 undergraduate students at two leading universities in Mainland China and Hong Kong in the 2023-2024 school year. This approach aims to deepen understanding of GenAI's influence on conceptual creativity, initiative, self-management, and stress tolerance within a holistic competency framework. The research results indicate that architecture students frequently use GenAI tools during the design concept stage, suggesting their relevance to specific pedagogy in-studio learning and conceptual creativity. Additionally, the findings reveal a potential correlation between frequent GenAI tool usage, improved time management, and reduced anxiety among Architecture students. The results enhance understanding of digital technology in Architecture education while providing valuable insights for future GenAI implementations. The study highlights the potential benefits of incorporating GenAI, emphasizing their role in fostering creativity, effective time management, and stress tolerance among Architecture students.



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## 1. INTRODUCTION

The emergence of new artificial intelligence generations, such as OpenAI's GPT-3, GPT-3.5, and GPT-4, Google's PaLM 1 and 2, LaMDA, Microsoft's Bing and DALL·E, DALL·E 2, and DALL·E 3, has generated unprecedented reform in higher education in teaching and research [1]. The release of ChatGPT by Open AI in November 2022 has swept across the current learning and teaching landscapes and sparked extensive debates and research on how generative artificial intelligence (GenAI) tools should be perceived and used in schools, universities, and other educational institutions [2]. GenAI is defined as a class of artificial intelligence systems designed to generate original content, including but not limited to text, images, audio, and video. These contents are generated through their users' complex, varied, and contextual prompts. They can create new, original, human-like products rather than simply processing or summarising existing data. The extraordinary abilities of ChatGPT and other GenAI tools in performing complex tasks within the field of education have generated mixed feelings among educators. This advancement in GenAI has the potential to revolutionize existing educational practices [3]. In particular, GenAI can serve as a valuable tool for enhancing teaching and learning resources by assisting students with proofreading texts for structural, punctuation, translation, text-to-images, and grammatical errors and providing suggestions to improve the overall quality of students' assignments [4]. Many educators have discovered the advantages of using GenAI for curriculum design, fostering personalized and interactive learning experiences, creating prompts for formative assessment activities, providing feedback, and enhancing professional development [4, 5]. As GenAI becomes increasingly accessible, students and teachers discover diverse and evolving digital teaching and learning opportunities. However, alongside its potential benefits, there are notable potential drawbacks with current ChatGPT technology, such as the possibility of generating incorrect information, biases in data training, and privacy concerns [3, 6]. In response to these challenges, many higher education institutions have quickly adapted new policies to cope with the evolving landscape and address students' use of GenAI [2]. Students exploring the new possibilities of using GenAI tools for content writing assignments, essays, journal articles, or graphic image creation may inadvertently face ethical issues such as copyright, plagiarism, and academic misconduct [7]. The rapidly evolving GenAI technology significantly impacts all higher education disciplines, creating a constant game of catch-up [8].

On the one hand, teachers and students are impressed with the increased access to information, personalization of complex learning, and decreased teaching workload, making key processes and tasks more efficient [9]. On the other hand, some argue that over-reliance on powerful AI tools may hinder students' development of problem-solving skills and critical thinking abilities, particularly when faced with falsified information and academic honesty [10]. Thus, while GenAI advancements promise to transform education, addressing these technologies' potential and other implications on students' development of learning skills is crucial. This article focuses on using GenAI in architecture education and its impact on students' digital literacy and holistic competency development. By utilizing a case study of undergraduate Architecture students in a GenAI studio and an online questionnaire of a sample size of 350 undergraduate students across two universities in Mainland China and Hong Kong between Semesters 1 and 2 in the 2023-2024 academic year, this research compares Architectural students and non-Architectural students use of GenAI on three of the most important skills within the holistic competencies' framework under the latest World Economic Forum's Future of Jobs Report (2023), namely, conceptual creativity and initiative, self-management, and stress tolerance (Figure 1).

## 1.1 GenAI and Architectural Education

Building upon the rapid emergence of GenAI in education, this study investigates the influence of GenAI technologies on Architectural learning in connection with holistic competencies [11, 12]. The phrase "holistic competencies" encompasses a variety of comprehensive skills, including communication, teamwork, problem-solving, creativity, time management, and digital literacy [13]. Before the advent of AI, digital literacy enabled students to acquire skills for applying technology in communication and effectively utilizing online tools both at home and in the workplace [14]. Enhancing digital literacy increases a student's value to prospective employers, elevating their competitiveness in the graduate job market [15]. As AI integration in education progresses, cultivating AI literacy becomes increasingly essential. Educational institutions are examining teachers' and students' perceptions of innovative technologies while exploring adjustments to their practices to achieve an optimal balance between leveraging benefits and addressing challenges.

The diverse application of GenAI tools in various disciplines within higher education, including Computer Science, Medicine, STEM, and Languages, is well-established [8, 16-19]. Specific disciplines, such as language education research [20], advocate for increased integration of GenAI tools like ChatGPT to enhance digital language learning (DLL) [21, 22]. In the medical field, ChatGPT is utilized for conversational interactions and for providing authoritative-sounding responses to complex medical inquiries [23]. ChatGPT's performance varies across different subject domains, with results ranging from exceptional (e.g., economics) and satisfactory (e.g., programming) to unsatisfactory (e.g., mathematics).


**Figure 1.** The top 10 most important skills in 2025 according to the World Economic Forum's Future of Jobs Report [24]

In Architecture, artificial intelligence has become increasingly prevalent to enhance the design process, develop innovative forms and structures, and improve the energy efficiency of buildings. Digital technologies have been applied in all stages of Architecture. During the design stage, the initial conceptualization task can be addressed by employing neural networks, which offer potential solutions to this challenge. Computer-aided design (CAD), Building Information Management (BIM), and other parametric plug-ins such as Grasshopper 3D, Mantis, and Hummingbird can expand digital software to conduct structural analysis, climate analysis, form-finding algorithms, innovative, collaborative platforms, AI-assisted imagery, data collector and organizer, narrative generator, and many other functions. Recent advances in GenAI have enabled the simultaneous consideration of multiple data types, including text, image, audio, perspective, thermal data, and motion data through sensor devices [25]. AI tools are now integrated into Architecture education in higher education, enhancing teaching and learning capabilities by generating new content based on input data. Various GenAI applications have emerged for pedagogical use, including text generation (e.g., GPT-3, BERT, OpenAI's Codex), image generation (e.g., DALL-E, StyleGAN, Adobe Sensei), sound and music generation (e.g., AIVA, Ecrett Music, ORB Composer, Jukedeck), and multimedia generative artificial intelligence (e.g., RunwayML, Magenta). Given the powerful impacts of GenAI in the study of Architecture, it is crucial to explore its potential implication on students' application, specifically regarding the potential benefits and drawbacks of GenAI in addressing essential aspects of students' development, academic performance, and well-being. This research examines how GenAI impacts Architectural students by comparing different undergraduate cohorts and investigating their frequency of use and their perception of various aspects of holistic competency, such as conceptual creativity and initiative, self-management, and stress tolerance. This research questions:

