

**THE POTENTIAL IMPACT OF GENERATIVE ARTIFICIAL
INTELLIGENCE ON THE FUTURE OF ARCHITECTURAL
DESIGN EDUCATION**

BY

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Dedicated to

To my beloved family, friends, mentors, and all knowledge seekers who inspire
innovation, exploration, and lifelong learning.

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LIST OF ABBREVIATIONS

AAI	:	Artificial Architectural Intelligence
ABS	:	Australian Bureau of Statistics
AEC	:	Architecture, Engineering, and Construction
AGI	:	Artificial General Intelligence
AI	:	Artificial Intelligence
ANI	:	Artificial Narrow Intelligence
ANN	:	Artificial Neural Network
AR	:	Augmented Reality
ASI	:	Artificial Super Intelligence
BIM	:	Building Information Modeling
DL	:	Deep Learning
GenAI	:	Generative Artificial Intelligence
GPT	:	Generative Pre-trained Transformer
HVAC	:	Heating, ventilation, and air conditioning
IoT	:	Internet of Things
LLM	:	Large Language Model
LSTM	:	Long Short-Term Memory
ML	:	Machine Learning
NLP	:	Natural Language Processing
RII	:	Relative Importance Index
RNN	:	Recurrent Neural Network
SWOT	:	Strengths, Weaknesses, Opportunities, and Threats
VR	:	Virtual Reality

ABSTRACT

Full Name : RAWAN EMADULDEN ALAMASI

Thesis Title : THE POTENTIAL IMPACT OF GENERATIVE ARTIFICIAL INTELLIGENCE ON THE FUTURE OF ARCHITECTURAL DESIGN EDUCATION

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Recent advancements in Artificial Intelligence (AI) have influenced various sectors, including education. In architectural design education, integrating Generative AI (GenAI) tools presents promising opportunities and critical challenges, particularly within design studios. This study investigates the role of GenAI in the architectural design process and its influence on students' design skills and outcomes. A mixed-method approach is employed, combining a comprehensive literature review, interviews with expert architecture educators interested in AI from universities across the world, a questionnaire with professional architects, and a field experiment involving architecture students. Findings reveal a growing acceptance of GenAI in architectural education, with the highest perceived effectiveness in the conceptual and pre-design phases. Major opportunities highlighted are improved productivity, time savings, and fostering students' creativity and inspiration. In contrast, the most frequently cited challenges are the lack of technical knowledge and training, the absence of university policies and guidelines, and ethical issues. This suggests that GenAI should complement, not replace, manual and critical thinking skills. Accordingly, the study recommends targeted training programs and clear institutional policies to ensure responsible integration. A strategic framework is also proposed to guide the balanced adoption of GenAI in architectural education, helping future architects embrace technology while preserving core design values.

ملخص الرسالة

الاسم الكامل: روان عماد الدين العمصي

عنوان الرسالة: التأثير المحتمل للذكاء الاصطناعي التوليدي على مستقبل تعليم التصميم المعماري

التخصص: العمارة

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شهدت التطورات الأخيرة في مجال الذكاء الاصطناعي تأثيراً واسعاً في مختلف القطاعات، بما في ذلك قطاع التعليم. في تعليم التصميم المعماري، يقدم دمج أدوات الذكاء الاصطناعي التوليدي (GenAI) فرصاً واعدة وتحديات حاسمة، خاصةً ضمن استوديوهات التصميم. تستقصي هذه الدراسة دور GenAI في العملية التصميمية المعمارية وتأثيره على مهارات الطلاب التصميمية والإبداعية ونتائج تعلمهم. اعتمدت الدراسة على منهجية متعددة الأساليب، تضمنت مراجعة شاملة للأدبيات، وإجراء مقابلات مع خبراء أكاديميين مهتمين بالذكاء الاصطناعي من جامعات مختلفة حول العالم، واستبيان موجه للمعماريين المهنيين، بالإضافة إلى تجربة ميدانية شارك فيها طلاب العمارة. كشفت النتائج عن قبول متزايد لاستخدام GenAI في التعليم المعماري، مع تسجيل أعلى مستويات الفعالية المدركة في مرحلتي التصميم المفهومي ومرحلة ما قبل التصميم. ومن أبرز الفرص التي أشار إليها المشاركون: تحسين الإنتاجية، توفير الوقت، وتعزيز إبداع الطلاب وإلهامهم. في المقابل، كانت التحديات الأكثر تكراراً هي نقص المعرفة الفنية والتدريب، وغياب السياسات والإرشادات الجامعية، والقضايا الأخلاقية المرتبطة بالاستخدام. وتشير هذه النتائج إلى أن GenAI ينبغي أن يكون مكملاً للمهارات اليدوية والتفكير النقدي، وليس بديلاً عنها. وبناءً على ذلك، توصي الدراسة بوضع برامج تدريبية موجهة، وسياسات مؤسسية واضحة لضمان دمج مسؤول ومستدام. كما تقترح الدراسة إطاراً استراتيجياً لدعم التبنّي المتوازن لأدوات GenAI في التعليم المعماري، بما يساهم في تمكين المعماريين المستقبليين من تبني التكنولوجيا مع الحفاظ على القيم الأساسية للتصميم.

Chapter 1 : Introduction

1.1 Background

The past decade has experienced the integration of Artificial Intelligence (AI) with other technological advancements, such as self-driving cars, robotic systems, and chatbots, leading to enhanced efficiency, increased productivity, and reduced human mistakes, resulting in improved decision-making, more thorough analysis, and improved precision and control (Bhandari, 2024). AI is widely defined as replicating human intelligence in machines, allowing them to think and act like humans, and includes capabilities such as understanding, learning, and problem-solving skills (Tripathi, 2021). Since its introduction in 1956 by John McCarthy at the Dartmouth Conference, it has rapidly progressed and become a research field with unparalleled influence across various sectors of human life, enhancing the efficiency of traditional processes, including transportation, agriculture, healthcare, energy, entertainment, and social life (Ilyas, 2022).

AI has gained widespread use across multiple sectors, including education. According to (Long & Magerko, 2020) AI has been assessed for its impact on administration, instruction, and learning. By enabling the development of machines and tools with human-like intelligence, AI has the potential to revolutionize teaching methodologies and significantly enhance students' learning experiences (Martínez-Maldonado et al., 2023).

This has opened up new possibilities for integrating AI into architectural design education. As architectural education serves as the foundational gateway to an architect's professional career and is intrinsically linked to the profession through ongoing technological

advancements and evolving societal needs, educational institutions must design their programs to be inherently flexible and readily adaptable (Ceylan, 2021).

Furthermore, Cooper (2023) argued that in addition to shaping teaching, AI in architectural design education has the potential to significantly impact the design process, enhance creativity, and improve building performance, leading to more innovative and creative solutions. AI can also help analyze and understand complex design data, enabling students to better understand architectural principles and practices. However, the studies also highlighted the challenges of misusing AI techniques, the changing roles of students and educators, and ethical issues in education due to AI (Chen et al., 2020).

The study aims to investigate the potential impact of integrating Generative AI (GenAI) in architectural design education and the design process. It examines how AI affects students' skills and creativity, highlighting both advantages and disadvantages, as well as opportunities and risks. This chapter provides insight into the study problem statement, objectives, and significance, offering a clear understanding of the research focus. A summary of the methodology used to conduct the research is also presented, and the scope and limitations of the study are discussed to define its boundaries. The chapter concludes with an overview of the thesis structure, outlining how the research is organized and what each chapter covers.

1.2 Problem Statement

The problem statement of the study revolves around the uncertainty about the impact of GenAI applications on architecture as a profession and an educational field. It emphasizes the importance of understanding how AI could influence architectural design processes from an educational perspective.

The rapid advancement of AI introduces both opportunities and challenges in architectural design education. While several studies discussed that AI has the potential to enhance design thinking, boost creativity, and help students save time, preparing them for a tech-driven industry, it also presents concerns, such as resistance within educational systems and a limited understanding of its capabilities. However, the limited research and studies on understanding the potential of AI tools and applications effectively in architectural education have hindered the full adoption of AI in this field.

Moreover, the disconnect between academic settings and practical demands highlights the need for an in-depth investigation to provide practical, evidence-based insights and address key opportunities and challenges that universities may face. It aims to tackle these issues by proposing an in-depth investigation to bridge the identified gap, explore the integration opportunities, and offer a strategic framework and recommendations for incorporating AI into architectural education.

1.3 Study Objectives

1. Determining the role of GenAI in architectural education, focusing on the architectural design process.
2. Developing recommendations and strategies for integrating GenAI technologies into architectural design education.

1.4 Study Significance

This study explores the potential influence of Generative AI in architectural design education, focusing on how emerging technologies might be integrated into current pedagogical practices. As AI continues to evolve across various domains, including

education, there is growing interest in understanding its role in developing relevant skills for the future demand of architectural professionals. Given the rapid transformations in architectural practice, educational institutions may need to consider and adopt adaptive strategies to ensure that program design remains flexible, updatable, and aligned with industry needs. This research investigates how AI can support such adaptability, potentially informing the development of dynamic and responsive educational models.

In the context of Saudi Vision 2030, this research is particularly significant as it aligns with the nation's emphasis on leveraging modern technologies across key sectors, including education. The findings offer potential insights that inform policymakers, educators, and instructional strategies, ensuring that architectural education in Saudi Arabia and beyond remains innovative, relevant, and responsive to the evolving needs of the profession.

Additionally, this research contributes to the global conversation on the practical and ethical considerations and implications of incorporating AI in education. It explores how a balanced approach might integrate emerging technologies alongside traditional methods while maintaining core architectural principles. The study investigates AI's potential role within architectural education and provides insights into how future architects may apply advanced technologies to support innovative, sustainable, and adaptable design practices.

1.5 Methodology Summary

The study methodology consists of four main techniques. Firstly, the literature review established the study's foundation by examining the approaches of architectural design education and its development, digital transformation, AI developments, and their applications in architecture. The study also provided a framework for utilizing generative AI tools from an educational perspective at each architectural design stage, highlighting

the most common tools and how they are currently being integrated into architectural education.

Secondly, a questionnaire targeting professional architects was conducted to assess their views on the influence of Gen AI on creativity, productivity, and decision-making throughout the architectural design process, bridging the gap between education and practice. The questionnaire also examined the perceived advantages and limitations of these tools and their relevance to architectural education in incorporating these technologies.

Third, expert interviews with architecture professors and academics were conducted to gather their perspectives on integrating Generative AI into education. These interviews aimed to gain a deeper understanding of AI's opportunities and challenges, as well as its effects on student outcomes and skills. The results and findings were analyzed to help develop practical guidelines for the effectiveness of incorporating AI into architectural education.

Finally, field experiments were conducted, involving workshops with senior undergraduate architecture students at KFUPM, to evaluate the impact of Gen AI tools on the students' skills and design quality. The data collected from educator evaluations and student feedback were analyzed to highlight students' outcomes and the benefits and challenges of AI in architectural education.

To enhance the reliability and validity of the findings and strengthen the study's contributions, methodological triangulation was applied by integrating and synthesizing multiple data collection methods, questionnaire, interviews, and field experiments, allowing for cross-validation and a more comprehensive understanding of the research

problem, which ultimately supported the development of clear and practical recommendations for effectively incorporating Generative AI into architectural design education.

1.6 Scope and Limitations of Study

This study examines the potential impact of generative AI on architectural design education, with a particular focus on design studios. It investigates how AI influences the design process and the development of students' creative and technical skills, identifying both opportunities and risks. The research seeks to evaluate whether generative AI should be integrated into architectural education, and if so, how it can be implemented in a more effective, structured, and ethical manner. The study also highlights the need to move beyond informal or unregulated AI use by proposing clearer guidelines and integration strategies.

While this study aims to provide multiple insights into integrating AI in architectural design education, certain limitations and challenges must be acknowledged. A prominent limitation of the study is time limitation, as AI is evolving rapidly, with tools and methodologies continually advancing. Consequently, the study's findings may need to be re-evaluated in the future to accommodate new technological developments and their implications for architectural education.

Another limitation is the study's narrow focus on AI in architectural design education, potentially overlooking broader AI applications in architecture and related fields. This focus may miss insights from interdisciplinary areas like urban planning or the construction industry. Additionally, there is a variation in access to advanced AI tools across different institutions and their proficiency levels. This variation could impact the practical

application of the study's findings, as institutions with limited resources or insufficient training may struggle to fully implement the recommended practices.

1.7 Thesis Structure

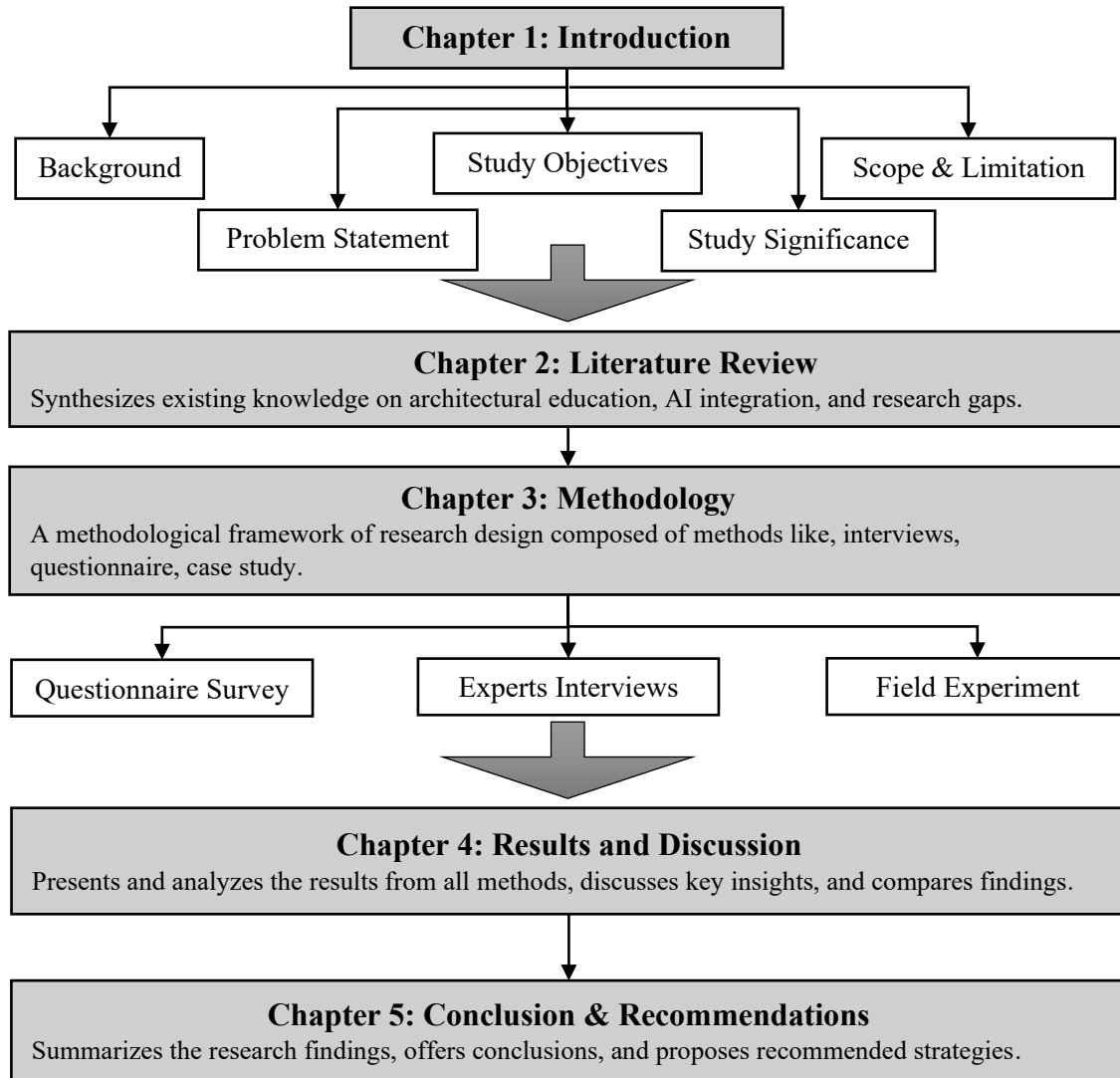


Figure 1.1: Structure of the study

Chapter 1: Introduction: This chapter establishes the foundation for the study, providing the background context and delving into the specific problem the study aims to address. It outlines the main objectives of the research, its significance, and defines the scope and

limitations of the study. The thesis structure is also presented here, guiding the reader through the organization of the research.

Chapter 2: Literature Review: This chapter engages with existing research relevant to the topic, reviewing, synthesizing, and providing an overview of the developments in architectural education approaches, digital advancements, and the current state of integrating Gen AI into the architectural design process from both professional and educational perspectives. This chapter aims to identify gaps in the literature which is addressed in this study.

Chapter 3: Methodology: The study employs four primary methodologies to investigate the integration of GenAI in architectural design education. It begins with a literature review that examines current educational practices, digital advancements, and AI developments, establishing foundational frameworks for design stages and relevant AI tools to guide the creation of surveys, interviews, and experiments. Secondly, a questionnaire with architects assesses the impact of GenAI on creativity, productivity, and decision-making in architectural design, as well as its relevance to educational practices. Thirdly, in-depth interviews with architecture professors gather expert perspectives on the opportunities, challenges, and effects of AI integration on student outcomes, which are analyzed to develop practical guidelines for effectively incorporating AI into architectural design education. Finally, field experiments involving workshops with KFUPM undergraduate students evaluate AI's influence on their skills, outcomes, and design quality.

Chapter 4: Results and Discussion: This chapter presents the findings from the data collected through the primary research methods, discusses their implications, synthesizes and compares them with existing research. The results are organized and analyzed

according to the research objectives. They are then critically interpreted, highlighting the influential factors and their significance for the field.