1. What is the impact of GenAI on students' learning about the development of essential components within the holistic competencies' framework, namely, conceptual creativity and initiative, self-management, and stress tolerance?
2. How do student perspective findings inform educators and program leaders on effective strategies for integrating GenAI into architectural education in fostering students' overall success?

## 2. LITERATURE REVIEW

The impact of digital technology on higher education across various disciplines has been a topic of interest for decades [14]. However, the significance of developing holistic competencies must be considered in today's rapidly evolving learning landscape. Holistic competencies encompass an individual's capacity to integrate diverse skills, knowledge, values, and attitudes across multiple domains, fostering a well-rounded and adaptable approach to life and work in the age of AI. This concept goes beyond acquiring technical or disciplinary expertise, emphasizing the cultivation of critical thinking, creativity, emotional intelligence, and interpersonal skills essential for a successful and fulfilling life. As society becomes increasingly complex, students are expected to acquire many skills and abilities in highly specialized fields such as Architecture, Medicine, and Engineering [13]. Holistic competency is critical for personal well-being and fulfillment and instrumental in fostering resilience and adaptability during challenging times. Research has shown that individuals with diverse skills, interests, and passions are better equipped to handle adversity [26-28]. By promoting emotional intelligence, self-awareness, and interpersonal skills, people can build stronger relationships, cope with stress, and develop a profound sense of purpose and meaning.

Holistic competencies are essential in the education system, so it is necessary to facilitate the development of these skills and qualities early on. The development involves moving away from traditional discipline-based curricula and adopting an interdisciplinary, experiential, and project-based learning approach that allows students to explore connections between different fields and apply their knowledge in real-world contexts. Alongside complex problem-solving skills, holistic competency encompasses the overall well-being of learners by emphasizing stress management through time management, social and emotional learning, empathy cultivation, self-regulation, and effective communication skills [29, 30]. Achieving holistic competition includes the following pedagogical strategies:

1. Integrating reflection and mindfulness practices.
2. Promoting collaborative group work.
3. Offering opportunities for students to engage with diverse perspectives and disciplines

Specifically, disciplines like Architecture and Design education are witnessing considerable advancements through the integration of AI technologies, which further underscores the necessity for holistic competencies to adapt and flourish in a constantly evolving environment. Consequently, this paper acknowledges that rapid technological advancements have transformed the nature of work and created new opportunities for innovation and collaboration. The study investigates and reviews the utilization of AI image generators in the Architectural education context in an undergraduate cohort in a semester-long Design studio. With the specific use of software such as Midjourney, BricsCAD BIM, and VR/AR software, the students who have completed housing revisitation projects have showcased some of their progress. Through a case study, student feedback, and a questionnaire survey, this research fosters a deeper understanding of how using GenAI influences 1) conceptual creativity and initiative, 2) self-management, and 3) stress tolerance under the holistic competency framework.

### 2.1 Case study on the use of GenAI in Architecture Design Studio

Generative systems have been integrated into the Architecture, Engineering, and Construction industry to support design practices since the 1970s [31, 32]. With the advent of the Industrial Revolution 4.0 in the early 21st century, Architecture experienced significant transformation due to the widespread incorporation of big data, cloud computing, robotics, cybernetics, 3D printing, and other design optimization and collaboration technologies. AI applications in architectural design have become indispensable for architects and designers, extending beyond the conceptualization stage. The building and construction industries rely on AI throughout all development phases, including detailed construction, generating virtual models with text prompts, and employing specialized CAD and BIM tools. AI software facilitates implemented solutions' analysis, prediction, modeling, calculation, and evaluation. These digital tools enable architects to develop projects while offering the ability to edit, delete, and make corrections as needed. Neural networks also facilitate the analysis of various parameters and factors, including climatic conditions, site geometry, project estimates, and customer requirements.

Consequently, AI architects can make informed decisions and design effective, functional buildings [31]. By comprehending the knowledge required in the architectural industry, this paper presents a case study involving a cohort of undergraduate architectural students who have developed a series of housing strategies for a hypothetical project in Semester 2 of 2023. This study highlights the five major stages of AI implementation in this Architecture studio and its impact on enhancing students' digital literacy and holistic competencies.

## Stage 1 – AI Image Generator at Design Inception

At the start of the semester, the teacher's project brief emphasized the importance of using GenAI-driven generative design tools, which have become crucial assets in the Architecture industry. Architectural students were encouraged to incorporate these tools for harnessing algorithms to generate numerous design alternatives based on predefined parameters and constraints. This exploration of diverse design options aimed to enhance students' critical thinking, decision-making, and problem-solving skills, ultimately fostering creativity and innovation.

During the initial stage of the studio, students were guided to employ text-to-image-based GenAI tools, such as Midjourney, to create original content and quickly brainstorm ideas. This integration of Midjourney allowed students to develop a series of photographic essays and contact collages, deepening their understanding of the context and background of housing needs and typologies. This approach not only streamlined the design inception process but also contributed to advancing students' digital literacy and holistic competencies. Figure 2 illustrates a series of students' photographic essays and contact collages due to the site investigation. A public review was held where teachers and practicing architects were invited as critics. Both teachers and critics have positive feedback on the learning's enhanced creativity, originality, and initiative.

## Stage 2 - AI-Assisted Internet of Things (IoT)

Subsequently, students utilized GenAI algorithms to support the structural integrity, energy efficiency, and material usage assessment. During this stage, students were introduced to essential concepts like the Internet of Things (IoT), a critical component in designing smart buildings [23, 24]. IoT facilitates enhanced control over energy usage and system performance, contributing to students' comprehensive knowledge of sustainable design practices. Moreover, IoT can enable predictive calculations for heating, ventilation, and air conditioning (HVAC) systems, further improving energy efficiency. This exposure to IoT and AI-assisted design evaluation enriched students' learning experiences and expanded their digital literacy and holistic competencies.

## Stage 3 - Building Information Modeling (BIM)

Incorporating GenAI into BIM systems has given rise to intelligent BIM tools capable of automating routine tasks, such as code compliance checks. Students leveraged BIM as a sophisticated form of 3D modelling to create digital representations of their buildings' physical and functional characteristics. They found BIM highly advantageous, as it streamlines repetitive tasks and manages the entire design process from conceptualization to construction within an integrated platform. This feature empowers students to make well-informed decisions swiftly and effectively. In particular, BricsCAD was used in this studio to automate constructing elements such as compositions and materials, profiles, storey heights, and window and stair parameters.

Students used the BricsCAD smart algorithm to create the exterior walls, floor slabs, roofs, and interior walls based on the room volume planes (Figure 3). Feedback from this learning stage highlighted that GenAI-enhanced BIM systems, such as BricsCAD, significantly reduce manual labor and improve time management through automation functions. In addition to gaining a deeper understanding of the construction process and the complexities involved in building design and management [25], using GenAI-enhanced BIM enables students to develop their digital literacy further and manage their time more effectively. Consequently, this alleviates the workload previously done manually, allowing students to focus on other aspects of their projects and foster creativity and innovation in their designs.

## Stage 4 - Virtual and Augmented Reality (VR/AR)

In this stage of studio learning, GenAI-powered virtual and augmented reality (VR/AR) technologies were introduced for building immersive and interactive experiences. Students were able to create and manipulate 3D models to simulate real-world environments. An interactive workshop was held on campus after completing the assignment (Figure 4), where peer learning was conducted, with each group showcasing their VR/AR output.

From the students' perspective, these VR/AR technologies have significantly influenced their learning process. They have reported that the ability to visualize and interact with their designs in a simulated environment has dramatically enhanced their grasp of complex architectural concepts. Furthermore, students have discovered that the real-time feedback provided by GenAI-driven systems allows them to adjust their designs immediately, ultimately leading to more refined and well-thought-out projects. This experience provided a deeper understanding of spatial relationships, materiality, and construction techniques, which traditional non-digital studios might not be able to offer. Moreover, students agreed that using GenAI-driven VR/AR systems helped them save time and ideate faster, and the presentation delivered personalized feedback, enriching the overall learning experience. [26].

Therefore, the immersive nature of VR/AR technologies has fostered a heightened sense of engagement and collaboration among students and contributed to improved time management and stress tolerance. By streamlining the design process and offering instant feedback, students can allocate their time more efficiently, focus on other aspects of their projects, and better cope with the demands of architectural education. This immersive learning experience motivates students to discuss and critique each other's work, promoting a more dynamic and enriching educational environment.

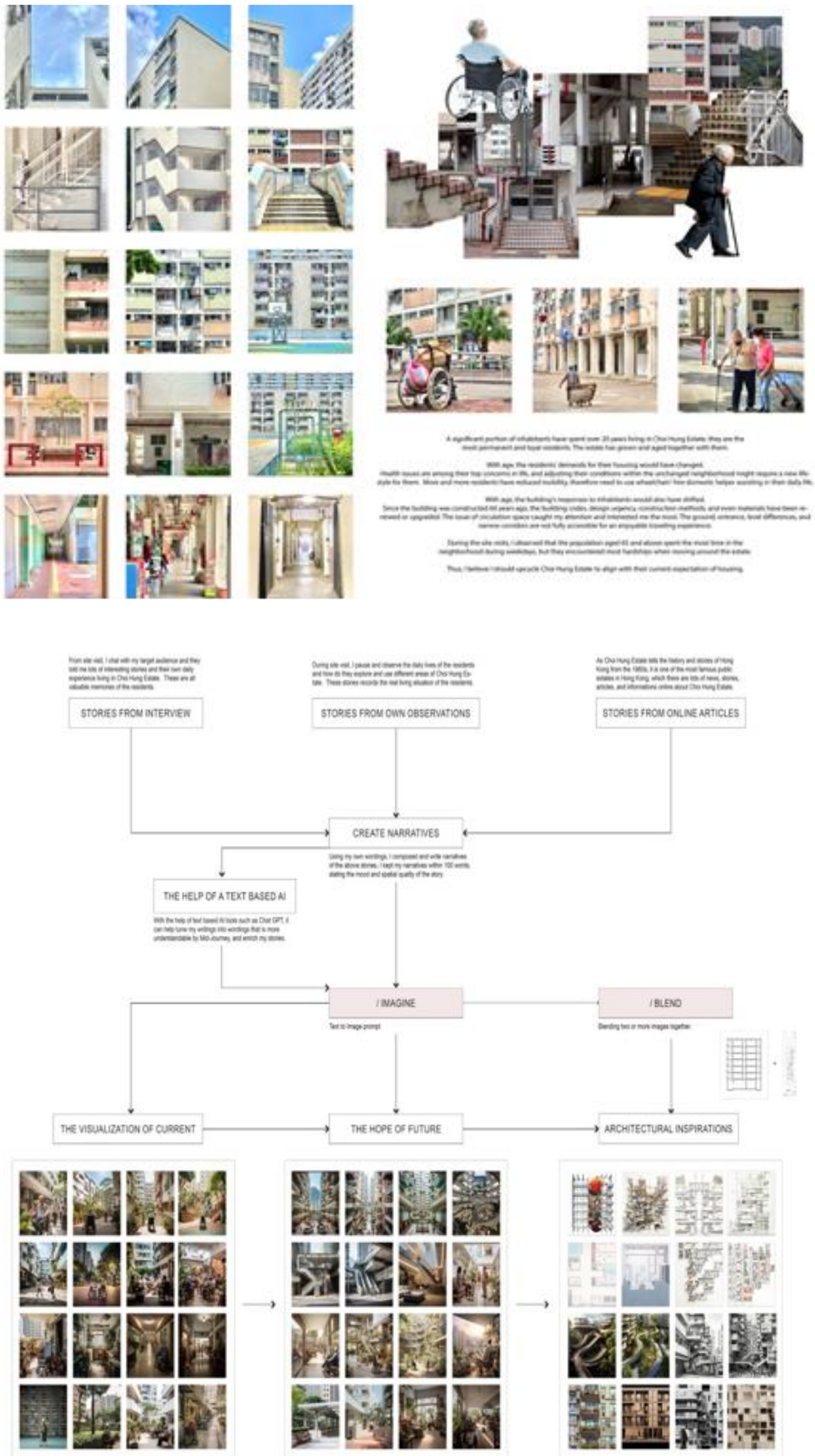
## Stage 5 - GenAI-driven 3D printing technologies