Chapter 5: Conclusion & Recommendations: The final chapter concludes the study by summarizing the key findings, presenting the research contributions, and suggesting areas for further investigation. It provides practical recommendations and strategies for guided AI integration into architectural design education, based on the insights gained from the research.

Chapter 2 : Literature Review

2.1 Introduction

This chapter provides an in-depth review of the current state of architectural education, highlighting its shift and evolution from traditional studio-based learning to more interactive, integrated, technology-driven models. The literature review systematically outlines the various stages of the architectural design process, offering a detailed summary based on multiple studies. It also delves into the integration of GenAI applications and tools within the field, examining their roles and impacts on architectural education and practice.

Furthermore, the chapter thoroughly analyzes the challenges, risks, and benefits associated with adopting AI in architectural design education. This analysis provides valuable insights to inform subsequent interviews and surveys, ensuring a thorough exploration of AI's impact on the field. In the conclusion of the literature review, a conceptual framework is developed to associate each AI tool with the corresponding stage of the architectural design process, facilitating the practical application of GenAI in architectural design education.

2.2 Overview of Architectural Design Education

Architecture is the art and discipline of shaping space through a combination of ideas, technical possibilities, creativity, and aesthetic beauty to meet human needs, ensuring comfort, safety, and emotional fulfillment (Chęć-Małyszczek, 2021). Also, design can be defined as the decision-making process that integrates science, mathematics, and technology to develop systems or solutions and optimize resources through creative and analytical thinking. It fosters experimentation and problem-solving to meet desired

requirements efficiently (Sudrajat et al., 2022). However, Architectural design is the process of systematically organizing materials and resources to address complex challenges and guide designs toward their best possible configuration. It employs tools such as modeling and optimization to achieve the most effective and efficient use of available resources while creating spaces that are both practical and meaningful (Canestrino, 2021).

Architecture stands out as a unique field of education that demands high creativity and innovation. Unlike other disciplines, architectural education requires a distinct pedagogical approach, encouraging students to adopt a new way of thinking and perceiving the world around them (Rizk, 2019). This field necessitates a new vocabulary and a set of specialized methods, tools, and techniques tailored to the various subjects within architectural pedagogy (Gour, 2019).

Architectural education is designed to equip students with the skills to think spatially and critically, enabling them to transform abstract concepts into tangible solutions (Namwad et al., 2023). It is a multidisciplinary approach that integrates research, design, and practical skills to create sustainable built environments, preparing professionals to meet societal, cultural, and global challenges (Tandon et al., 2024). In design education, teaching and learning methods strive to harmonize the creative process with an understanding of objective criteria during the development of design proposals (Newland et al., 1987). Architectural design encompasses more than just the physical and structural aspects of buildings; it includes a broad spectrum of factors, such as the community's life and values (Hensel, 2013). This complexity necessitates a multifaceted approach in architectural education, which integrates not only building design but also social, cultural, philosophical,

and technological considerations, along with sustainability. Incorporating diverse subjects within architectural courses is essential to developing innovative, creative, and holistic architects attuned to societal needs, environmental concerns, and technological advancements (Ibrahim and Utaberta, 2012).

Throughout a design project, students transform their inquiries into propositions or schemes. This learning process is marked by ongoing dialogue, where students gain insights by exchanging information with peers and instructors and receiving critiques from jury members. (Demirbas & Demirkan, 2007). Furthermore, architectural education is integral in shaping future architects, equipping them with the skills and knowledge needed to address contemporary challenges in the built environment (Yap et al., 2022).

However, architectural design education has undergone significant transformations over the last decades. Research on educational methodologies and processes began in the early 20th century, focusing significantly on the Bauhaus movement, emphasizing a hands-on, interdisciplinary approach to design education (Forlano, 2019).

This section reviews the current state of architectural education, examining the core components of architectural education, beginning with the central role of design studios in fostering creative solutions. The review critiques traditional teaching methods, discussing their limitations and challenges. It then explores reforming and innovative education strategies that enhance learning experiences for architecture students. Lastly, it evaluates how various design processes have been adapted to promote student creativity and innovation in educational settings.

2.2.1 Architectural Design Processes

A. Role of Design Studio in Architectural Education

The design studio is a cornerstone of architectural education, functioning as the primary environment where students engage in creative problem-solving and develop their design skills (Shi et al., 2021). Traditionally housed within institutional settings, the studio offers a structured environment that supports learning through doing, reflective practice, and iterative design processes (Hettithanthri & Hansen, 2022).

This environment fosters collaboration between students and instructors, which is crucial for addressing real-life architectural challenges and developing the critical and technical skills necessary for architectural practice (Milošević, 2021). Compared to other subjects in architecture, the design studio is the most dominant, with the highest number of weekly credit hours. It serves as the central focus, with other subjects, such as Building Technology, Architectural History and Theory, and Architectural Communication, designed to support and enrich the learning that occurs within the studio (Ibrahim & Utaberta, 2012).

As illustrated in *Figure 2.1*, these subjects converge within the design studio, which provides students with the capabilities and knowledge required to produce creative, innovative, and efficient design solutions.

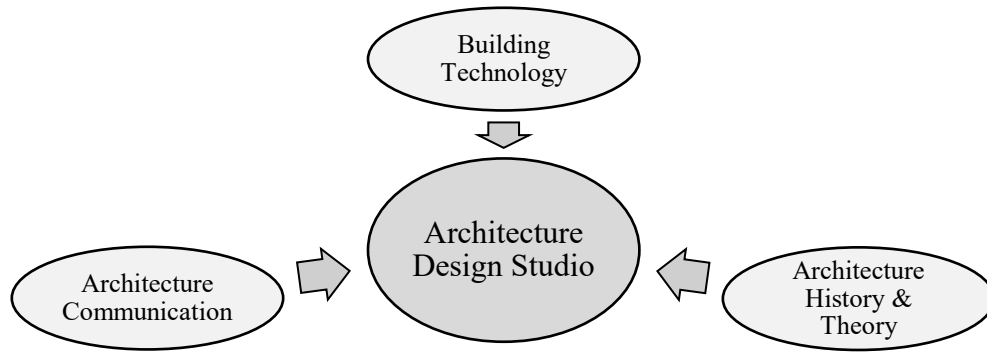


Figure 2.1: Integration of core subjects supporting the architectural design studio
Source: (Ibrahim & Utaberta, 2012)

The dynamic environment of an architectural design studio encourages hands-on learning and reflective practice, which are essential for developing a deep understanding of architectural concepts (Masatlioğlu et al., 2024). Students show their architectural thoughts and creativity via various communication techniques and approaches, including drawings, physical and computer models, photographs, and video content, thereby honing their ability to work in both intuitive and actual contexts (Ibrahim & Utaberta, 2012). However, the design studio's role extends beyond its physical structure; it encompasses the social and pedagogical practices contributing to a vibrant learning atmosphere.

The interaction between students and lecturers within the studio is vital, as it cultivates a collaborative environment where real-life architectural challenges are addressed (Emam et al., 2019). Despite its critical role in fostering creativity and technical proficiency, traditional studios often operate within a rigid framework that could limit students' ability to explore diverse design approaches (Dervisoglu & Yılmaz, 2023). This limitation has prompted educators to reconsider the structure and content of design studios to better align with the evolving needs of architectural education and practice (Desouki et al., 2022). The

increasing demands of the architectural profession, combined with rapid technological advancements, have led to growing scrutiny of the traditional design studio's effectiveness in preparing students for the future of architecture (Shi et al., 2021).

B. Architectural Design Stages

The architectural design process in education is inherently iterative, requiring students to continuously refine and develop their ideas through feedback and critique. This approach allows students to explore multiple design alternatives, fostering innovation and problem-solving abilities (Lawson, 2005). Integrating technical and aesthetic considerations, the process challenges students to balance structural integrity with artistic expression, demanding a deep understanding of both construction and creative aspects (Schön, 1983). Creativity in design education is essential, encouraging students to think beyond conventional boundaries and explore innovative solutions to complex challenges (Ketizmen Onal, 2003). According to Namwad et al. (2023), creativity involves generating novel ideas and seeing new connections and possibilities within existing constraints.

In addition, the design process is a critical educational method, enabling students to translate conceptual ideas into visual representations through drawings and models, thus fostering a culture of feedback and iterative improvement (Gour, 2019). As Schön (1983) emphasized, designing involves technical skills and the ability to convey the narrative and intent behind a design, requiring a reflective practice where students engage in a dialogue with their work. The collaborative nature of design studios supports this creative exploration, where students engage in learning from their peers and receive guidance from instructors to hone their skills (Salama, 2015). Making the design process explicit allows

students to develop a systematic approach to design challenges, enhancing their ability to articulate reasoning and decisions throughout the design journey (Van Dooren, 2020). Moreover, this iterative cycle of creation and critique supports enhancing critical thinking and the problem-solving skills required for exploring the complexities of architectural practice.

The architectural design process is a multifaceted and iterative journey, approached through various models that differ across architectural schools. These models offer distinct perspectives on how design education can effectively prepare students for professional practice. However, while this process provides a rich framework for fostering creativity and technical skills, its effectiveness varies significantly across different educational approaches, raising questions about the consistency and comprehensiveness of design methodology instruction in adequately preparing students for the demands of professional practice.

Over time, efforts have been made to align the design process stages with the decision-making phases, reflecting the evolving understanding of design education's role in professional development. The most prominent was a structured model proposed by Archer (1963), as shown in *Figure 2.2*. Archer's model emphasizes a structured approach. Each phase builds upon the previous one, ensuring the design process is systematic and iterative, integrating analytical rigor and creative exploration. The proposed model delineates the design stages into three distinct phases: the Analytical Phase, Creative Phase, and Executive Phase; these main phases include programming, Data Collection, Synthesis, Development, Communication and Analysis.

1. Analytical Phase: This phase involves Data Collection and Analysis, where observations, measurements, and inductive reasoning are employed to gather and assess relevant information. It focuses on understanding the problem and setting the foundation for the creative process.
2. Creative Phase: The core design work involves Synthesis and Development. The collected data is synthesized, and creative ideas are generated, moving from abstract concepts to tangible solutions.
3. Executive Phase: This is where the design is communicated and executed. This phase includes Communication, where the design is described and translated. The phase culminates in the delivery of the design solution, completing the process.

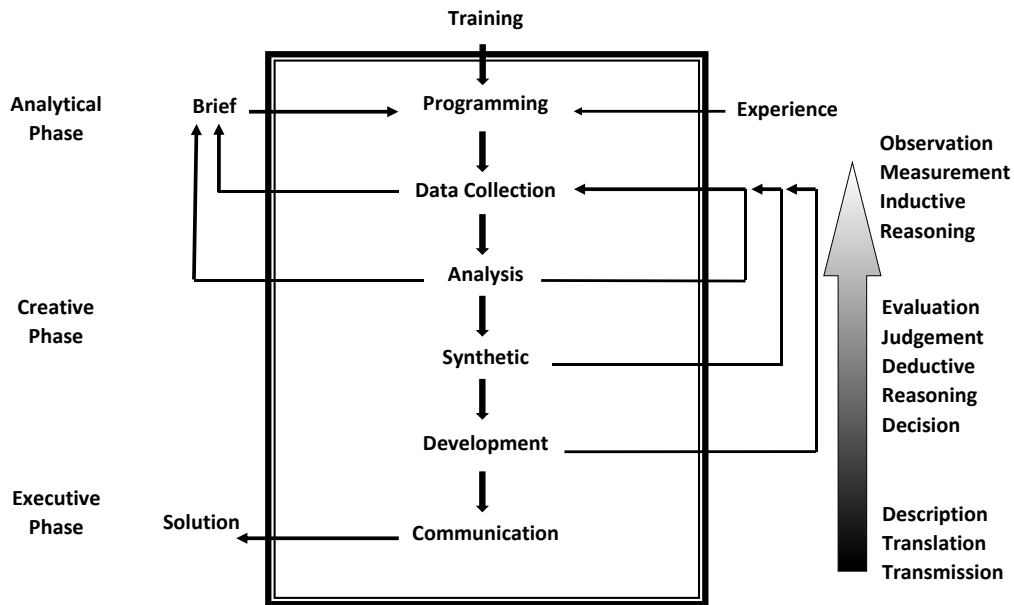


Figure 2.2: Archer's model of the stages of the architectural design process
Source: (Mahmoodi, 2001), Reproduced by the Author

Among other different proposals, Duerk (1993) presented the American Institute of Architects (AIA) model. This model provides a structured approach to architectural design,

emphasizing systematic progression through various phases and communication to ensure the project's success from concept to construction. It divides the design process into six stages:

1. Pre-Design: This involves gathering and analyzing information to define project objectives and laying the foundation for the design process.
2. Schematic Design: This develops preliminary design concepts through sketches and models.
3. Design Development: This phase refines the chosen design concept by producing architectural drawings and defining the architectural organization.
4. Construction Documents: Detailed drawings and specifications are prepared to guide the construction process.
5. Construction Administration: Involves overseeing construction and implementing necessary revisions to maintain quality and compliance with specifications.
6. Post-Design: encompassing post-occupancy evaluation, creating user manuals, and conducting evaluation research

Similarly, A. Soliman (2017) expanded on this by offering a more educationally focused framework, emphasizing the overlapping four main phases, as shown in *Figure 2.3*: The Programming, Schematic Design, Design Development, and Construction Documents phases. Similar to Duerk's approach, Soliman highlights the importance of overlapping stages to foster a holistic development of design skills, enabling students to integrate

knowledge from various disciplines as they move through the design process and the ability to address complex architectural challenges.

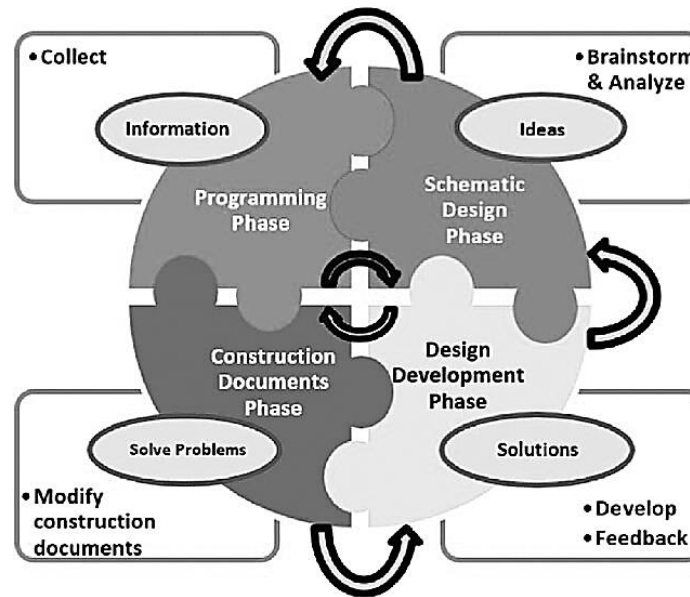


Figure 2.3: Design process of architectural design practice
Source: (Soliman, 2017)

One of the innovative approaches is introduced by Mahmoodi (2001), who presented a cyclical model intertwining the stages of Understanding, Idealizing, and Presenting. This model shows the interactive nature of analysis, synthesis, and evaluation within each stage. *Figure 2.4* illustrates the cyclic nature of the design process. The design problem can enter the process at any point, mirroring real-world design practices in which solutions often emerge early and evolve through iterative cycles. This reflects how, in practical settings like design studios, students often begin generating ideas, such as doodle sketches, even before a thorough analysis of the problem is conducted, demonstrating the fluid and iterative nature of the design process.

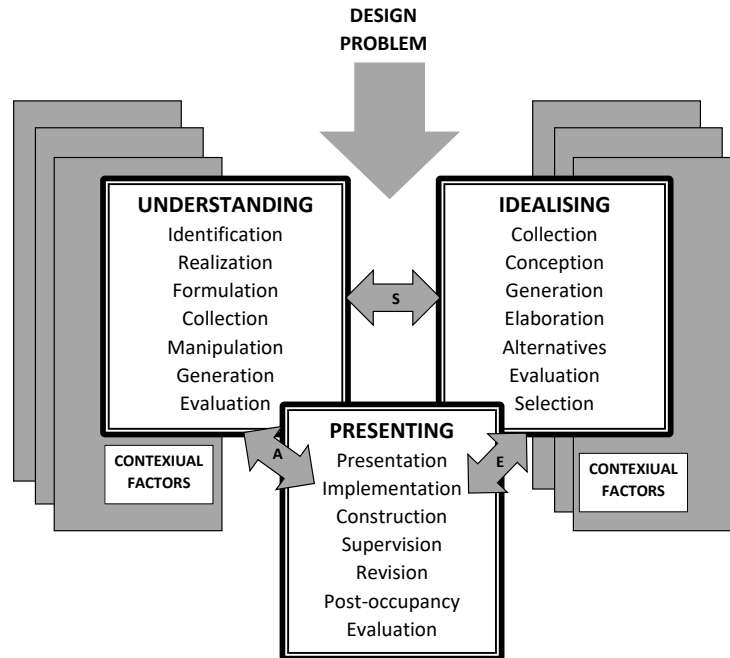


Figure 2.4: The interactive model of the architectural design process
Source: (Mahmoodi, 2001), Reproduced by the Author

Lawson (2005) participated in this discussion by proposing a framework comprising five core design skills: 1- Problem Identification, 2- Conceptualization, 3- Development, Evaluation, and 4- Communication. These elements are interconnected and vary in emphasis depending on the project's needs and the designer's approach, making Lawson's framework a flexible tool for design education. Weytjens et al. (2009) also offer a structured model for architectural design. Like the models mentioned above, this approach ensures that information flows seamlessly throughout the various stages, supporting informed decision-making and iterative refinement. As shown in *Figure 2.5*, the process begins with the briefing stage, which establishes the initial project requirements and objectives. This is followed by the Conceptual Design phase, where preliminary ideas and design concepts are explored. As the process progresses into the Design Development phase, these concepts are further refined and detailed, incorporating technical and

functional aspects. The final stage, the Final Design, culminates in presenting the completed design solution. Throughout this process, continuous Communication and evaluation analysis is essential, ensuring that the design is critically assessed and effectively communicated at each stage.