At the end of the semester, students were required to develop physical models based on synthesizing their learning throughout the design studio. GenAI-driven 3D printing has the potential to revolutionize the learning experience at this stage by enabling students to synthesize complex architectural concepts with greater ease and efficiency. By incorporating AI algorithms and 3D printing technologies, students could explore various design possibilities, test their ideas quickly, and iterate on their designs in real-time. This innovative approach to learning enhances students' understanding of form and spatial relationships and encourages experimentation and innovation, fostering a deeper comprehension of the architectural design process.

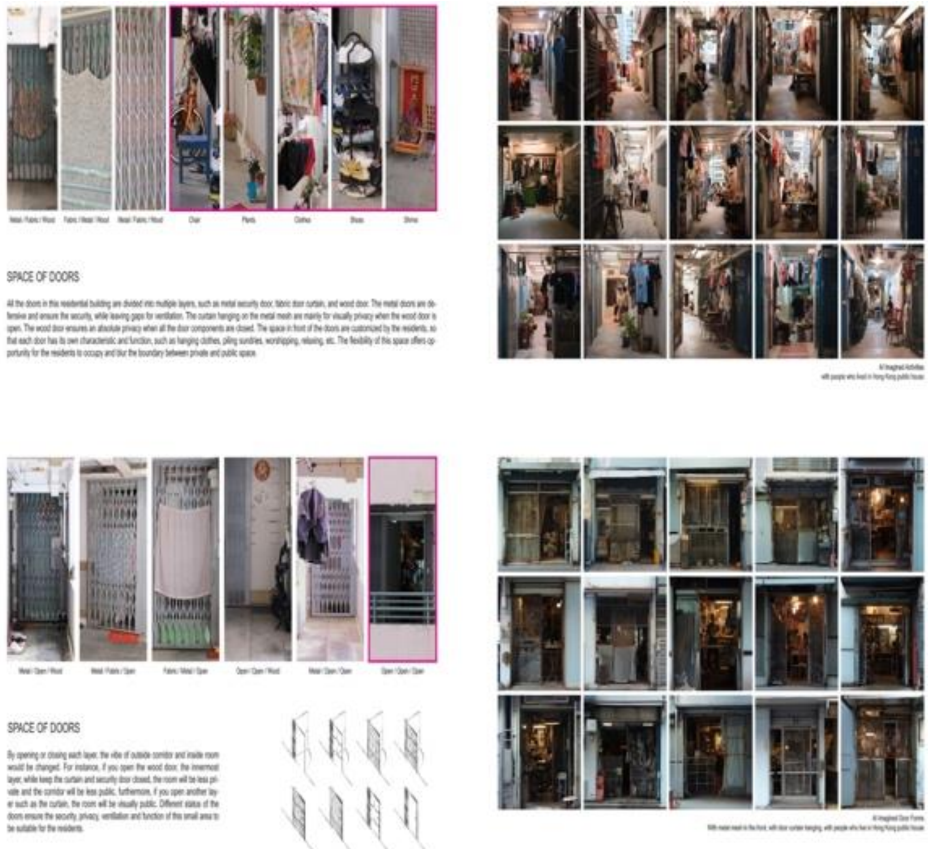
Crucially, this approach also improves student time management and stress tolerance. The ability to rapidly prototype and refine their designs using GenAI-driven 3D printing technologies allows students to manage their time and workload better, ultimately reducing stress levels. By facilitating a smoother and more efficient design process, students can focus on refining their ideas and pushing the boundaries of their creativity rather than being bogged down by time-consuming manual model-making tasks.

While recognizing the importance of fostering holistic competencies as students transition from higher education to the workforce, it is essential to examine how adopting AI technologies within the industry affects learning experiences from the student's perspective. By exploring students' viewpoints, educational institutions can better tailor AI-integrated learning experiences, ensuring they align with students' needs and expectations while preparing them for the challenges and opportunities of an AI-driven industry landscape and best fit into the latest digital development of architectural education [27].

(a) Teachers and practicing architects were invited as critics in public review




(b) Students' photographic essays and contact collages




(c) Students' photographic essays and contact collages

**Figure 2.** Architectural students used Midjourney to generate a series of photographic essays and contact collages of different housing typologies to show creativity, originality, and initiative.
(a) Teachers and practicing architects were invited as critics in public review, (b, c) Students' photographic essays and contact collages. Source: Author's Documentation

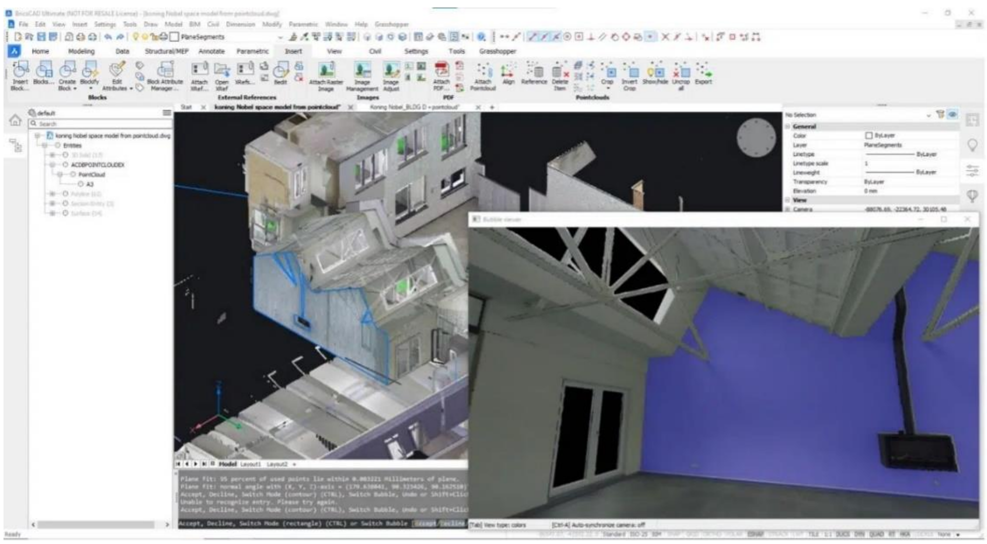


**Figure 3.** The use of BricsCAD BIM specializes in the quick composition of form, materials, profiles, and various architectural parameters with automation, saving a great deal of time and manual work
Source: BricsCAD BIM