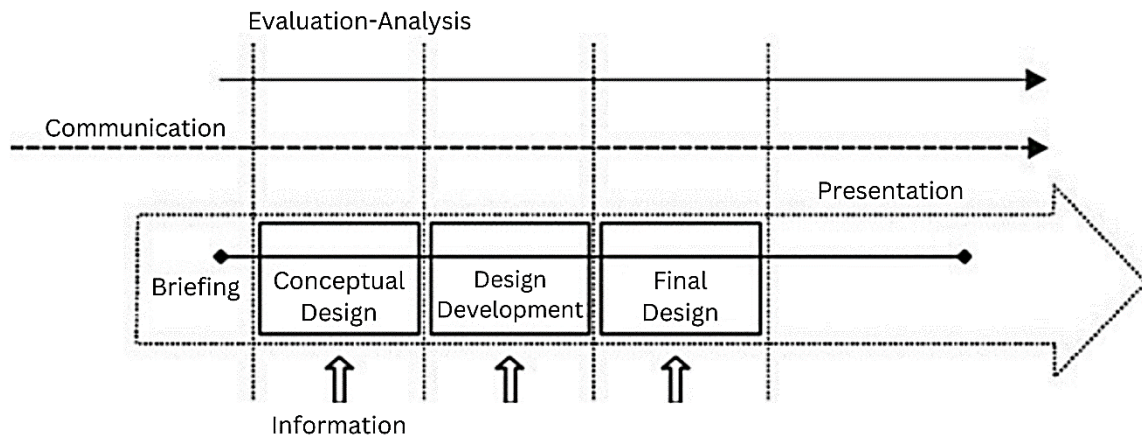


Figure 2.5: Structured model for the architectural design process
Source: (Weytjens et al, 2009)

In addition, Bozkurt (2016) and Milošević (2021) further contributed to the discussion with their respective models. Bozkurt focused on integrating theory with practice in architectural education. This method reflects the importance of aligning theoretical knowledge with practical studio work, ensuring students can effectively apply learned concepts in their designs. The process begins with Site Analysis in the early weeks, accompanied by theoretical background and case studies that provide foundational knowledge. As students progress, Initial Ideas are developed in the studio, supported by Software Teaching and Design Strategy Development in the classroom. This interaction between theory and practice continues, with Design Tutorials facilitating detailed design work and iterative refinements. The Detailing and Presentation phases are emphasized in

the later weeks, where the theoretical concepts learned earlier are applied to refine and present the final design. Milošević (2021) also categorized architectural education's design process into distinct yet interconnected phases, emphasizing a blended learning approach.

These phases are:

1. Analysis Phase: Students gather contextual information and study the program requirements.
2. Conceptual Design Phase: Focuses on refining the functional and formal aspects of the design.
3. Structural Design Development Phase: Involves structural analysis and optimization to ensure the design's integrity.
4. Presentation and Post-Production Phase: Prepares the design for professional presentation and incorporates digital tools. This structured approach combines traditional and digital methods, fostering student collaboration and equipping them for real-world architectural challenges.

Furthermore, Afify (2014) introduced one of the most notable models. In his model, Afify introduces an interactive process between the phases of Problem Identification, Analysis, Concept Development, Evaluation, and Communication. The model stresses a cyclical approach, allowing for continuous refinement and interaction between stages, ultimately leading to an effective architectural solution that addresses multiple aspects of architectural challenges. As depicted in the *Figure 2.6*, this process begins with the following:

1. Problem Identification: Establishing project objectives, goals, and context through gathering project information.

2. Analysis: Exploring factors like building form, human considerations, and contextual responses that significantly influence the design.
3. Concept Development: Engaging in creative thinking, design philosophy, and spatial conception to generate multiple architectural ideas.
4. Development and Evaluation: Assessing these ideas based on technological, economic, environmental, and social criteria, along with design and construction standards.
5. Communication-Presentation: Preparing and presenting the final design solution, synthesizing all previous stages, and leading to the project's completion.

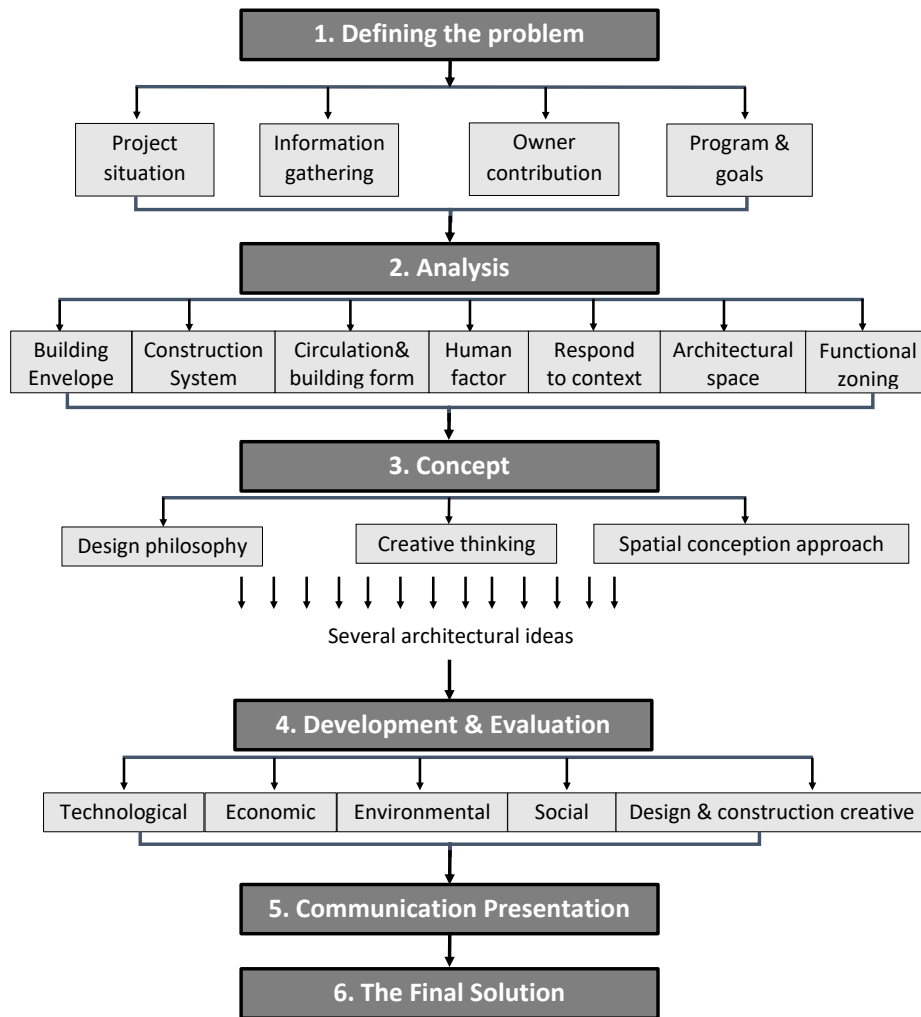


Figure 2.6: Afify's model of design process
Source: Afify (2014), Reproduced by the Author

According to a recent study by Abowardah (2020) for the phases of the architectural graduation project, the design process is divided into five stages. The first phase is the research phase, during which students select their main subject, collect data, and identify the project typology, problems, and goals. The second phase is the predesign phase, which focuses on inspiration and conceptual development. The third phase is the schematic design phase, where students present their first draft of the conceptual design, emphasizing creativity. Following this is the design development phase, where students clarify the

project's dimensions, materials, room sizes, and circulation. The final phase is the construction documentation phase, also referred to as the presentation phase, where students present their projects through documents that include drawings and specifications.

As per the same study, the predesign phase consists of three main steps: mind mapping, which is the visual illustration of ideas and concepts and a strategy for integrating text, graphics, and images into a unified diagram; freehand sketching, which brings design ideas to life by exploring the spatial connections and functions of the design; and preparing the physical model, which can be provided initially in this stage, with the final model delivered during the final presentation phase.

These various frameworks and models collectively highlight the diversity in structuring the design process in architectural education. They underscore the importance of a structured yet flexible design process, which equips students with the required skills to succeed in the profession while allowing for the fluid and iterative nature of design thinking, creativity, and imagination. Before presenting the proposed alternative design model, some of the most valuable definitions of design process methodology were reviewed and compiled during this investigation, as shown in Table 2.1, which highlights various perspectives on the design process, categorized into three primary stages: Analytical Phase, Creative Phase, and Executive Phase. Recognizing these tasks underscores the importance of fully integrating and addressing them when developing a comprehensive design methodology. However, the rapid advancement of technology and Digitalization further necessitates exploring how these innovations can be integrated into architectural design education to enhance the learning experience and outcomes, which is explored in the next section.

Table 2.1: Various views of the design process under the primary three-stage model
(Compiled by the Author)

Source:	Design Process-Stages:		
	Analytical Phase	Creative Phase	Executive Phase
Archer (1963),	Programming	Synthesis	Development
	Data Collection		Communication
	Analysis		
Duerk (1993),	Pre-Design	Schematic Design	Design Development
			Construction Documents
			Construction Administration
			Post-construction
Soliman, 2017	Programming	Schematic Design	Design Development
			Construction Documents
(Mahmoodi, 2001)	Design Problem	Idealizing	Presenting
	Understanding		
(Lawson, 2005)	Problem Identification	Conceptualization	Development
			Evaluation
			Communication
(Weytjens et al, 2009)	Briefing Stage	Conceptual Design	Design Development
			Final Design and Presentation
(Afify, 2014)	Problem identification	Concept Stage	Development and Evaluation
	Analysis		Communication-Presentation
(Bozkurt, 2016)	Site Analysis	Initial Ideas	Detailing
		Design Tutorials	Presentation
Milošević (2021)	Analysis	Conceptual Design	Structural Design Development
			Presentation and Post-Production
AboWardah (2020)	Research	Schematic design	Design development
	predesign		Construction documentation

2.2.2 Limitations of Traditional Teaching Methods

Traditional architectural design education faces several significant challenges that limit its effectiveness in preparing students for the complexities of contemporary practice. As A. Soliman (2017) mentioned, a primary issue lies in the reliance on conventional, outdated teaching methods, which limits students' ability to engage in exploratory and reflective practices, which are crucial for innovative design thinking. Despite its foundational role of

the design studio in architectural education, its traditional model has often been criticized for its rigid, linear structure, which does not adequately support the iterative and dynamic processes essential to real-world design work (Milošević, 2021).

The structured, systematic approach typically employed in design studios can further disconnect students from real-world scenarios, as their work is often confined within the studio rather than directly engaging with the environments they are designing for (Emam et al., 2019). Adding to these challenges is the limited integration of theoretical and practical courses into the studio experience. This disconnect can make it difficult for students to see the relevance of technical knowledge in their design work, often leading to passive learning, a shallow understanding, and poor retention of knowledge as students fail to see the practical application of what they learn (Chen, 2016).

Another major limitation of the traditional design studio is the master-apprentice model, which can reduce student independence. Students may rely too much on their tutors, copying established styles instead of creating their own. This dependence can hinder the growth of independent critical thinking, which is crucial for architects (Ciravoğlu, 2014). Additionally, Traditional studios also focus more on the final design than the process, discouraging experimentation and limiting creativity (Masathoğlu et al., 2024). This focus on the end product can lead students to prioritize appearance over a deeper, thoughtful approach to problem-solving (Desouki et al., 2022).

Further challenges of traditional architectural education were highlighted, including the failure to effectively integrate sustainability into education. Shi et al. (2021) pointed out that the historical focus on aesthetics and formal aspects of design has frequently been at the expense of addressing broader environmental, social, and economic sustainability

issues; this narrow focus leaves students underprepared to tackle the complex sustainability challenges they will encounter in professional practice. The coordination among different levels of the design studio further exacerbates this issue, leading to inconsistencies in how sustainability is taught and understood across the education (Al-Hagla, 2012). Finally, the limited integration of digital tools and technologies within traditional studios exacerbates this issue, as modern students are increasingly accustomed to using a variety of digital platforms in their daily lives (Milošević, 2021). Therefore, the outdated education, which has not kept pace with advancements in construction technology and sustainability, leaves students inadequately prepared for the demands of contemporary architectural practice (Desouki et al., 2022; Shi et al., 2021).

2.2.3 Approaches of Architectural Education Development

Architectural education has undergone significant transformation in recent years, with innovative teaching methods being developed to prepare students for the complexities of professional practice (Masatlıoğlu et al., 2024). To address the limits of traditional education, modern approaches now focus on active, student-centered learning that promotes critical thinking, creativity, and real-world skills (Gour, 2019). Interdisciplinary teamwork and blended studios have also become vital, reflecting professional practice and building communication skills (Dervisoglu & Yılmaz, 2023). Additionally, sustainability-focused teaching helps students critically evaluate their work and tackle modern architectural challenges (Al-Hagla, 2012).

Undoubtedly, integrating digital tools and technologies has also revolutionized architectural education and facilitated greater collaboration, even across distances (Grover & Wright, 2023). In the following section, these methods are explored in detail, examining

how they enhance the learning experience and equip students with the skills necessary to succeed in the evolving field of architecture, *Figure 2.7*.



Figure 2.7: The developed approaches in architectural education based on the literature review

A. The Modified Bloom Taxonomy in Architecture Design Studio

Bloom's taxonomy is widely recognized and utilized as an educational framework that helps instructors design effective learning experiences (Anderson & Krathwohl, 2001). It was originally developed by Benjamin Bloom in 1956 and revised in 2001 (Armstrong, 2010). Original Bloom's Taxonomy was a single-dimensional framework that categorized educational goals into six degrees of complexity stated as knowledge, comprehension, application, analysis, synthesis, and evaluation. These levels were structured as a pyramid, shown in *Figure 2.8*, with the lower three levels (knowledge, comprehension, and application) forming the base and focusing on foundational skills. In comparison, the upper three levels (analysis, synthesis, and evaluation) represented higher-order thinking skills (Attia, 2020).

Furthermore, integrating Bloom's Taxonomy into educational frameworks enhances teaching effectiveness and learning outcomes (Krathwohl, 2002). It encourages educators to focus on higher-order thinking skills rather than rote memorization, fostering an environment where students engage in critical thinking, problem-solving, and creativity (Adams, 2015). By aligning instructional strategies with the levels of Bloom's Taxonomy,

teachers can create more organized and student-centered learning experiences that cater to diverse learner needs (Nurmatova & Altun, 2023). This literature review examines how Bloom's taxonomy and model can enhance comprehension of the history of architecture courses.

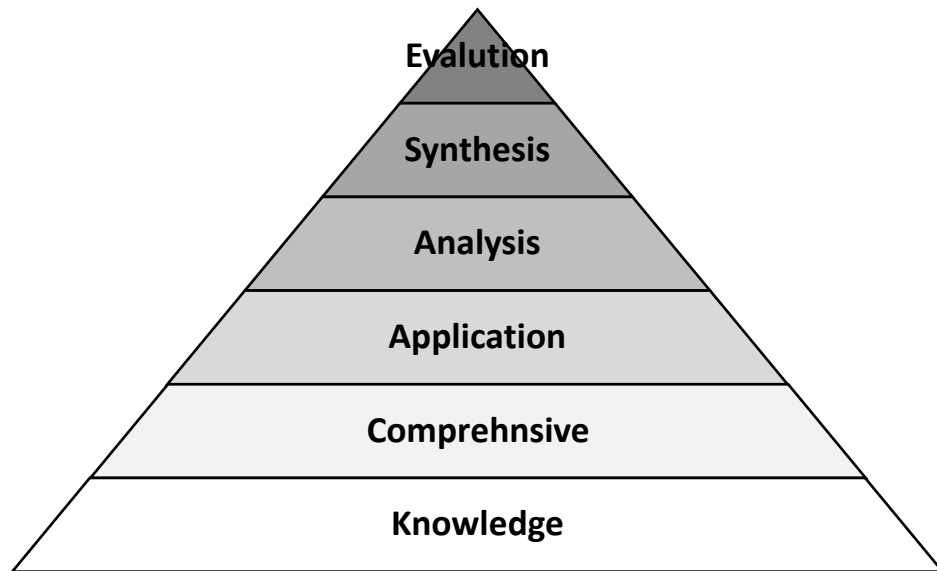


Figure 2.8: Original version of Bloom's taxonomy
Source: (De Bruyckere, 2017)

In architectural education, while the revised Bloom's Taxonomy offers valuable updates, the original version is preferred due to its holistic framework, established tradition, emphasis on higher-order thinking, and pedagogical flexibility, making it well-suited for the complex, interdisciplinary nature of architectural design education (El Sayary et al., 2016). Bloom's Taxonomy has been effectively integrated into architectural design studios to structure and enhance learning (Valsson, 2022).

Bloom's Taxonomy, with its six cognitive levels, from basic recall to higher-order skills like analysis, evaluation, and creation, offers a robust framework for guiding students

through the complexities of architectural design (Gour, 2019). This approach helps educators build activities that take students from understanding core concepts to creating innovative solutions (Ibrahim & Utaberta, 2012). In architectural education, Bloom's Taxonomy supports technical skill development and critical thinking-solving (Patil & Gaurshettiwar, 2016). Aligning studio tasks with their levels creates a more organized, student-centered learning experience, improving outcomes (Arens et al., 2009).

A study conducted by Rahbarianyazd & Nia (2019) presented a modified version of Bloom's Taxonomy specifically adapted to the architectural design process. This adaptation aligns the cognitive stages of learning with the stages of the design process, guiding students from the initial problem formulation to the final design solution. The process depicted in *Figure 2.9* begins with Knowledge, where students gather design requirements and context. It progresses through Comprehension and Application, where students deepen their understanding and develop prototypes. In Analysis, they critically evaluate design components, leading to Synthesis, where they innovate by proposing new ideas. The final stage, evaluation, involves assessing and refining the design solution to ensure a systematic approach to solving architectural design problems.

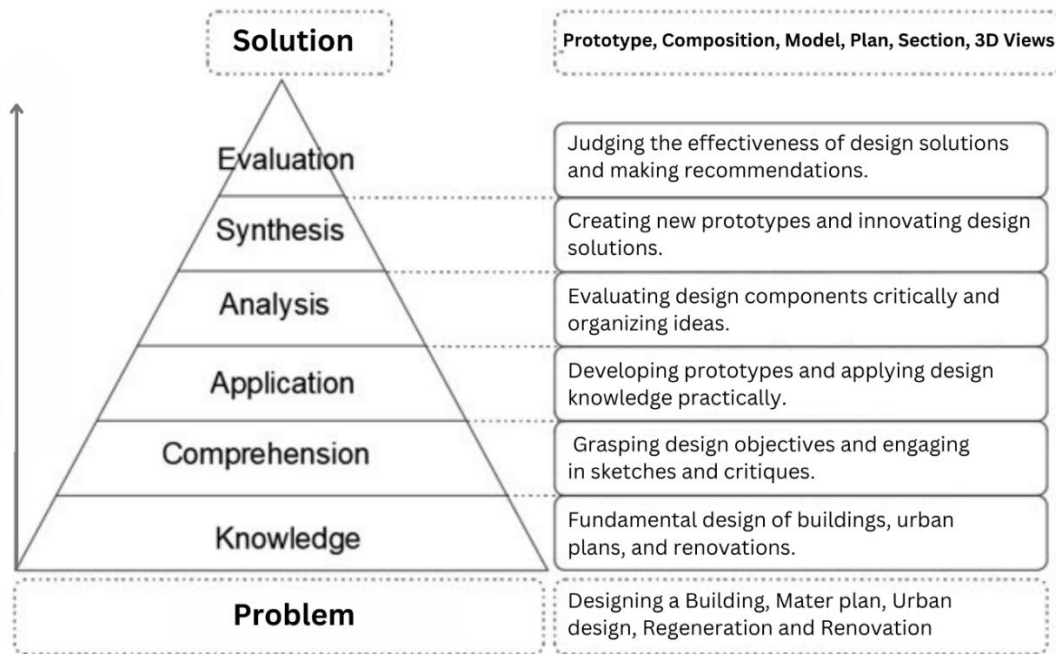


Figure 2.9: Adaptation of Bloom's taxonomy in architectural design studio
Source: (Rahbarianyazd & Nia, 2019)

In addition, Valsson (2022) identifies six key stages in the design process, each aligned with levels of Bloom's Taxonomy, as shown in Table 2.2. This correlation systematically guides student cognitive abilities development throughout design projects. By mapping design stages to Bloom's Taxonomy, educators ensure that students build cognitive and practical skills, from acquiring knowledge to creating innovative solutions, thus enhancing learning outcomes in architectural education.

Table 2.2: Correlation between Bloom's Taxonomy levels and design stages
Source: (Valsson, 2022), Reproduced by the author

Level-Stages	Bloom Taxonomy	Design Process
1	Knowledge	Define the Problem
2	Comprehension	Collect Information
3	Application	Brainstorm and Analyze Ideas
4	Analysis	Develop Solutions
5	Synthesis	Gather Feedback
6	Evaluation	Improve

B. Integrating Theory and Practice in the Design Studio

Rizk (2019) emphasizes the importance of combining academic knowledge with real-world application in architectural design studios through strategies such as inductive reasoning, systems analysis, and creativity enhancement techniques like brainstorming and peer reviews. Additionally, assigning research tasks to students, as highlighted by Masatlioğlu et al. (2024), encourages independent exploration of architectural topics, thereby strengthening research skills and enabling the application of theoretical concepts in practical design projects. Building on this, Kristianova & Jaszczak (2020) advocated for thematic research-oriented assignments in design studios, where students engage with projects centered around a common theme. This method fosters collaboration and deeper engagement with the subject matter and aligns students' design work with broader research themes, such as sustainability and cultural heritage preservation. By integrating these approaches, students enhance their analytical skills, contribute to ongoing research projects, and develop more informed and innovative design solutions (Park, 2020).

Furthermore, Rahbarianyazd & Nia (2019) proposed a methodological approach to integrating aesthetic cognition into architectural design education. Aesthetics, often underemphasized in traditional curricula, is crucial for shaping the functionality and beauty of architectural designs. The authors advocate for a qualitative, grounded theory approach to teaching aesthetics within design studios. This approach includes brainstorming sessions, peer learning, and the application of Bloom's Taxonomy to foster a deep understanding of aesthetics among students.

C. Active Learning-based Methods of Teaching

Active learning-based methods have become integral to modern architectural education. These methods have increasingly replaced traditional, passive instructional models, fostering a more dynamic and interactive learning environment, and students are involved in their educational journey in design studios (Gour, 2019). This interaction is crucial for enhancing critical thinking, as well as creativity, and also the problem-solving skills, which are necessary for professional architecture practice (Rizk, 2019). Active learning in architectural education integrates criticism within design studios, as highlighted by Desouki et al. (2022), where criticism is used not only for evaluation but also as a tool for generating ideas and refining concepts. This approach enhances students' design abilities, self-critique, and communication skills. Active learning emphasizes student participation, where students are not merely passive recipients of information but active contributors to their learning process (Ioannou, 2018). Students engage in iterative design activities, receiving critiques from peers and instructors, leading to more innovative solutions (Hettithanthri & Hansen, 2022). Faculty guide discussions and provide feedback, facilitating complex design projects (Ketizmen Onal, 2003).

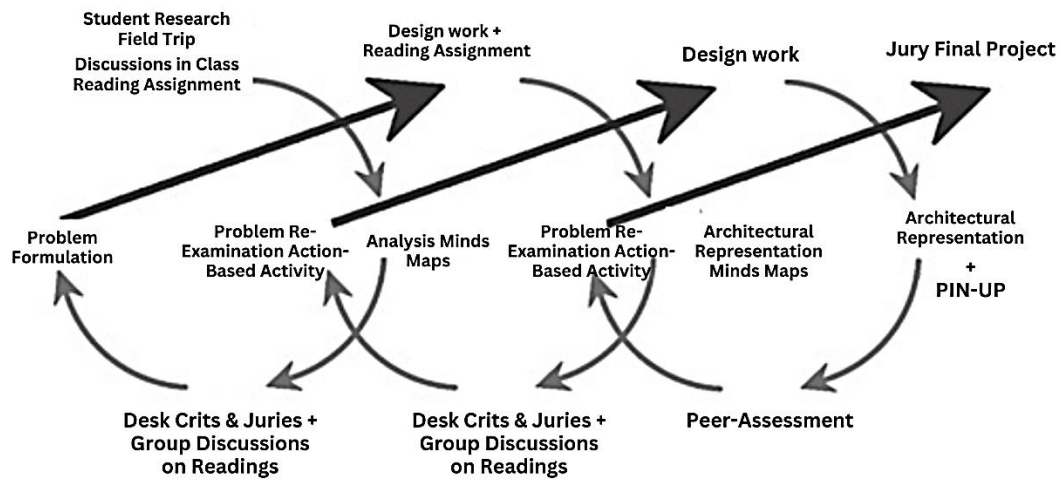


Figure 2.10: Reflective analysis and self-evaluation model in architectural design studios
Source: (Masatlıoğlu et al., 2024)

Active learning also promotes inclusivity by encouraging students to engage with diverse user groups, enhance technical skills, and understand the social impact of architecture (Szewczenko & Widzisz-Pronobis, 2020). Modern strategies like problem-based learning (PBL) and biomimicry-based curricula further foster higher-order thinking skills in architectural design (Soliman et al., 2023). However, the integration of technology has enhanced active learning in architectural education. Tools like Building Information Modeling (BIM), Virtual Reality (VR), and immersive gaze-sharing systems make learning more interactive and collaborative, allowing real-time feedback and extending engagement beyond the traditional studio (Kahlon et al., 2023). Furthermore, blended learning models, combining in-person and online instruction, offer flexibility, continuous learning, and resource sharing, which better adapt to the needs of contemporary students (Milošević, 2021).

D. Integrating Sustainability Principles in Architectural Design Education

Incorporating sustainability standards and guidelines into architectural education, particularly within design studios, is not just a trend but a pressing need in our current environmental context. This urgency is increasingly recognized as essential for preparing future architects to address the pressing environmental challenges of our time (Vrontissi et al., 2023). Multiple studies highlight the importance of embedding sustainability into architectural curricula, particularly within design studios where these principles are most effectively taught (Al-Hagla, 2012). There is a growing need for a comprehensive education integrating sustainability at all levels, driven by socio-technical factors and the growing emphasis on sustainability in architecture (Kastner & Langenberg, 2023).

Ceylan (2021) Proposed a model incorporating sustainability and energy efficiency principles throughout the educational process, ensuring students can apply these concepts in real-world scenarios. Bozkurt (2016) argued for aligning theory courses with design studios to equip students better to create environmentally responsible, economically viable, and socially inclusive designs.

Further highlighting the importance of hands-on learning, Mohamed & Özkan (2018) conducted a pilot study in a third-year design studio, introducing a new pedagogical approach emphasizing the direct application of sustainability principles. Their findings showed that this method significantly improved students' ability to incorporate sustainable elements into their projects, demonstrating the effectiveness of experiential learning in fostering a deep understanding of sustainability. Moreover, Abboushi & Elzeyadi (2020) advocated for using building performance simulations (BPS) in design studios to enhance student's ability to make informed, sustainability-driven design decisions; students can

make informed decisions that align with sustainability goals, such as energy efficiency and environmental impact reduction.

Additionally, Bradecki et al. (2024) highlighted the role of ecological education centers (CEEs) in promoting sustainability by serving as both sustainable buildings and educational tools, providing students with practical examples of sustainable architecture. These studies emphasize the need to incorporate sustainability holistically into architectural education, particularly through design studios, to equip future architects for 21st-century environmental challenges.

E. Disciplinary Integration and Collaboration

Disciplinary integration in architectural education is a multifaceted approach that seeks to bridge the gap between architecture and related fields such as engineering and construction, helping students meet the demands of the modern built environment. The Bauhaus movement and theories from Foucault and Bourdieu have significantly influenced this understanding of integrating disciplinary knowledge in architecture. It redefined the relationship between discipline, profession, and society, emphasizing the need for education to adapt to societal changes (İmamoğlu, 2022).

Institutions like UCL have embraced multidisciplinary curricula, combining architecture and engineering, with design studios playing a key role in fostering student collaboration and innovation (Oliveira et al., 2021). In addition, Badawi & Abdullah (2021) showed that Interdisciplinary Design Courses (IDCs) enhance students' understanding of the integrated design process by fostering collaboration between architecture and engineering students. This leads to greater knowledge and appreciation of each other's disciplines. Ali (2019)

added that case studies demonstrate how these interdisciplinary projects improve students' grasp of collaborative learning and the contributions of various fields.

Moreover, Altun & Tyurkay (2016) described the "Construction Project Studio" at Istanbul Technical University, which simulates a professional architectural office. This approach combines various design systems, helping students navigate the complexities of real-world practice. As lead architects, students collaborate with experts from different disciplines, such as structural engineers and mechanical systems specialists, to create integrated designs. This method bridges the gap between academic studios and professional practice, ensuring students are prepared to manage and integrate different building systems into their designs.

Overall, Table 2.3 summarizes these strategies, which involve synthesizing diverse teaching approaches in architectural design education. This table classifies the applied approaches into key areas. It supports each approach with a direct advantage, helping to illustrate how these methodologies contribute to the development of the multifaceted nature of architectural education. To further refine and enhance these architectural educational strategies, it is noted that architectural education has been affected by digital and technological transformation, which are addressed in the next section.

Table 2.3: Summary of applied reform approaches in architectural design education

Approaches in Architectural Education	Advantages of This Approach	Sources
Bloom Taxonomy in Architecture Design Studio	Enhances comprehension and application of complex concepts through structured cognitive development from basic knowledge to creative application.	(Krathwohl, 2002; Armstrong, 2010; Adams, 2015; Attia, 2020; Anderson & Krathwohl, 2001; Nurmatova & Altun, 2023; Valsson, 2022; Gour, 2019; Ibrahim & Utaberta, 2012; Patil & Gaurshettiwar, 2016; Arens et al., 2009; Rahbarianyazd & Nia, 2019)

Integrating Academic and practice in the Design Studio	Promotes the real-world application of theoretical knowledge, enhancing analytical and creative skills in real-world settings.	(Altun & Tyurkay, 2016; Kristianova & Jaszcak, 2020; Park, 2020; Albukhari, 2021; Rizk, 2019; Rahbarianyazd & Nia, 2019; Masatlioğlu et al., 2024)
Active learning-based methods, Team Collaboration	Encourages critical thinking and problem-solving through interactive and participative learning environments.	(Gour, 2019; A. Soliman, 2017; Hettithanthri & Hansen, 2021; Milosevic, 2021; Ciravoğlu, 2014; Desouki et al., 2022; Kahlon et al., 2023; Rizk, 2019; Ioannou, 2018; Szewczenko & Widzisz-Pronobis, 2020; Masathioğlu & Balaban, 2024)
Sustainability Principles Adaptation	Prepares students to address modern environmental challenges in architecture by embedding sustainability into design processes.	(Al-Hagla, 2012; Mohamed & Elias-Ozkan, 2019; Shi et al., 2021; Mohamed, 2020; Vrontissi et al., 2023; Kastner & Langenberg, 2023; Ceylan, 2021; Bozkurt, 2016; Mohamed & Özkan, 2018; Bradecki et al., 2024; Abboushi & Elzeyadi, 2020)
Disciplinary Integration and Collaboration	Fosters multidisciplinary knowledge and teamwork skills, reflecting the collaborative nature of modern architectural practice.	(Ali, 2019; Oliveira et al., 2021; Badawi & Abdullah, 2021; İmamoğlu, 2022)
The Adaptation of Digital Tools	Facilitates greater collaboration and innovation using digital technologies, enabling remote and interdisciplinary work.	(Ketizmen Onal, 2003; A. Soliman, 2017; Gour, 2019; Hettithanthri & Hansen, 2021; Milosevic, 2021; Dervişoğlu & Yılmaz, 2023; Shi et al., 2021)

2.3 The Transition to Digitalization in Architectural Design Education

The accelerated integration of advanced digital technologies into architectural design has significantly reshaped the discipline, driving remarkable advancements in precision, efficiency, and innovation that are now central to both professional practice and academic curricula. Since the invention of Computer Assisted Architectural Design (CAAD) in the 1960s, the development of Sketchpad in 1963, and the rapid evolution of computer software over the following decades, these milestones are considered key points in the introduction of IT into architectural design (Papamanolis & Geropanta, 2018). Due to advancements in digital tools, printers, and computer software, modern design techniques significantly reduce task implementation time, enhance accuracy, and improve the overall quality of designs. These tools, combined with pre-installed material and asset libraries,

enable the creation of photorealistic 2D/3D visualizations, provide greater flexibility for modifications, and offer optimized long-term storage and archiving solutions, making them superior to traditional design methods (Yildirim & Yavuz, 2012).

With the widespread adoption of digitalization across all industries, the potential for innovation has been expanded to its limits, transforming architectural design into a complex integration of computational techniques, digital tools, structural design, and the increasingly essential aspect of user engagement (Birgonul & Carrasco, 2022).

In addition to the above, the COVID-19 pandemic expedited the transformation of architectural design and education into a more technology-driven, flexible, and user-centered field, accelerating the adoption of digital tools and virtual learning environments (Mahmoud Saleh et al., 2023). This shift not only enhanced the overall architectural design and architectural education but also led to the development of new software, online collaboration platforms, and immersive technologies like parametric design, virtual and extended reality, BIM, Image Processing, Parametric Design Tools, Simulations software, and Computer Aided Architectural Design, which have since become essential components of the architectural design and education.

Using digital tools in architectural design has become mandatory from an educational perspective. This ensures that future architects align with the current professional demand. This change has many challenges, such as the need to have pedagogical methods that can aid in redefining the learning objectives (Masdéu, 2017).

2.3.1 Digital Image Processing

Image processing is a crucial tool in architectural design. It is the method for enhancing, analyzing, and refining visual data. This technique enables architects to create more accurate and aesthetically appealing design concepts to enhance architectural renderings' clarity, precision, and realism. It improves the visualization and communication of design ideas and supports decision-making throughout a project's development. Furthermore, it bridges conceptual design and the project's outcome to ensure that the architectural results are aligned with the initial creative vision. According to Huseynova & Mutallimova (2024), image processing is the technique used to improve image quality or extract information from it by using three main steps, including importing the image, analyzing, and modification, and lastly, producing the outputs needed or expected. Moreover, Vernekar & Bhat (2024) classified image processing into two main categories: simple and digital image processing where the digital as histogram equalization, spatial filtering, and contrast stretching, and finally, the display process. Image processing stages include pre-processing, which is the initial processing steps, and then enhancements using different techniques.

Since the 1960s and the beginning of digital image processing as we know it today, with the establishment of computers, digital image processing techniques were developed primarily for space exploration by NASA. However, Vernekar and Bhat (2024) concluded that recent studies for digital image processing are focusing on Convolutional Neural Networks (CNNs), Machine Learning (ML), and Deep Learning (DL) methods for image processing to improve traditional digital imaging techniques in applications including medical imaging analysis, self-driving vehicles, security and monitoring systems, technologies.

Image processing techniques are divided into different categories, including basic techniques to improve color and eliminate noise, compression, which is considered a medium-level technique, and information extraction, which is the highest-level approach that includes recognition, segmentation, and detection algorithms (Patil et al., 2024). Going deeper in understanding image processing with Ilyas et al. (2019), who discussed image-processing architectures that should be in a two-dimensional form, such as FPGA, SIMPil, and SURE engine, concluded that different image-processing architectures are best for different applications in image-processing systems.