**Figure 4.** Architectural students conducted workshops using VR/AR to create simulated scenarios to enhance student engagement and peer collaboration.
Source: Author's Documentation

## 2.2 Signature Pedagogy of Architecture

The uniqueness of Architecture in higher education has been characterized by its studio-based learning approach [33]. This signature pedagogy emphasizes learning by doing, problem-solving, and collaboration, fostering creativity, critical thinking, and hands-on experience within a studio-learning environment. Architectural students continuously engage with real-world design problems, iterating and refining their ideas. As Architecture education adapts to complex and multimodal learning environments, it is crucial to understand how students perceive and adjust to these changes and how they respond to technological advancements. In this context, developing AI literacy is essential for equipping students with the skills and competencies to navigate an increasingly digital world. However, observing how digital technology learning has resulted in lower learning efficiency and increased academic anxiety, learning atmosphere, and interruptions is critical [34].

There are multiple pedagogical aspects related to GenAI integration in Architectural education. On the one hand, digital technology offers convenience to all design stages and has made architects more aware of complex environmental, social, and economic challenges related to sustainable development [33]. On the other hand, there are many hidden challenges, such as ethical awareness and different forms of copyright and plagiarism [35], [36]. Therefore, it is crucial to address the consequences of AI-generated content on students' perceptions of its utilization. The previous case study is supported by quantitative research utilizing a cross-sectional questionnaire design to make within-and between-group comparisons of students' perceptions of GenAI in three essential components highlighted in the holistic competency framework, mainly focusing on conceptual creativity and initiative, self-management, and stress tolerance.

Architectural students' conceptual creativity and initiative were demonstrated in the case study using Midjourney. Students' self-management and stress tolerance can be characterized by cognitive, physiological, and behavioral responses to educational environments [15]. It can be influenced by factors such as low academic engagement, self-efficacy, and time management disposition [16, 31]. Time management, as an aspect of self-management, has been shown to affect both mental well-being and academic performance. [32]. In this context, GenAI technologies have the potential to alleviate academic anxiety and improve time management by offering personalized learning experiences, immediate feedback, and adaptive learning paths. Given that GenAI-driven personalized learning experiences can cater to unique learning needs, pedagogies, and preferences in Architectural education, it is hypothesized that GenAI-driven learning can enhance stress tolerance by reducing learning anxiety associated with competing with peers or meeting strict deadlines [33].

GenAI technologies offer the potential to mitigate academic anxiety and enhance time management by providing personalized learning experiences, immediate feedback, and adaptive learning paths. By addressing students' specific needs and preferences, GenAI can empower learners to take control of their education and better manage their time, ultimately reducing anxiety and improving academic performance. As GenAI continues to evolve and become more integrated into educational environments, examining its potential impacts on students' mental health and overall well-being is essential.

## 3. RESEARCH METHODOLOGY

### 3.1 Research Design

The research team distributed an online questionnaire to students from two comprehensive universities in Mainland China and Hong Kong during the 2023-2024 academic year, using a simple random sampling approach. The study is approved by the Human Research Ethics Committee (HREC) of the University of Hong Kong (number EA230422). This study aimed to explore the potential benefits and challenges of GenAI integration in higher education, focusing on the frequency of use, the purpose of the use of GenAI tools such as Midjourney, DELL E and their impact on students' self-management, stress tolerance, and holistic competencies. The questionnaire survey was designed to gather data on students' experiences with and perceptions of GenAI-driven educational tools and technologies.

The survey included questions related to:

1. Students' familiarity and experience with GenAI in their learning process.
2. The perceived impact of GenAI on creativity, time management, academic anxiety, and overall learning experience.
3. The potential benefits and challenges of incorporating GenAI in higher education.

   The questionnaire comprised eight closed questions covering three areas:

   a) Personal information: This section gathered background context, such as the participants' school and major.
   b) Usage of GenAI: This part focused on how students use GenAI, in what situations, the extent of assistance it provides, and the types of tasks it is employed for.
   c) Attitudes towards GenAI: This section aimed to understand students' thoughts on GenAI's usefulness for creativity, time management and its potential to reduce anxiety.

The quality and validity of the questionnaire need to be ensured by pilot testing to collect initial feedback and comments. The research team reviewed the questionnaire to ensure proper flow of questions. Data collected from the questionnaire survey were analyzed using descriptive statistics and inferential statistical tests, i.e., the Chi-Square test, to examine potential differences between majors, regions, and universities. Moreover, qualitative data from open-ended questions will be analyzed using thematic analysis to identify common themes and patterns in students' perceptions of GenAI.

The findings of this study could contribute to a better understanding of the potential benefits and challenges of integrating GenAI in higher education and provide insights into how GenAI can be effectively incorporated into teaching and learning practices to improve students' time management, stress tolerance, creativity and foster holistic competencies across various disciplines.

### 3.2 Results

Three hundred fifty questionnaire surveys were distributed, with control options incorporated to ensure that only correctly completed submissions were considered valid. Following data collection, sensitive and confidential information was removed, and data cleaning and pre-processing were conducted before data analysis. Of the 350 distributed questionnaires, 340 were collected as valid responses, while ten duplicates were excluded, resulting in an effective response rate of 97.1%. The validity of the research needs to be ensured by adopting a simple random sampling method that focuses on students' perceptions regarding the use of generative AI. Four groups of students were selected according to the following criteria :

1. Majors: Students from diverse majors were invited to participate in the survey to explore potential differences between disciplines. Participants were invited from various Faculties, including Architecture, Science, Law, etc.
2. Regions and universities: To obtain diverse perspectives and investigate potential regional variability in students' perspectives on using GenAI, participants were selected from a comprehensive university in Hong Kong and a comprehensive university in Mainland China that offers a wide range of academic programs and degrees across various disciplines. Divisions of participants can be found in Table 1.

**Table 1.** Divisions of participants and explanation

| Value | Group | Explanation | N |
|---|---|---|---|
| Discipline | A | Architecture students among the participants. | 153 |
| | N | Non-architecture students among the participants. | 187 |
| Area | 1 | Students from a comprehensive university in Hong Kong. | 210 |
| | 2 | Students from a comprehensive university in Mainland China | 130 |
| Discipline-Area | A-1 | Architecture students from a comprehensive university in Hong Kong. | 111 |
| | A-2 | Architecture students from a comprehensive university in Mainland China. | 42 |
| | N-1 | Non-architecture students from a comprehensive university in Hong Kong. | 99 |
| | N-2 | Non-architecture students from a comprehensive university in Mainland China. | 88 |

### 3.3 Survey Results

The alpha coefficient of the total questionnaire was 0.820, indicating excellent reliability for the entire model. An exploratory factor analysis was conducted on all completed surveys (n=340) using principal component analysis and a varimax rotation method to examine the validity of the eight survey items. The Kaiser-Meyer-Olkin (KMO) test value was 0.811, demonstrating an adequate proportion of variance in the survey that could reveal underlying factors. Additionally, Bartlett's Test of Sphericity was significant at the 0.001 alpha level. The analysis confirmed a three-factor solution (Table 2), which accounted for 75.041% of the variance.

**Table 2. Principal component analysis**

| | 1 | 2 | 3 |
|---|---|---|---|
| What is the proportion of your usage of GenAI, like DALL·E, MidJourney, etc., in your assignments? | 0.849 | | |
| What is your frequency of using GenAI like DALL·E, MidJourney, etc.? | 0.809 | | |
| How much do you typically rely on GenAI to complete the work? | 0.737 | | |
| What types of tasks have you used GenAI, like DALL·E, MidJourney, etc., to assist with? | 0.706 | | |
| Has GenAI minimized your anxiety as a result of advanced technology? | | 0.892 | |
| Has GenAI minimized your assignment time to better time manage your courses? | | 0.842 | |
| Are you a student of Architecture / Design major? | | | 0.984 |

### 3.4 Data Analysis

The data analysis procedure consisted of two steps to ensure a precise and thorough examination of the collected information. First, missing data were addressed using the Expectation Maximization algorithm implemented in SPSS 26. This method facilitated the estimation of missing values, ensuring the dataset's completeness for further analysis. Second, Chi-Square tests were employed to investigate potential differences in GenAI usage and attitudes toward GenAI among students from various majors and regions. This statistical test identified significant associations between the categorical variables, offering insights into the diverse student population's varying experiences and perceptions of GenAI. Following these two steps, the data analysis procedure aimed to provide a comprehensive understanding of GenAI's impact on students' academic anxiety and time management and any differences across different disciplines and regions.

## 4. FINDINGS

Various student groups shared similar views on their habits and attitudes towards AI usage. While there was a broad consensus, some notable differences in certain responses were observed based on the Chi-Square test. Details of these response frequencies can be found in Table 3, along with group comparisons.

**Table 3.** The mean and standard deviation for student responses to the use of GenAI across four divisions of disciplines and regions.

| | A | N | 1 | 2 |
|---|---|---|---|---|
| Using Frequency | 2.67(1.428) | 3.12(1.484) | 2.72 (1.467) | 3.22 (1.437) |
| Using Proportion | 1.89 (.957) | 1.94(.987) | 1.77 (.861) | 2.15 (1.093) |
| Using Extent | 1.90 (.825) | 1.92(.775) | 1.83 (.731) | 2.05(0.879) |
| Task types | 2.71 (.922) | 2.67(.840) | 2.55 (.813) | 2.92 (0.929) |
| Time-management | 3.48 (.954) | 3.70(.993) | 3.51 (.970) | 3.75(0.981) |
| Anxiety reduction | 3.19 (1.087) | 3.44(.984) | 3.29 (1.029) | 3.39 (1.053) |

### 4.1 Frequency of Use of GenAI

The study's findings indicate that more than 27% of the respondents, representing the most significant proportion, reported "rarely use" as their level of GenAI tool utilization (Figure 5). Furthermore, a statistically significant difference in AI usage frequency was observed between students majoring in Architecture/Design and those in non-design majors ($p < .05$). Specifically, among Architecture/Design students, the combined percentage of individuals who reported using GenAI tools "almost daily" and "2-3 times a week" exceeded 30%. In contrast, non-Design students selecting these two options constituted nearly 50% of the respondents.

A Chi-Square test compared students' answers in Hong Kong and Mainland China to examine the relationship between responses and students' educational backgrounds. The analysis revealed a statistically significant difference in the responses ($p = .006 < .05$), indicating that students with different educational backgrounds exhibited varying behaviours in their GenAI usage. Interestingly, when considering both the region and major as factors, no significant difference in AI usage frequency was found between design students from Hong Kong and Mainland China ($p > .05$). However, a significant difference was observed among non-design students based on their region ($p = .003 < .05$), as illustrated in Figure 5.