Image processing applications are limitless; they enhance images and analyze data that can be used for a wide range of purposes. Mahmood (2024) stated that there were around 15 contributions to image processing that ML or DL may be used, and categorized them into three main groups: object detection, such as multi-pedestrian detection and tracking and license plate detection; object recognition, such as animal behavior, optical character recognition (OCR), and fruit freshness classification. Lastly, Image manipulations, such as the analysis of mammography images and the PhotoMatch tool are used for image matching.

Digital image processing has become an essential tool in various fields, including architectural design, where it plays a pivotal role in enhancing visual data and supporting creative vision. Over the years, the field has expanded from simple image enhancements to incorporating advanced techniques like DL, significantly broadening its range of applications. In the architecture design studio, this technology not only improves the clarity and communication of design concepts but also aids in making informed decisions throughout the design process. As technology continues to progress, the potential uses of

image processing keep growing, making it a critical component in modern design and other technological innovations.

2.3.2 Simulation and Parametric Design Tools

Architecture design is a mixed activity of manual and automated processes, where the creativity of human designers intersects with the precision of digital tools to shape functional and innovative works. To assess these designs, simulation models are essential to help create more efficient, sustainable, and compliant architectural solutions and provide predictive analysis that leads to enhanced results. However, despite the advantages of simulation models in architectural design, there remains a significant challenge in bridging the gap between informal architecture specifications and the formal requirements needed for accurate simulations (Antonino et al., 2018).

Simulator models play a crucial role in modern architectural design, which can go beyond the traditional analysis of the design. They enhance architects' designs by revealing the implications of their decisions on energy consumption and environmental impact, leading to more sustainable and efficient outcomes (Fernandez-Antolin et al., 2022). However, while these models offer significant benefits, they should not replace the deep knowledge and understanding of building science required to perform creative and well-informed work (Abboushi & Elzeyadi, 2020). Instead, they should function as supportive tools that complement the architect's expertise, ensuring that technology enhances the creative and informed decision process.

Another approach in architectural design involves utilizing parametric design tools, where the user can provide his design in parameters form into compatible computer software. Then, it generates multiple designs based on these inputs and provides a range of optimized

solutions from which the designer can choose. The key aspect of parametric design is its ability to handle complex design concepts through scalable and adaptable models. For example, the user can adjust parameters such as curvature, dimensions, and materials, and the parametric software can provide a wide range of architecture outcome models (Li, 2024). The parametric model can adjust or reconfigure itself in response to changes by adapting to the updated parameter values provided by the users (Nasir & Arif, 2023),

Figure 2.11.



Figure 2.11: Parametric design of the Infinity Loop, optimizing natural light, self-shading, and energy efficiency

Source: (Nasir & Arif, 2023)

2.3.3 Building Information Modelling (BIM) and Digital Fabrication

BIM has emerged as a transformative tool in architectural design. It offers a holistic model that enhances collaboration, accuracy, and efficiency, thereby playing a pivotal role in the rapidly advancing landscape of architectural education. BIM has become a crucial tool in architectural project development and offers a collaborative management process that integrates various stakeholders in a project, creating a virtual space that precisely replicates buildings and urban spaces (Nawal Benmicia & Lakhdar Belarbi, 2024). At present, the pressure of using BIM has come from the complexity of building structures and the clients'

requests to access the project data easily and manage the project cost more efficiently (Masdéu, 2017).

On the other hand, and with collaboration with other specialists or consultants who are experts in these digital tools, architects need to develop a diverse set of skills and base knowledge to work effectively and professionally in new digital technology, which is essential for meeting the demands of modern architectural practice, which increasingly requires a cross-functional approach (Masdéu, 2017). Despite the challenges faced by schools of architecture, such as the need for professional competencies and providing the proper training, these requirements force newly graduated architects to seek modern education that aligns with the demands of the professional market, leading to growth within the academic sector of architecture (Masdéu, 2017).

In addition to the above, almost every educational institution has a digital fabrication lab or fabrication tools, such as 3D printers, laser cutting machines, and milling machines. This approach empowers students to learn by doing, enabling them to translate theoretical concepts into practical projects, encouraging creativity, and preparing them for real-world challenges in their future careers. According to Di Marco (2019), the application of fabrication tools, such as plasma, water-jet, and laser, in the architectural design requires a thorough understanding of geometry, 3D modeling, and coding, which can be solved with the support of the Business Incubator.

In digital fabrication, the user cannot control the machine or the tool. Control of that machine or tool is done through computers, with sometimes limited access to some process features, such as speed adjustment. A significant advantage of digital fabrication is its

seamless compatibility with parametric design and computational tools (Rai & Sharma, 2023). Recently, according to a study conducted by Marfo-Yiadom and Owusu (2023) architecture and architectural education have experienced significant developments in the adoption of robotic fabrication due to labor costs, productivity, and environmental issues.

Dörfler (2018) discusses state-of-the-art robotic systems for in situ fabrication in architecture, categorizing them into stationary and mobile robots. Stationary systems provide precise control but are limited by size, while mobile robots offer greater flexibility by moving across the site, requiring advanced sensing for accuracy. These systems aim to reduce prefabrication needs and streamline construction processes, *Figure 2.12*.



Figure 2.12: Stationary rotational robotic system developed by ApsiCor
Source: (Dörfler, 2018)

In architecture education, students and educators show more interest in developing robotic technologies to serve not only as a standard tool to serve an exact task but also to help them create their own models that can break the standard boundaries, where the educators are

playing a crucial role in advancing robotic methodologies, enabling students to merge their design concepts using the automated systems. Also, the integration of these new tools into architectural design strengthens the connection between education and industry, promoting the development of knowledge and productive systems that will shape the future of the discipline (Halabi, 2020).

2.3.4 Augmented Reality (AR) and Virtual Reality (VR)

Augmented Reality (AR) and Virtual Reality (VR), along with Mixed Reality (MR), are often referred to as Extended Reality (XR). They are transformative technologies that have revolutionized architectural design by offering dynamic and interactive experiences and by creating an engaging environment that can narrow the distance between theoretical science and real-life practices and experiences. VR delivers immersive computer simulations that make users feel as if they are part of the virtual environment, and AR adds digital information to the real world, enhancing the user's experience with interactive elements. At the same time, the XR is the intersection of AR and VR, blending physical and digital environments (Sherman & Craig, 2018). These devices will supersede computers and smartphones into a new world where, using glasses or lenses, layering information over our vision fields, the digital will fully integrate with the physical world or possibly even replace it altogether, (Goepel et al., 2023).

In architecture education, many researchers have pointed out the need to transition from traditional methods to new approaches that incorporate digital tools and innovative technologies. Rasouli et al. (2023) stated that VR technologies in architecture education enhance design communication, creativity, and representation through 3D modeling and

real-time interactive environments. Furthermore, Şahbaz (2020) conducted a scientific experiment involving 45 architectural student volunteers, who were divided into three groups to study a historical Greek bathhouse. The group that used the interactive VR program (IHVR) had notable success and gained a deeper understanding than the other two groups.

In addition to the above, and referring to two workshops conducted at The Chinese University of Hong Kong (CUHK) by Goepel et al. (2023), for two workshops that asked students to apply MR techniques in constructing and assembling fabrication of complex bamboo structures, the students who used the XR to assist them in the workshops by giving them instructions through projecting digital information in their field of vision offered an outstanding performance compared to the other groups of students who used conventional construction documentation.

As mentioned earlier, implementing the BIM faces multiple obstacles related to collaboration and communication between stakeholders and the project phases. VR can address this gap by offering expanded capabilities for BIM, enhancing visualization using digital tools such as laser scanning and point cloud with VR, collaborating through digital platforms in solving problems and finding solutions, and improving capabilities and workspace planning to reduce mistakes and crisis conditions ahead of time (Safikhani et al., 2022).

Lastly, we move to education, which should be crucial for architects to keep up with the growing need to shift to the digital world and technology. The result of a questionnaire survey conducted by Crolla et al. (2024) with students from the Master of Architecture

programmes at The University of Hong Kong (HKU) supported by a workshop conducted in a Master of an Architecture program to create a collaborative XR learning environment aiming to enhance student engagement and improve learning outcomes highlighted the urgent need to adopt XR technologies in the educational framework and significantly improve students' visualization capabilities and can narrow the distance between theoretical and practical considerations of the architectural design, *Figure 2.13*.

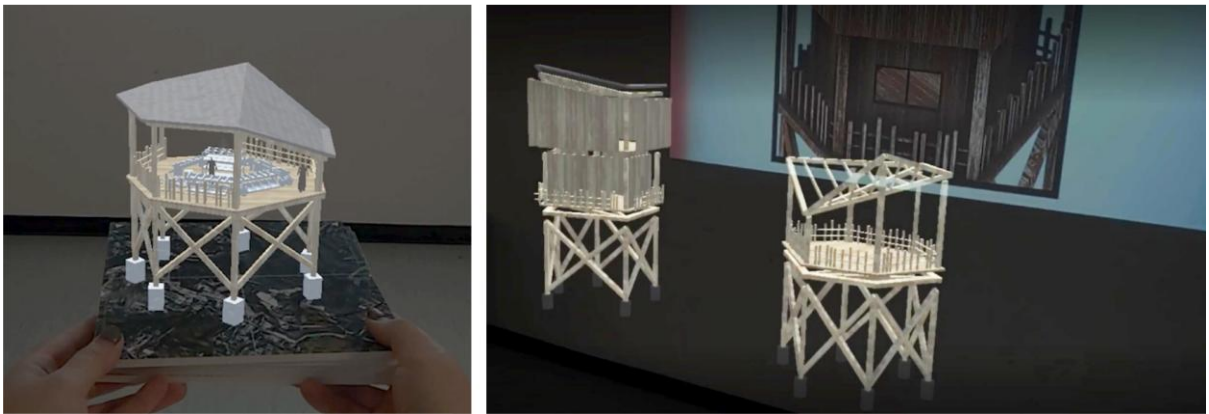


Figure 2.13: AR-enabled presentation tracker triggers a holographic projection
Source: (Crolla et al. 2024)

At the end of this section, in the rapidly advancing field of architectural education, integrating digital applications has become essential for narrowing the distance between theoretical learning and practical application. Table 2.4 outlines the key types of digital tools and technologies used in architectural design, highlighting their specific benefits in enhancing efficiency and creativity. By incorporating these technologies into academic curricula, educators can better prepare students to meet the demands of modern architectural practice in the professional environment and ensure they are prepared with the required skills. Moreover, As technology continues to evolve, it is crucial to explore how the application of AI in architectural design can further transform and enhance the educational process. This topic is examined in the next chapter.

Table 2.4: Benefits of digital applications in supporting the theoretical and practical aspects of architectural education

Application Type	Benefits	References
Computer Assisted Architectural Design (CAAD)	- Enhances design accuracy and quality. - Reduces task implementation time. - Provides flexibility for modifications. - Optimizes storage and archiving.	(Yildirim & Yavuz, 2012; Papamanolis & Geropanta, 2018)
Simulation Tools	- Assists in creating efficient, sustainable, and compliant designs. - Provides predictive analysis for enhanced outcomes. - Supports the environmental impact assessment of design decisions. - Complements architects' expertise with precise digital assessments.	(Fernandez-Antolin et al., 2022; Antonino et al., 2018)
Building Information Modeling (BIM)	- Enhances collaboration and accuracy in project management. - Facilitates the integration of stakeholders in a virtual environment. - Improves project data management and cost efficiency. - Aligns educational training with professional market demands.	(Masdéu, 2017; Nawal Benmicia & Lakhdar Belarbi, 2024)
Augmented Reality (AR) and Virtual Reality (VR)	- Narrow the distance between academic science and real-world application. - Enhances design communication and creativity. - Improves visualization capabilities and understanding of complex structures. - Supports collaborative learning environments and student engagement.	(Rasouli et al., 2023; Şahbaz, 2020; Crolla et al., 2024)
Digital Fabrication Tools	- Translates theoretical concepts into practical projects. - Encourages creativity and prepares students for real-world challenges. - Supports the development of complex designs through parametric modeling. - Promotes hands-on learning and integration of digital and physical processes.	(Di Marco, 2019; Rai & Sharma, 2023)
Digital Image Processing	- Enhances the clarity, precision, and realism of design renderings. - Supports decision-making and communication throughout project development. - Bridges conceptual design with the final architectural outcome. - Expands potential uses in design analysis and creative expression.	(Huseynova & Mutallimova, 2024; Vernekar & Bhat, 2024)

2.4 AI Concept, Definitions, and Development

Starting with the question 'Can machines think?' raised by the mathematician Alan Turing in his paper published in 1950, AI has gone through numerous transformations and advancements throughout its development stages, supported by the progress of computers and technologies, until it reached the advanced form we see today, which is influencing and revolutionizing many fields. In other words, AI is the machine's ability to simulate or

mimic human cognition and reasoning to perform specific tasks with higher efficiency (Pandey, 2024). AI is the merging of various fields, including computer science, engineering, philosophy, linguistics, neuroscience, and psychology (Triantafyllou, 2024).

According to Almulhim (2024), AI consists of three main types: Artificial Narrow Intelligence (ANI), which is used to solve particular tasks and is the most common type of AI, Artificial General Intelligence (AGI), which simulates human intelligence and the way humans think, and Artificial Super Intelligence (ASI), which is the advance form of the AGI, aiming to encompass all human capabilities. This classification matches with Damar et al. (2024) paper that divided AI into three main categories: super-intelligent AI, general AI, and narrow AI.

AI is a broad term that covers different capabilities and technologies. *Figure 2.14* provides a thorough understanding of the AI concept and its related fields, such as ML and DL, eventually leading to the GenAI model that can create new content from data, like text, images, or code, through learned patterns (Banh & Strobel, 2023).

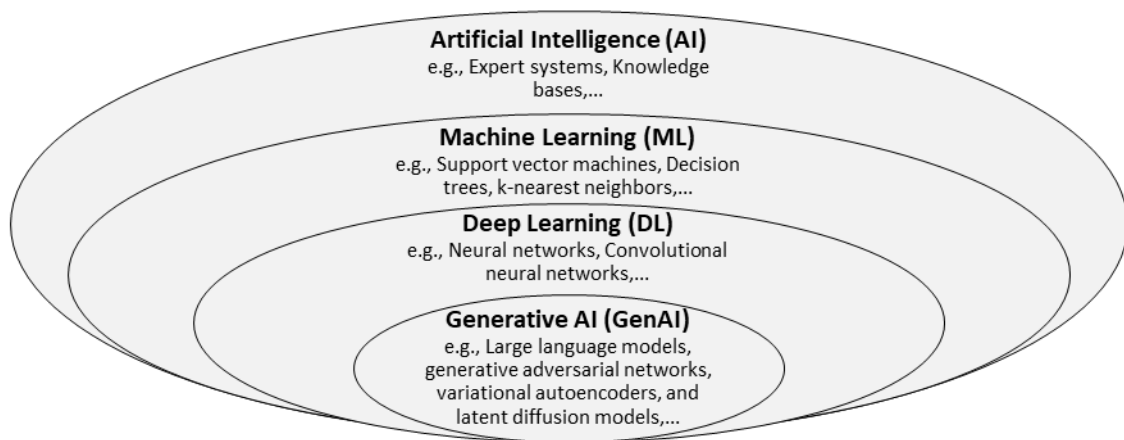


Figure 2.14: AI and GenAI contents
Source: (Banh & Strobel, 2023), Reproduced by the Author

AI began with the question, “Can machines think?”. Today, AI has grown significantly, providing outstanding performance and abilities. Its current form consists of a combination of multiple disciplines. The advancement of technologies has developed various types of AI along with the skills of each. This diverse field now ranges from Narrow AI, also known as “Weak AI,” which performs specific tasks, to Super AI, which aims to replicate all human traits. The following sections dive deeper into the meaning of AI, explore its history and current trends, figure out its concepts, and how it can impact design and education.

2.4.1 Definitions, History, and Development of AI

Sadiku et al. (2020) Defined intelligence in their study on the “Essence of Human Intelligence” as the ability to learn, reason, and understand. It includes the capacity to solve problems, formulate plans, and apply knowledge to adapt to various environments. Intelligence comprises key cognitive skills such as perception, memory, attention, and planning, and it also enables the use of language to express thoughts, ideas, and communicate effectively.

This natural human drive for learning and problem-solving has also extended to machines. Since the invention of mechanical machines, people have continuously sought ways to improve and enhance them, eventually leading to the development of AI, a field that has gone through various stages, experiencing both progress and regression.

Figure 2.15 illustrates the journey and evolution of AI, highlighting the key dates that have shaped the field into its current form. According to a study conducted by Kılınç and Keçecioğlu (2024) on the history of GenAI, AI began in 1956 when it was introduced as a formal scientific field at the Dartmouth Conference. In 1958, Frank Rosenblatt designed

the first neural network. In the 1960s, the first chatbot, ELIZA, was developed, along with basic computer vision systems advancements. The 1970s saw the early formation of GenAI. In 1982, Recurrent Neural Networks (RNNs) were created, enhancing AI's ability to generate sentences. The year 1997 witnessed the development of Long Short-Term Memory (LSTM), improving AI's ability to handle long data sequences. The 2000s recorded many advancements in neural networks and deep learning (DL). In the 2010s, there was a rapid evolution of GenAI using deep learning techniques, with 2014 marking the introduction of GenAI as we know it today. In 2018, OpenAI launched the Generative Pre-trained Transformer (GPT). In 2021, DALL-E and other models like Midjourney were launched, and finally, 2023 saw the release of GPT-4, the most advanced language model to date.

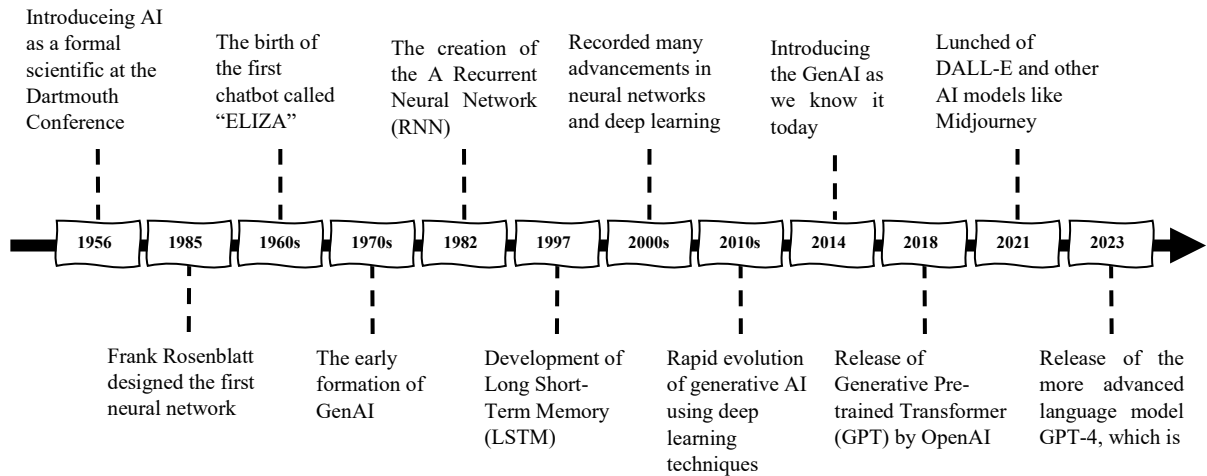


Figure 2.15: Illustrating the journey and evolution of AI
Source: (Kılınç & Keçecioglu, 2024), Reproduced by the Author

2.4.2 Components of AI, Approaches, and Generative AI

As mentioned above, AI is a broad term encompassing various technologies and fields, including ML, Natural Language Processing (NLP), computer vision, robotics, and more.

On the other hand, GenAI, as its name 'generative' suggests, can produce or create new content, such as text, images, videos, and voice. This makes it suitable for use in design, art, writing, music, marketing, and education. GenAI is created in a blending of ML, DL, Artificial Neural Networks (ANN) that simulates the Neural Network of the human brain, NLP that allows machines using computer software to understand and communicate using the natural human language, and finally, the Large Language Model (LLM) which uses the probabilities to allow machines to predict the next word in the speech context (Kalota, 2024).

The key feature of the GenAI is its ability to learn from existing data to create and follow new ones (Alt et al., 2024). Accordingly, it provides a wide range of applications, as shown in *Figure 2.16*, including text-to-image, text-to-code, text-to-video, text-to-voice, and vice versa (Kılınç & Keçecioğlu, 2024).

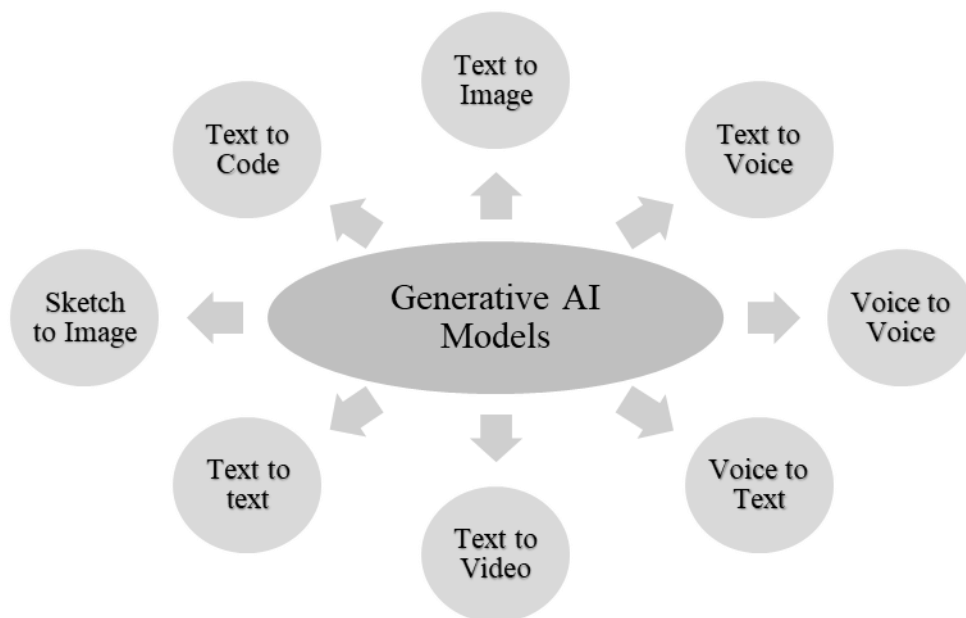


Figure 2.16: Main applications and capabilities of the GenAI related to architectural design

Source: (Kılınç & Keçecioğlu, 2024), Reporuced by the Author

2.5 Current Status of Generative AI in Architectural Design

AI applications in architecture profoundly transform and reshape design practices (Castro Pena et al., 2021). GenAI in architecture refers to applying AI to assist architects by leveraging specific tools to create innovative designs and optimize workflows (Kee et al., 2023). According to Ceylan (2021), AI technologies, particularly generative design algorithms, have revolutionized how architects approach design exploration. Osman (2024) pointed out that generative design not only enhances the creative process but also optimizes performance criteria such as sustainability, cost, and structural integrity.

Generative design utilizes algorithms to create a multitude of design alternatives based on specific parameters set by the designer, allowing architects to explore a broader range of possibilities than traditional methods permit (Ayman et al., 2024). This expansion of design possibilities through AI can inspire architects and foster a more open-minded approach to their work.

Due to AI's abilities to analyze, think, and make decisions. Its applications are limitless across various fields around us. A study conducted by Oluwagbenro (2024) stated around 64 applications in approximately 16 fields where AI can assist in improving efficiency, innovation, and decision-making processes, their fields include Agriculture, Content Creation, Cybersecurity, Data Augmentation, Education, Energy, Entertainment, Design, Finance, Gaming and VR, Healthcare, Law, Manufacturing, Real Estate, Retail, and Transportation.

Another survey performed by Gozalo-Brizuela and Merchan (2024), presented more than 350 applications for the GenAI, divided into 13 parts categorized based on the output, the

context, and the technology used, and covers sectors such as biotechnology, design, art, and business. These categories include Brain, Business, Code and Software, Computational Efficiency, Gaming, Images, Music, Biotechnology, Speech, Text, 3D, Video, and Multimodal.

On the other hand, there are concerns that over-reliance on AI might diminish architects' creative autonomy. As Desouki et al. (2022) stated, that it is essential that AI augments rather than replaces human judgment, ensuring architects remain integral to the design process.

This literature review examines the significant impact of integrating AI technologies on architecture as a profession and architectural education, the potential role of AI in architectural workflow improvement, as well as the challenges that it may face.

2.5.1 Applications and Capabilities of AI in Architecture Practices

A. Building Design

Numerous studies have demonstrated that AI plays a crucial role in the early stages of design exploration and concept generation. AI has significantly transformed the conceptual design process in architecture by offering advanced tools that expand the boundaries of creativity and exploration (Castro Pena et al., 2021). A key contribution of AI is its ability to generate a wide range of unique, out-of-the-box design concept ideas from text-based input (Alvarez, 2024). Text-to-image tools like DALL-E, Craiyon, and MidJourney conversion allow architects to transform simple inputs into high-quality designs effectively (HOŞER & KÖYMEN, 2023).

Furthermore, Novoselchuk et al. (2024) highlighted that AI-generated designs can serve as an initial source of inspiration. AI-based platforms, for example, can select images and designs from a massive database, providing architects with various visual stimuli to spark new ideas and offer unexpected solutions. This capability is particularly useful in educational settings, where students use AI to explore diverse design philosophies and deepen their understanding of architectural concepts.

Moreover, Osman (2024) emphasized the significant role of AI in 3D rendering and architectural visualization. AI-driven tools generate realistic 3D models and renderings that help designers better visualize their designs in the early stages. Golkarian (2024) also explains that AI rendering systems enable high-quality, photorealistic visualizations essential for client presentations and internal iterations. These tools help architects quickly produce renderings with realistic lighting, textures, and materials, improving the design process and communication.

Additionally, Yudhanta & Hadinata (2023) noted that in some cases, AI-generated renderings are used to explore architectural forms inspired by nature or cultural motifs, showing how AI can seamlessly blend creativity with functionality. By incorporating AI into the design exploration process, architects gain access to an expansive library of design ideas that enhance their creative output (Desouki et al., 2023).

B. In Construction and building form

Baduge et al. (2022) stated that AI in construction marks significant progress by enabling architects and engineers to analyze large datasets, improve designs, streamline workflows, and reduce material costs. AI's role spans from the early conceptual stages of design to

real-time project execution, significantly enhancing efficiency and innovation across architectural and construction processes. According to Ceylan (2021), AI-driven tools, such as BIM and generative design software, provide architects and engineers with enhanced capabilities for optimizing construction outcomes. These tools facilitate efficient planning and simulation and automate tasks like clash detection, structural analysis, and design iteration, leading to more accurate and efficient construction processes (Amer, 2023).

Moreover, AI has reshaped traditional building methods through innovations like 3D printing, enabling the automated creation of intricate structures that provide eco-friendly and cost-effective alternatives to traditional construction methods (Fareed et al., 2024). These advanced construction techniques highlight AI's capacity to reduce construction time and resource consumption (Novoselchuk et al., 2024).

C. In Project management

AI's capabilities in construction go beyond design, playing a crucial role in managing projects in real-time. AI-powered systems assist in construction site monitoring, predictive maintenance, and safety management, as Rane (2023) discussed. These technologies reduce human error and improve overall project execution. Furthermore, AI supports material optimization, risk prediction, and process automation in large-scale projects, increasing productivity while minimizing manual labor (Atwa & Saleh, 2023).

The integration of AI into construction methods like robotics and smart vision further enhances project management and on-site safety. Dunaevskiy et al. (2022) emphasized the

potential of AI to automate tasks like 3D modeling, material assembly, and quality checks, streamlining the entire construction workflow.

D. In Environmental Solutions

Harapan et al. (2021) discussed how AI enhances environmental and building solutions. AI technologies, such as BIM and EcoDesigner, allow architects to simulate environmental factors like sunlight exposure, wind patterns, and thermal insulation, making data-driven decisions to optimize energy efficiency and sustainability without requiring on-site evaluations. These tools facilitate the creation of eco-friendly designs that reduce resource consumption and ensure environmental friendliness.

AI further enhances energy optimization through real-time monitoring and predictive analytics. AI-driven tools improve energy efficiency by optimizing Heating, ventilation, and air conditioning (HVAC) systems, predicting maintenance needs to reduce downtime, and supporting net-zero buildings through smart energy management to ensure optimal energy utilization (Rane, 2023).

E. In Advancing Sustainability and Energy Efficiency

Ceylan (2021) discussed how AI transforms sustainable building design by providing architects and engineers with tools to refine energy use, lower environmental impact, and make design decisions more reliable. Tools like Knowledge-Based Engineering and genetic algorithms improve decision-making in early design stages, leading to energy-efficient solutions (Gilner et al., 2019). Furthermore, AI models, like Digital Twins, continuously monitor and optimize building performance, ensuring sustainability

throughout the building lifecycle (Almusaed & Yitmen, 2023). Generative AI tools, such as GANs and CA, help architects design buildings that balance aesthetics and energy efficiency by simulating environmental factors (Milošević et al., 2023). These models are further supported by AI-driven systems that integrate renewable energy sources and optimize systems like HVAC and lighting for long-term sustainability (Karadag & Yildiz, 2024).

Khogali (2024) highlighted that AI-powered design solutions allow architects to generate green building designs incorporating features such as green roofs, terraces, and natural lighting, significantly reducing energy use and ensuring long-term sustainability. These features and AI-driven optimization models may reduce energy use by up to 20%, further advancing sustainable architecture (Karimi et al., 2024).

F. Life Cycle Assessment

Several studies have discussed the significant role of AI in enhancing life cycle assessment by automating data collection, improving predictive modeling, and enabling real-time analysis. Tools like ML and DL help architects and engineers analyze large datasets, making it easier to forecast environmental impacts and streamline sustainability efforts throughout a building's lifecycle, from material selection to energy consumption and waste reduction (Baduge et al., 2022).

Bassey et al. (2024) explained that AI-driven LCA models use large datasets to enhance the accuracy and depth of environmental assessments. These models can adapt to new data, allowing for real-time monitoring and dynamic adjustments, which helps ensure continuous sustainability throughout a building's lifecycle. Furthermore, Płoszaj-Mazurek

& Ryńska (2024) highlight that integrating AI with ML and BIM allows for more accurate carbon footprint estimates, design optimizations, and improved decision-making in architectural projects. This fosters low-carbon designs and contributes to reducing global carbon emissions. In educational contexts, Tabrizi et al. (2023) argued that AI simplifies complex LCA processes for students by automating data collection, predictive modeling, and visualization. This helps students predict environmental impacts, enhance their understanding of sustainable design principles, and promote resource-efficient construction practices.

G. In Material Selection

Ran (2023) highlighted how AI has significant capabilities in material selection in architecture, enabling architects to make informed, data-driven decisions. Tools like ChatGPT analyze material properties, such as strength, durability, and environmental impact, helping architects choose eco-friendly materials that meet structural and sustainability goals.

Atwa & Saleh (2023) emphasized how AI, combined with 3D printing, improves resource efficiency by enabling the creation of complex structures with fewer materials, reducing waste while maintaining structural integrity and promoting sustainability. Furthermore, Baduge et al. (2022) focused on AI's predictive capabilities in material performance. Using ML and DL models, AI forecasts the durability and strength of materials like concrete and steel, ensuring they meet performance standards, reducing physical testing and waste, and enhancing efficiency and sustainability in construction.

H. In Smart Cities and urban planning

Lukovich (2023) discussed AI's transformative impact on smart cities and urban planning, where it analyzes vast datasets related to infrastructure, population growth, and environmental factors. Tools like parametric design systems enable planners to create sustainable urban layouts, while real-time data from citizens improves infrastructure, transportation, and environmental management, making cities more adaptable to growth and aligning with sustainability goals.

Atwa & Saleh (2023) highlighted AI's role in optimizing urban resource management through sensors and IoT technologies. These systems enhance public services by improving transportation, energy, and waste management while monitoring environmental conditions to reduce traffic and promote sustainability. Baduge et al. (2022) discussed how AI integrates data from IoT devices and sensors using ML and DL. These tools enable predictive modeling and resource optimization, helping cities become more resilient and environmentally sustainable through smarter decision-making and improved infrastructure. However, Othengrafen et al. (2024) stated AI's ability to streamline urban planning by categorizing data and identifying patterns to assist with tasks like assessing road conditions while leaving final decisions to human planners.

Xu et al. (2024) expanded on the use of generative AI to autonomously create data, 3D models, and designs. This AI helps optimize urban operations across sectors like transportation, energy, and infrastructure by automating processes and improving scalability. As depicted in

Table 2.5, generative AI plays a critical role in major smart city sectors, showing its influence on enhancing sustainable urban development and decision-making processes.

Table 2.5: GenAI applications in smart cities
Source: (Xu et al., 2024)

Generative AI in Smart Cities			
Transportation and Mobility	Energy System	Urban Water	Building and Infrastructure
Data Augmentation		Synthetic Data & Scenario Generation	
○ Improving data diversity and balance ○ Improving the training of predictive models		○ Simulating rare events under future or hypothetical conditions ○ Enabling prediction and forecasting	
3D City Modeling		Generating Urban Design	
○ Automating the generation of 3 D building Infrastructure, and street ○ Supporting Autonomous system development		○ AI-aided urban design and planning for generating opinion and alternative ○ Optimizing complex urban decision	

I. AI in Traditional Architecture and Heritage

Integrating AI into traditional and heritage architecture reshapes how architects preserve, reinterpret, and modernize historical designs. Hegazy & Saleh (2023) highlighted AI's ability to analyze patterns and elements from heritage structures and apply them to new designs, helping preserve cultural identity. AI replicates traditional architectural elements through machine learning algorithms while streamlining restoration processes by predicting structural needs and preserving materials, making it essential for heritage conservation.

Golkarian (2024) further explored AI's impact on traditional architecture, highlighting how AI-driven visual tools like Midjourney and DALL-E 3 assist architects in creating culturally resonant designs. These technologies help reimagine and modernize traditional architectural elements, ensuring heritage design remains relevant in contemporary

practices. However, Sukkar et al. (2024) warned that while AI enhances design capabilities, it risks oversimplifying cultural heritage without careful application, making human expertise essential for verifying the accuracy and authenticity of recreated architectural elements.

Moreover, Zhang et al. (2024) introduced ArchGPT, an AI agent that aids in conserving and renovating traditional structures by analyzing architectural data, assessing structural damage, and facilitating stakeholder communication. As shown in *Figure 2.17*, this AI system uses image recognition and 3D modeling to propose restoration plans that balance modern needs with historical preservation, promoting more efficient renovation processes.