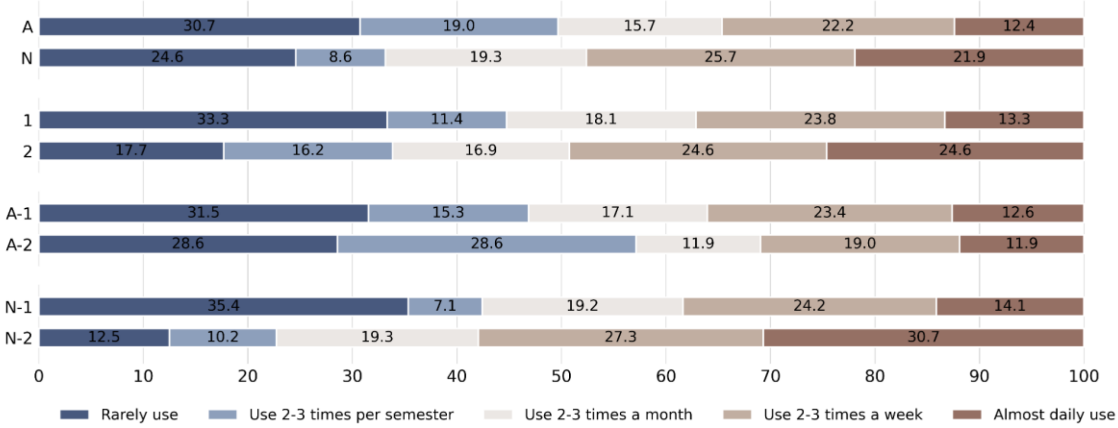



**Figure 5.** Students' response on the GenAI frequency of use

## 4.2 Proportion of GenAI Use

As depicted in Figure 6, the distribution of GenAI usage across different student groups regarding assignment proportion is noteworthy. More specifically, over 80% of students reported utilising GenAI in less than 30% of their assignments, while approximately 10% indicated a usage rate exceeding 90% of their assignments. When comparing the A (Architecture) and N (Non-Architecture) groups, no significant differences were found regarding the proportion of assignments in which GenAI was used. However, a significant difference emerged when examining the usage patterns between students in Hong Kong and those in Mainland China ($p = 0.014$). Notably, students in Hong Kong exhibited a lower percentage of GenAI usage in their assignments compared to their counterparts in Mainland China. Furthermore, for non-Architecture students (group N), the Chi-Square test revealed a significant difference ($p = 0.012$). Specifically, the percentage of non-Architecture students utilizing GenAI to assist in completing their assignments was considerably lower for Hong Kong students than those in Mainland China.

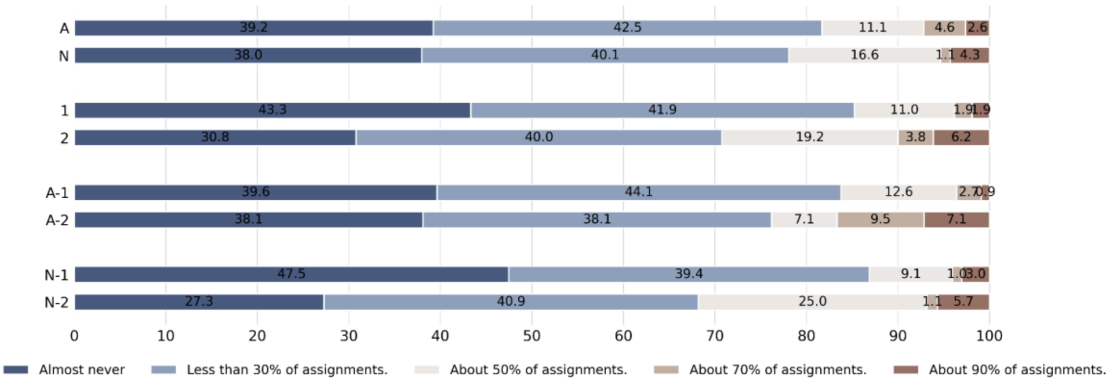



**Figure 6.** Response frequencies for GenAI using proportion

## 4.3 Creativity With the Use of GenAI to Generate Conceptual Ideas

In terms of the extent to which students rely on GenAI to generate conceptual ideas, the majority (over 80%) of students considered themselves "Completely independent/independent." (Figure 7). Conversely, less than 1% of students reported relying almost exclusively on AI for assignments at the conceptual stage. When comparing the groups, A (Architecture) and N (Non-Architecture), no significant differences were found in the extent of GenAI usage. However, significant differences were observed when examining the responses of groups 1 and 2. Notably, for students in Hong Kong, only around 10% of them believed they relied more on GenAI for generating ideas, whereas this figure was 25.3% for students in

Mainland China. Additionally, for non-Architecture students, the extent of AI usage exhibited a significant difference between the two regions (r = 11.666, p = .007 < .05). Specifically, over 90% of non-Architecture students in Hong Kong considered themselves "Completely independent/independent" in completing their assignments. At the same time, this percentage was 73.9% for non-Architecture students in Mainland China.

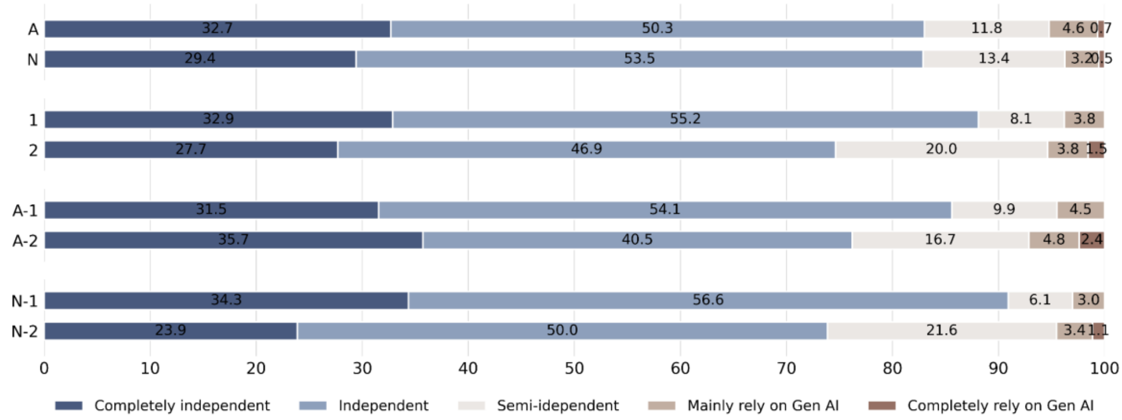



**Figure 7.** Response frequencies on GenAI and the generation of conceptual ideas in assignments

## 4.4 GenAI Time Management Tool

Various student groups' perceptions of utilizing GenAI for time management exhibited similarities (Figure 8). Approximately 30-40% of the students agreed that using GenAI could assist with time management. Notably, no significant differences were found between Group A (Architecture) and Group N (Non-Architecture) regarding these perceptions. However, a significant difference was observed between Group 1 and Group 2 (r = 10.871, p = 0.028). Specifically, students in Mainland China were more inclined to acknowledge the helpfulness of GenAI for time management, whereas students in Hong Kong demonstrated a more cautious stance towards it.