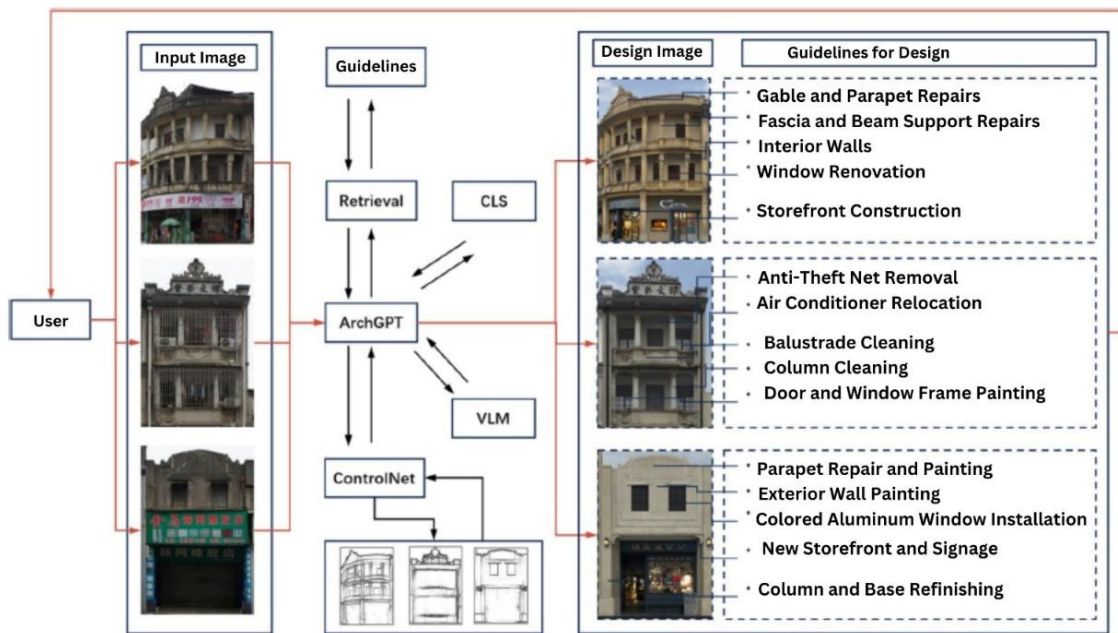


Figure 2.17: ArchGPT application for renovation of the traditional architectural heritage
Source: (Zhang et al., 2024)

2.5.2 Current Application of AI Tools in Architectural Design

A. Pre-design and Problem Solving

Another approach in architecture design that can be used at an early stage is the use of general AI platforms, such as ChatGPT. ChatGPT stands for “Chat Generative Pre-trained Transformer,” a chatbot that can be defined as a LLM and can interact with users like humans. ChatGPT is an AI-powered tool that provides human-like conversations, which can answer questions and assist with tasks like crafting emails, essays, and code (Sindhu Devi S, 2024). An interview that consists of eleven questions was conducted by Caliskan (2023) with ChatGPT in January 2023 to explore the possibilities, conflicts, and limitations of using ChatGPT as a knowledge source in shaping third-year architectural design studio work. The result shows that while ChatGPT offers valuable suggestions and generates a broad range of ideas for design studio projects, a collaborative approach, combining instructor experience, education, and various research resources, is indispensable.

B. Visualization and Concept Generation

This section delves into the details and explores the integration of AI-driven tools specifically tailored for use in architectural design, focusing on their diverse applications and potential impact. In a study by Ploennigs and Berger (2022), they discussed and compared three common AI tools in architectural design, called Midjourney, DALL-E 2, and StableDiffusion, and analyzed their capabilities using case studies. The results demonstrated variant capabilities for various design tasks, including ideation, sketches, collages, image combinations, build and style variants, construction plans, exterior and interior design, and creating textures, while proving potential for future improvement. These previous tools can be classified as text-to-image AI tools. Text-to-image generation

models such as DALL-E, Midjourney, and Stable Diffusion can generate images when the user provides a text input by using ML techniques utilized in AI language models (Stanusch, 2021).

In addition to the above, another study done by Fareed et al. (2024), about two workshops conducted with their university students about the AI Text-to-Image generators called Criteria, DALL-E, Midjourney, Stable Diffusion, and Leonardo AI, to identify their capabilities and investigate the potential future enhancements.

The process of creating and refining images using AI models like Midjourney, DALL-E, and Stable Diffusion involves a detailed manipulation of prompts to achieve desired visual results. *Figure 2.18* illustrates how Midjourney is particularly useful for generating initial creative concepts through free-form ideation, as exemplified by the prompt "single-family home with garden, full exterior view, modern architecture, photo, sunlight" (Ploennigs & Berger, 2022).

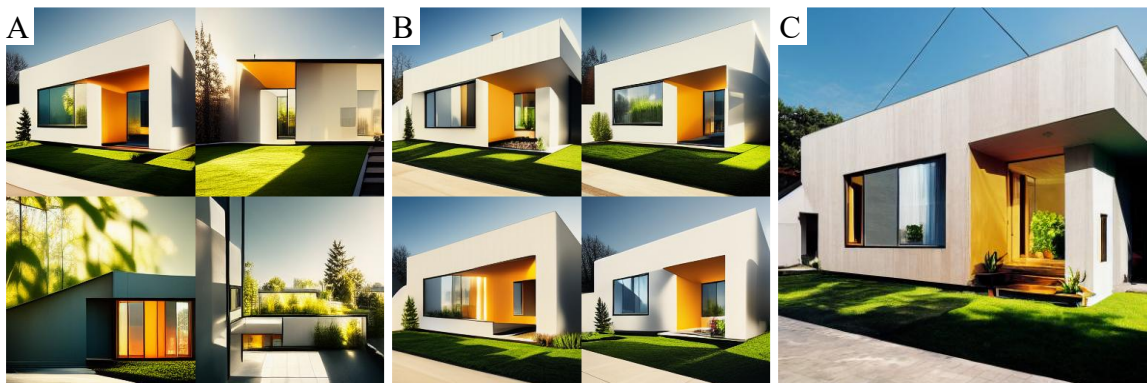


Figure 2.18: Multiple generations and enhancements using Midjourney. Panel A shows the original query result; Panel B displays variant options; Panel C is the enhanced and refined version.

Source: (Ploennigs & Berger, 2022)

C. Generative Design and Parametric Tools

Parametric Design, as its name applies, refers to a technique of using parameters to create an architecture design using available tools and software. M. Desouki et al. (2023) studied several AI software for architecture design, including Archistar, Conix, Spacemaker, and TestFit, where they studied their features and practices. Also, his study incorporated a questionnaire that included questions about parametric software, and the result showed familiarity among Egyptian architects toward parametric software such as Grasshopper, Dynamo, Maya, Rhino, and Ansys Fluent.

Figure 2.19 showcases the real-time analysis and visual information provided by Autodesk Forma (previously Spacemaker), a cloud-based tool designed to assist architects in the early stages of planning and design. It allowed users to assess factors such as terrain, wind, lighting, and zoning. This figure emphasizes how the software integrates data-driven insights to optimize various aspects of urban development, such as environmental factors, building massing, and site-specific constraints. By leveraging AI, the tool enables rapid iteration and visualization, helping architects make informed decisions and improve the overall quality of design proposals (Sourek, 2024).



Figure 2.19: Real-time design analysis in Autodesk Forma
Source: (Sourek, 2024)

D. Sketch-to-Architecture

Another method for implementing architectural design is the sketch-to-image or the sketch-to-architectural technique, where the designer draws their imaginary layout, and an AI tool converts it to an image. Li et al. studied this technique in their paper published in 2023. They utilized generative AI models to convert simple sketches into conceptual floorplans and 3D models. In other words, they employed the Stable Diffusion tool for image generation and integrated LoRA (Low-Rank Adaptation) and ControlNet; then, they processed using Rhino and Grasshopper to create 3D models and architectural renderings. This approach enables precise control over the input text, accelerates the early design phases, and provides creative possibilities for architects (P. Li et al., 2024).

According to Khogali's (2024) paper about 8 case studies utilizing AI. In case study 8, the student applied AI tools to develop the 3D model and render environmental solutions,

focusing on biophilic design and sustainability. *Figure 2.20* showcase the progression of architectural concepts from initial sketches to more refined designs using AI tools. The figure starts with a basic sketch, where AI is applied to develop key design elements, such as form and structure, through multiple iterations. The figure highlights how AI can assist in visualizing different design outcomes based on user inputs, making the transformation from a rough sketch to a more defined architectural concept more efficient. Also, it illustrates how an architectural concept inspired by nature is shaped from a sketch into a final design. The integration of natural elements, such as biophilic forms, adds depth to the architectural narrative, blending functionality with aesthetic inspiration.



Figure 2.20: A. Initial concept: Sketches develop into a conceptual model; B. Development: The concept evolves into a detailed 3D model; C. Enhancement: The model is refined with realistic textures and lighting; D. Final rendering: The completed design features sustainable elements like green roofs.

Source: (Khogali, 2024)

In addition to above, *Figure 2.21* emphasizes the role of AI in the rendering phase, where the initial architectural design is brought to life with detailed visualizations. This figure focuses on applying sustainability principles, showing how AI can enhance the design by incorporating elements like green roofs, terraces, and natural lighting.

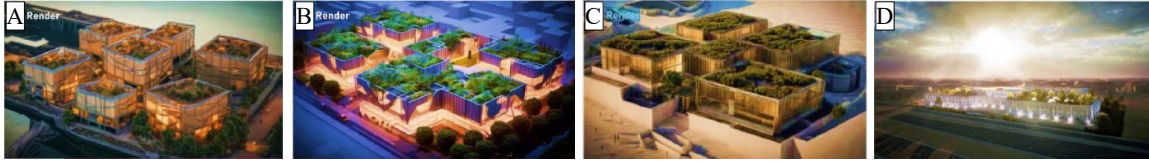


Figure 2.21: A. Initial model: Integrates terraces; B. Colorful enhancement: Highlights vibrant lighting; C. Sustainable features: Includes green roofs and glass; D. Final rendering: Displays lighting effects.

Source: (Khogali, 2024)

E. Building Analysis and Environmental Optimization

Moreover, other AI tools can be used in building analysis and environmental optimization to help improve energy efficiency, optimize material usage, and enhance the sustainability of building designs. The Shadedat tool measures the duration of a building's exposure to sunlight and tracks the direction of its shadow. This data can be analyzed and applied to design building envelopes that are optimized for local climatic conditions (Yudhanta & Hadinata, 2023).

In summary, AI applications and tools for architectural design are extensive, continuously evolving, and expanding daily. *Figure 2.22* presents an overview compiled by the author from the literature and a web search for the most commonly used AI tools in architectural design, arranged based on their functionalities.

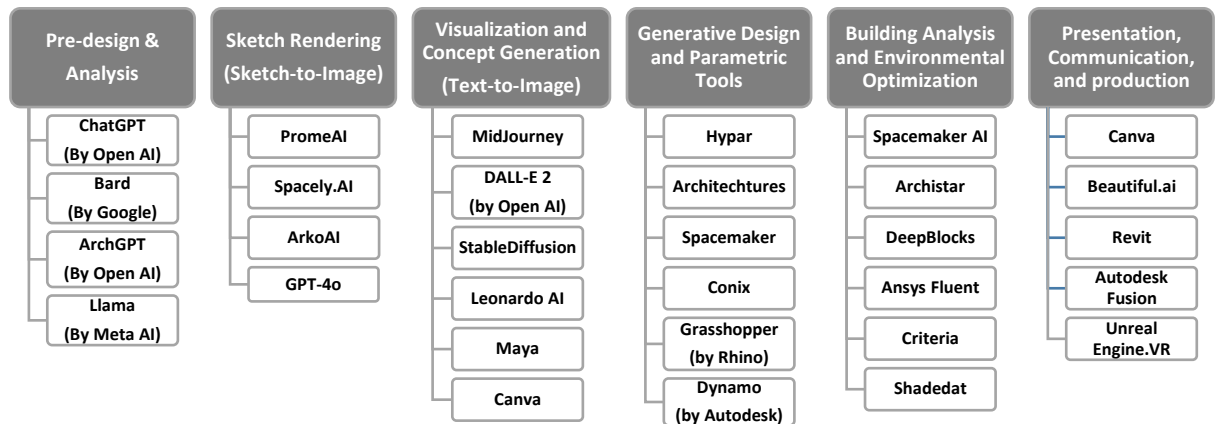


Figure 2.22: Common AI tools for architecture design arranged based on their functionalities
Compiled by the Author

2.6 Integration of Generative AI in Architectural Design Education

AI is increasingly influencing architectural practice, prompting discussions about the need for its integration into architectural education. Thula (2024) suggests that architecture schools may incorporate AI to equip students with relevant tools and strategies for the evolving profession. Similarly, Yildirim (2023) notes that the adoption of AI tools in education has highlighted the potential need to reconsider traditional pedagogical approaches.

In addition, a study by Kee et al. (2023), conducted through an online questionnaire in two universities in Mainland China and Hong Kong, with students from architecture and non-architecture disciplines participating, revealed that the architecture students have already frequently applied AI tools during their design phases.

AI has evolved significantly every day, which requires collaboration from all parties to maximize the benefits of AI technology and avoid any potential risks to ensure

the optimum implementation of this technology. For AI integration to be successful, teachers need to focus on reshaping curricula, integrating AI tools into design studios, and ensuring that students master AI-based software to meet the demands of contemporary architectural practices (Petráková & Šimkovič, 2023). Ceylan, (2021b) highlighted that architecture is one of the most discipline affected by the advancement of AI technology, and because of its nature and the level of complexity in its practice, it is a significant area for AI experiments and applications.

On the other hand, (Çelik et al., 2023) state that in the presence of such a need, a balance must be maintained between technology-based and human-centered design processes without compromising the development of manual skills and practical competencies of students, as noted also by (Sadek & Mohamed, 2023).

2.6.1 Process of the Architectural Design Studio

Referring to section 2.2.1, which addresses reviewing architectural design processes in education and referencing to Table 2.1 developed in the same section, and according to the study vision, the design process can be categorized as follows: The Analysis phase (Pre-design) involves data collection to gather essential information, determining the project typology, identifying and addressing problems, establishing the design settings, and clearly defining project goals.

Following this, the Conceptual Design (Synthesis) phase involves crafting and developing the initial conceptual model, including the design idea and philosophy, supported by sources of inspiration and creative exploration.

The third phase is Design Development, where the project's characteristics, such as spatial organization, circulation, and material strategies, are clarified. This phase includes creating 2D drawings and documentation, developing 3D massing models, and assessing the design through refinement and feedback.

Finally, the Design Production phase includes producing visual 3D renders of the project in its urban context, editing renderings, and preparing presentation materials to effectively communicate the design. As part of this phase, post-production tasks may also be performed, including optional editing of renderings such as lighting and colors, and adding design elements, *Figure 2.23*.

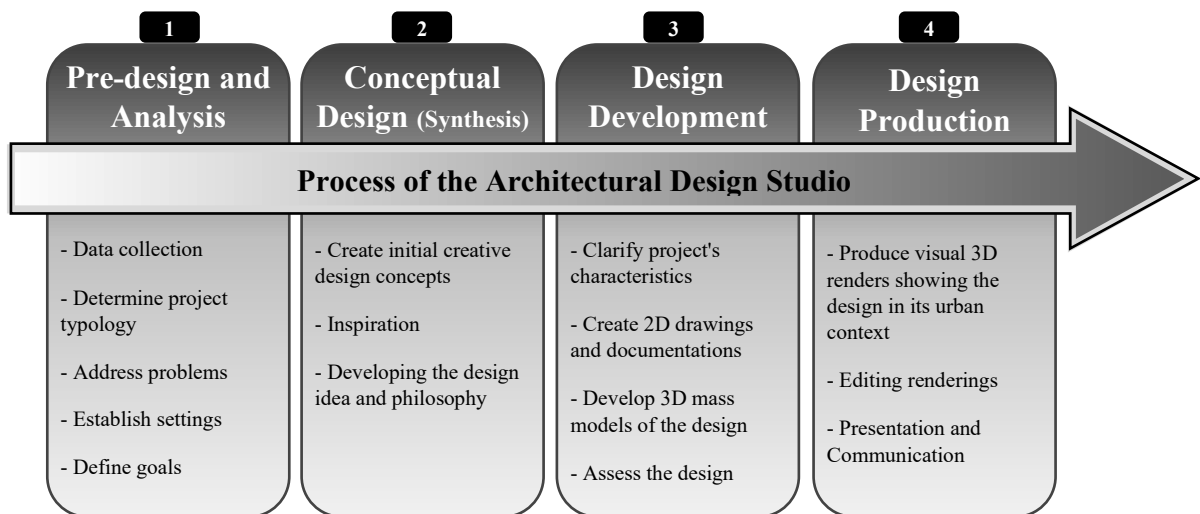


Figure 2.23: Process of the architecture design studio

Moving forward with implementing AI tools in architectural design studios, *Figure 2.22* presents an overview of the common AI tools utilized in architectural design. This section thoroughly explore the current role of AI tools across every phase of the architectural design process.

A. Pre-design and Analysis

At this initial stage, AI-powered chatbots, LLM, such as ChatGPT and Bard, can assist in gathering project information, analyzing site constraints, and generating preliminary design ideas. They also can help review environmental factors, zoning regulations, and user preferences to inform the design process. Meron and Tekmen Araci (2023) who are current lecturers and course coordinators, conducted a semi-structured exploratory conversation with ChatGPT to investigate its potential as a virtual colleague. Their study consisted of multiple case studies; the first case study was working alongside ChatGPT to prepare a design student assignment, and the second case study was utilizing ChatGPT to develop a postgraduate design studio course. The authors found that ChatGPT accelerated the creation of structured templates for course development and was a useful tool for brainstorming and editing, improving time management, and reducing workload. However, the authors found that ChatGPT shows a shortage of its ability to fully replace human administrators and requires guidance from experienced educators in complex tasks and where context-specific results are required. The result shows that ChatGPT outputs is generic, structured and formatted, and it is not a fully developed content. Also, it lacks creativity and struggles with higher-order thinking.

Kenney (2023) in his study, he also mentioned that ChatGPT was developed and programmed strictly within a limited number of parameters, and it can not operate outside of these parameters. Hence, it is incapable of being fully creative. Chellappa and Luximon (2024) conclude in their study that it is still unclear whether ChatGPT can elevate the creativity of design students or not.

Moreover, ChatGPT can generate summaries and identify main points, saving considerable time and effort and allowing users to pay more attention to higher-priority tasks and analysis. However, it can not be used for tasks that require a high level of creativity and can not fully replace human intelligence (Aljanabi et al., 2023). As stated by Samad et al., (2024) ChatGPT can analyze data and provide explanations. It can also summarize key findings, spot connections, and suggest hypotheses based on available data. Finally, it is crucial to draw attention to critical information and review results while using LLM, such as GPT, Bard, or Llama. According to the developer company “Open AI” may provide inaccurate information (Oertner, 2024).