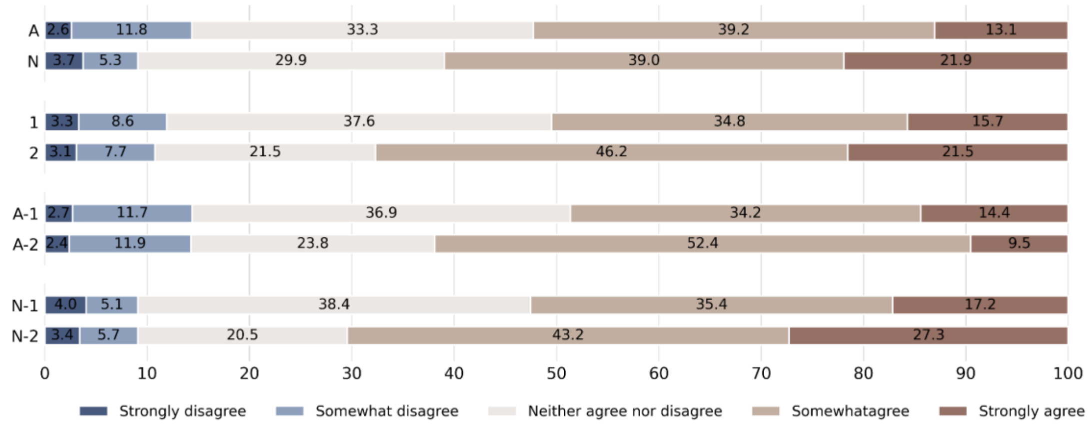



**Figure 8.** Response frequencies on GenAI time-management assistance

## 4.5 Stress Tolerance and Anxiety Reduction

For the question regarding stress tolerance and anxiety reduction, Figure 9 displays students' perceptions of how GenAI assists in reducing anxiety. It can be observed that over 35% of students expressed a relatively neutral stance, indicating "neither agree nor disagree." Approximately 40% of students held a relatively positive view, suggesting that they somewhat or strongly agreed that GenAI helped alleviate anxiety. Notably, architectural students appeared to be more negative in their attitudes towards anxiety reduction compared to non-architectural students, as evidenced by a higher frequency of responses indicating "completely disagree" or "slightly disagree."

However, the Chi-Square test results indicate that regardless of the discipline or region, students' views on anxiety reduction with GenAI are similar, and no significant differences were found.

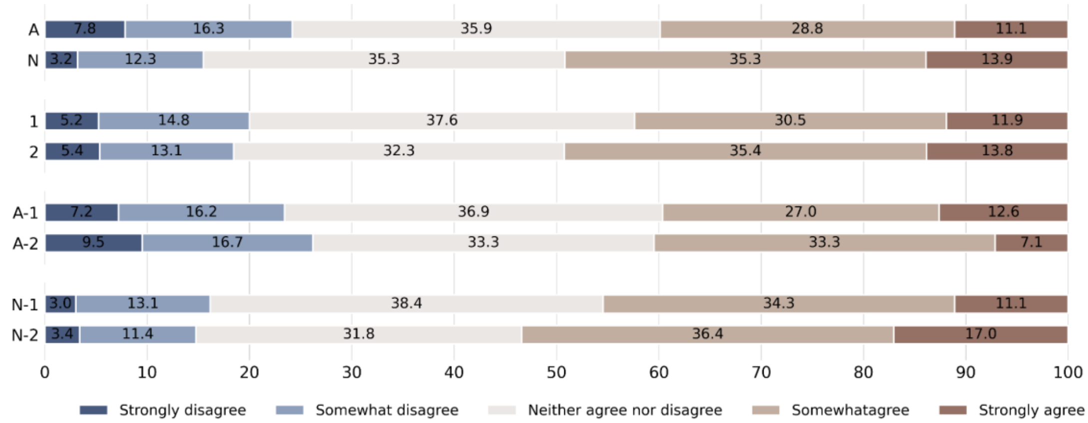



**Figure 9.** Response frequencies on GenAI anxiety reduction

## 5. CONCLUSION

The research, composed of a case study and a quantitative study, provides academic insights into utilizing GenAI tools among Architecture students and their implications on digital learning. The findings reveal that a noteworthy proportion of Architecture students frequently use various new GenAI tools at different stages of the assignments and various studio learning stages to gain digital literacy. This observation suggests that GenAI tools may possess enhanced relevance and benefits for students pursuing disciplines within Architecture and other Design-related majors, owing to the prevalent use of GenAI tools within the professional industry.

Moreover, the study identifies the relationship between GenAI tool usage and students' time management and stress tolerance perceptions. It is posited that frequent utilization of GenAI tools may contribute to improved time management and reduced anxiety levels, particularly within Architecture-related majors where meeting project deadlines within studio learning represents a characteristic pedagogical approach. This association may be attributed to GenAI tools' potential to automate tasks, streamline workflows, and stimulate creativity, yielding time savings and diminished stress levels. By employing a case study that scrutinized each stage of the design studio process, we gain a more comprehensive understanding of students' experiences and perspectives when engaging with GenAI tools, ascertaining the direct impact of specific tool usage on creativity, originality, and initiative.

This study establishes a foundational understanding of GenAI tool usage within Architecture education and its potential implications for the holistic competency framework. However, further research is necessary to delve into these findings with greater granularity and to develop more effective strategies for integrating GenAI tools into Architecture education. While scholars acknowledge that GenAI tools generate complex and mixed sentiments among educators, signifying the potential for revolutionary transformations in educational practices, more research should be done to understand the strengths, weaknesses, opportunities, and threats associated with the new digital applications of GenAI. This research offers students' perspectives on GenAI usage within Architecture education. It can provide valuable guidance for educators and program leaders striving to effectively embed GenAI tools within the curriculum, fostering students' overall academic success. By strategically integrating GenAI tools into pertinent courses and design studios, educators can empower students to automate tasks, streamline workflows, and cultivate creative inspiration. Moreover, the findings suggest that incorporating GenAI tools can enhance time management and reduce stress levels among Architecture students. Consequently, educators and program leaders should prioritize training and support initiatives to equip students with the requisite skills and knowledge to leverage GenAI tools proficiently. By fostering a supportive and inclusive learning environment, educators can enable students to harness the potential of GenAI tools as invaluable resources, thereby elevating their design processes, problem-solving abilities, and overall academic performance within Architecture education.

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