B. Conceptual Design (Synthesis)

This is the next phase of the design process, where the conceptual framework of a project is developed. During this stage, designers explore and refine ideas through various mediums, such as sketches, physical models, digital simulations, and diagrams. These tools help visualize and shape the core concepts, creating a foundation for further design development and decision-making.

(Derevyanko & Zalevska, 2023), compared Midjourney, Stable Diffusion, and DALL-E in terms of purpose, features, training, and use, and their main differences in education. The outcome shows that Midjourney and DALL-E can generate creative ideas for students and provide expressive visuals, while Stable Diffusion helps students create visualizations for their projects. Another study conducted by Cudzik & Nyka (2024b) focused on employing AI tools in architectural design, and the results showed that using AI tools enhanced students' efficiency in image generation and material selection. Also, in this art stage,

utilizing AI tools can inspire students and lead to fast idea development intended to achieve.

Novoselchuk et al. (2023) pointed out that AI adoption in architectural education offers numerous advantages, especially in enhancing creativity, efficiency, and technical alignment. Applications of these generative AI tools and neural networks, such as DALL-E and MidJourney, allowed students and architects to visualize complex designs faster and in more detail. This allows the investigation of innovative solutions during the concept development phase that can be proposed by feeding creativity with more possibilities.

Sketching is another technique used in architectural design, transforming thoughts into visible and tangible concepts. AI can be incorporated at this stage to open new opportunities, allowing architects to explore a broader range of possibilities before moving forward with more detailed planning. Even with the advancement of technology and interactive screens, free-hand sketching is still the most popular way to express the designers' ideas quickly (Budiman¹ et al., 2021). Also, many creative professionals consider sketches as the main tool in their design process (Moreira da Silva, 2023).

Additional AI image-generation platforms, such as Imagine Art and Leonardo AI, are also gaining traction for concept development and offer students further visual inspiration and design variation capabilities.

C. Design Development

At this phase, the project's characteristics are clarified, a design model is developed, assessed for functionality and aesthetics, and detailed drawings and documentation are

created for implementation. Parametric AI tools significantly enhance the design development phase in architecture by enabling the creation of complex, adaptive forms. These tools, such as Grasshopper, allow architects to generate multiple design variations that respond to environmental factors like sunlight and site conditions. By integrating AI, designers can optimize their models for sustainability and efficiency, making the design process faster and more innovative (Maksoud & Al-Beer, 2022).

According to Bölek et al. (2023), Grasshopper and Dynamo are popular examples of visual programming tools, both of which function by integrating with various design applications. When comparing the two, Dynamo tends to offer more advantages over Grasshopper. This is primarily due to its distinctive features, which enhance collaboration with a broader range of stakeholders, particularly within BIM-based workflows.

A study by (Taico-Valverde & Castillo-Sosa, 2024) concluded that parametric design tools and the integration of AI have a significant impact on the construction industry. Parametric design tools, such as Rhinoceros 3D combined with Grasshopper, are widely used for creating adaptive and complex models, transforming the design process by enabling detailed simulations and automating tasks. These findings highlight the importance of embracing these technologies to enhance efficiency and improve the quality of outcomes in the construction sector.

Moreover, the use of software like Conix has transformed the design process by introducing a digital, symbolic approach. Designers can modify models using computational techniques and artificial intelligence, streamlining the process and enhancing efficiency. This continuous refinement allows access to stored architectural and

design elements from libraries or catalogs, enabling the efficient selection and modification of components to optimize the final design with precision and creativity (Almajaibel, 2024).

In addition to these tools, platforms such as Finch 3D, TestFit, Hypar, and Spacemaker AI offer specialized generative design capabilities, ranging from unit layout automation to large-scale site planning and urban analysis. Architectures AI is another tool that leverages parametric logic to improve form generation and structural adaptation, allowing designers to explore context-sensitive solutions. Integrating these diverse tools supports visual and structural refinement, cross-disciplinary collaboration, performance optimization, and the acceleration of design workflows.

D. Design Production

The Design Production phase involves transforming developed design models into high-quality visual outputs that render and communicate the project clearly and persuasively. At this stage, AI-powered rendering tools are increasingly used to enhance image quality, optimize visual storytelling, and reduce the time needed for post-processing. Platforms such as Lookx.AI, PromeAI, Minimal.ai, and Rerender.ai enable users to produce realistic 3D renderings with advanced control over materials, lighting, and environmental context. These tools leverage machine learning algorithms to automate rendering techniques traditionally handled through manual software like Lumion or V-Ray. (Cudzik & Nyka, 2024b) highlighted how AI image-generation tools enhance the design production phase by enabling students to quickly produce high-quality visuals that support spatial clarity and

design communication. The use of AI reduced time spent on traditional rendering, allowing more focus on refining the conceptual and expressive aspects of design.

Furthermore, the post-production phase focuses on refining visual outputs and preparing presentation materials to communicate the final design effectively. AI-based tools such as Adobe Firefly and Topaz Gigapixel AI offer advanced editing features, upscaling image quality, and enabling visually engaging layout creation. They also streamline the design communication process by allowing quick adjustments to lighting, colors, textures, and overall board composition.

Recent Advancements in ChatGPT Capabilities for Architectural Design Studio

Recent updates announced by (OpenAI, 2025) have expanded ChatGPT's capabilities, particularly with the release of GPT-4o, which supports advanced image inputs and multimodal interaction. As demonstrated by AI Hub (2025), new features enable users to directly convert 3D visual spaces into CAD drawings automatically, streamlining the traditional drafting process as shown in examples A and B in *Figure 2.24*.



Figure 2.24: Conversion of 3D visuals into CAD drawings using ChatGPT.
(Source: AI Hub, 2025)

Other innovations illustrated in *Figure 2.25* include transferring moodboards directly into 3D rendered scenes, simplifying conceptualization. These features have the potential to be applied in architectural design and offer architects and students innovative ways to accelerate conceptual development and visualize and design spaces more efficiently (AI Hub, 2025).

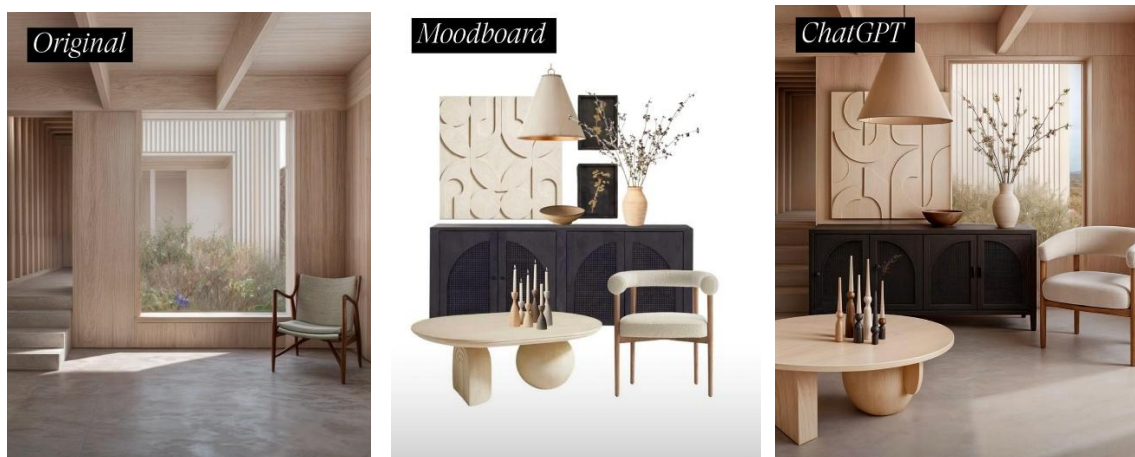


Figure 2.25: Transferring moodboards into rendered 3D scenes using ChatGPT (Source: AI Hub, 2025).

2.6.2 Benefits and Advantages of AI in Architectural Design Education

In a world driven by technology, we constantly seek faster and more efficient ways to complete tasks and employ all available tools. Indeed, AI stands out as one of these technologies with the potential to revolutionize how we work, learn, and interact. The design studio is the most crucial part of architectural education (Erturk & Ucar, 2023). It is where students spend most of their time, extract their full talent, and integrate their knowledge from all other courses to achieve the most innovative and optimal design solutions (Wong, 2023).

Fareed et al. (2024) noted that AI enhances cognitive learning by providing simulation tools that help students visualize complex architectural contexts and engage deeply with

historical styles. Additionally, AI-generated visuals and simulations foster higher-order thinking, such as analysis and creation, aligning with Bloom's taxonomy, as depicted in *Figure 2.26*. By allowing students to manipulate complex designs, AI promotes creativity, critical thinking, and a deeper integration of digital tools with traditional learning to enrich their understanding of architectural theory and practice. Rane (2023) also explained how important AI has been in filling the gaps between theoretical knowledge and practical implementation. By automating routine tasks, AI allows students to allocate more time to creative tasks and critical thinking, resulting in more effective learning.

According to Erdem et al., (2024), incorporating AI into architecture education will increase the need for educators with software expertise and skills. As Cudzik and Nyka (2024a) suggested that empowering educators with the skills to utilize AI tools is crucial, guiding students to apply these technologies for creative design outcomes. These studies by Erdem et al. and by Cudzik and Nyka demonstrated that students who utilized AI in the architecture design studio achieved more creative and innovative results than those who designed using traditional methods.

Moreover, case studies and surveys conducted by Khogali (2024) showed that AI plays a vital role in architectural design, from concept generation to sustainability. The study found that while students successfully used AI for concept development (75%) and sustainability (70%), it emphasizes that educators must adopt AI teaching as a core course in architectural education to help students improve their essential AI skills. However, (Fareed et al., 2024) further highlighted the need for teachers to adapt to this shift, not only by learning how to integrate AI tools but also by addressing ethical concerns, with teachers ensuring that these

technologies enhance students' visual and technical design skills while protecting their critical thinking abilities. (Grajeda-Rosado et al., 2024).

In addition, experimental case studies conducted by Kee et al. (2023) showed how AI tools optimized time-consuming tasks and allowed students to focus on more critical design decisions. Students who used AI in design benefited from better time management and less anxiety, allowing them to explore multiple design alternatives without repetitive load. Karimi et al. (2024) also presented that AI tools strategically optimize sustainability in architectural education by offering solutions for material usage and energy efficiency. Their case study showed that AI-driven design achieved a 20% reduction in energy demand in architectural designs.

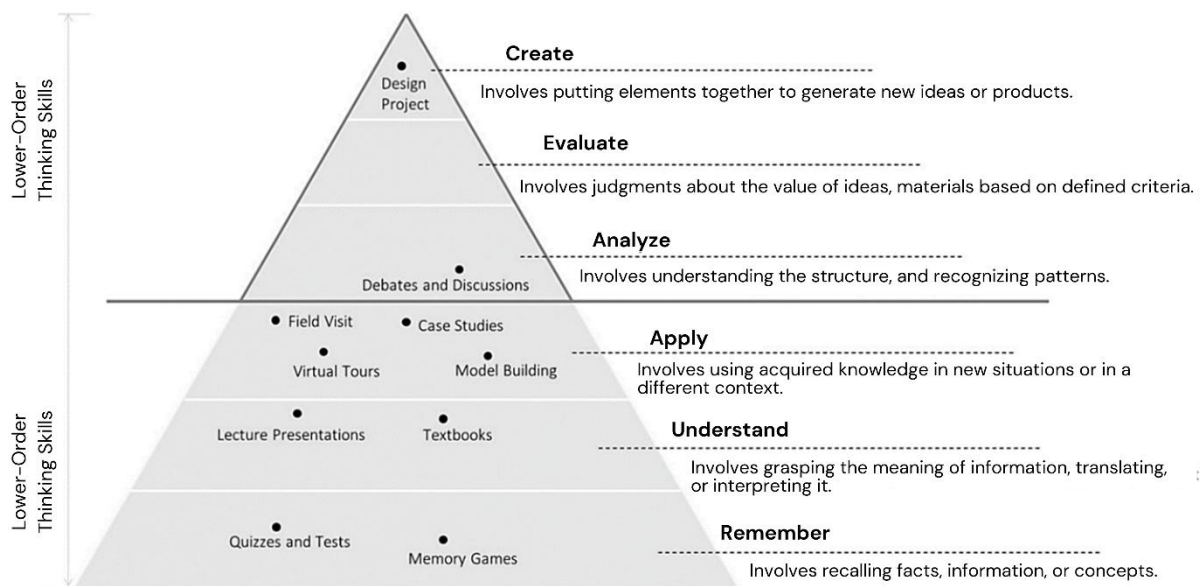


Figure 2.26: Alignment of AI image generator enhancement with advanced cognitive skills in education and Bloom's taxonomy
Source: (Fareed et al., 2024)

However, incorporating AI into the design studio presents new opportunities, along with challenges and potential risks. (Novoselchuk et al., (2024) see that we lack a clear and

consistent way to understand AI within the technical area and in architecture education. Such uncertainty extends into legal, social, moral, and ethical perspectives.

2.6.3 Challenges and Risks of AI Adoption in Architectural Education

Despite the benefits of adopting AI into architectural education, it also poses several risks and challenges. Desouki et al. (2023) pointed to the potential loss of key manual design skills and creative independence. One significant concern was that over-reliance on AI tools could diminish students' abilities in critical thinking, problem-solving, and Practical design experience, which are essential in architecture (Kee et al., 2023). Also, Novoselchuk et al. (2023) noticed that while AI increases in performing routine and data-driven tasks, it may make students passive users of technology and not invest deeply in the creative process or manual refinement of their ideas.

Yildirim (2023) highlighted another challenge, the gap between the tools in professional practice and those in academic settings. Educators were unfamiliar enough with AI technologies; hence, there was a disconnect between architectural education and professional needs. This gap would risk graduating students who cannot handle challenges in the real world because their education does not meet those tools and methods within the profession. Moreover, Caliskan (2023) and Zhang et al. (2023) added that AI, which is necessarily reliant on large datasets and inherently unable to fully replicate cultural and contextual sensitivity, faces challenges in applying this architecture in cases that require a thorough understanding of particular historical or geographical contexts.

Almaz et al. (2024) Argued that GenAI designs lack the human touch and architectural creative core. The creative and emotional intuition required for sensitive architectural projects was rather tough to convey in AI algorithms, which rely on data-driven processes. Furthermore, Sukkar et al. (2024) and Hegazy & Saleh (2023) discussed primary ethical concerns regarding data privacy and the biases embedded in AI models. Such biases may complicate AI's integration into architectural education, as AI tools developed with images from imbalanced datasets would regenerate cultural stereotypes, leading to designs that lack diversity and inclusion.

Ji (2022) expressed concerns about the high costs associated with AI adoption. Institutions with limited resources might not easily afford the needed software, hardware, and training, which could lead to unequal distribution among learning environments. This technological gap could lead to unequal access to AI, giving well-resourced institutions a competitive advantage in educating future architects over those with fewer funds.

While AI presented promising opportunities for enhancing architectural education, Nabizadeh Rafsanjani & Nabizadeh (2023) stressed that its integration must be managed carefully to balance tech advancement with preserving core design skills. Borglund (2022) Agreed, emphasizing that educators must ensure that AI tools complement human creativity and critical thinking rather than replace them.

Table 2.6 Extensively outlines the various risks and challenges of adopting AI in architectural design education based on the current studies, which are highlighted in the research methodology in the next section.

Table 2.6: Risks and challenges of AI adoption in architectural education

Risks and Challenges	References
1. Loss of Manual Design Skills, Human Touch, and Creative Independence.	(Çelik et al., 2023), (Desouki et al., 2023), (Sadiq & Muhammad, 2023), (Yıldırım, 2023), (Ji, 2022), (Harapan et al., 2021), (Sukkar et al., 2024), (Grajeda-Rosado et al., 2024), (Kee et al., 2024), (Novoselchuk et al., 2023), (Petráková & Šimkovič, 2023), (Zhang et al., 2023), (Atwa & Saleh, 2023), (Gallo et al., 2020), (Almaz et al., 2024), (Karadag & Yıldız, 2024), (Borglund, 2022), (Rafsanjani & Nabizadeh, 2023)
2. Imbalance and Over-reliance on AI: (Leading to diminished students' problem-solving abilities and critical thinking skills).	(Kee et al., 2024), (Çelik et al., 2023), (Yıldırım, 2023), (Novoselchuk et al., 2023), (Fareed et al., 2024), (Caliskan, 2023), (Ji, 2022), (Harapan et al., 2021), (Desouki et al., 2023), (Petráková & Šimkovič, 2023), (Zhang et al., 2023), (García del Castillo y López, 2022), (Hegazy & Saleh, 2023), (Atwa & Saleh, 2023), (Jin et al., 2024).
3. Resistance to AI and Threat to Architects' Roles.	(Desouki et al., 2023), (Yıldırım, 2023), (Harapan et al., 2021), (Alcaraz et al., 2024), (Borglund, 2022).
4. Ethical Concerns, Risks of Plagiarism, and Intellectual Property.	(Fareed et al., 2024), (Yıldırım, 2023), (Ji, 2022), (García del Castillo y López, 2022), (Alcaraz et al., 2024), (Rane et al., 2023), (Karimi et al., 2024).
5. Inequitable Access to AI Tools Among Architectural Institutions.	(Yıldırım, 2023), (Gallo et al., 2020), (Karadag & Yıldız, 2024), (Korra et al., 2022), (Karimi et al., 2024), (Borglund, 2022).
6. Bias Data in AI-generated Solutions and Lack of Cultural and Contextual Sensitivity.	(Ji, 2022), (Sukkar et al., 2024), (Desouki et al., 2023), (Zhang et al., 2023), (García del Castillo y López, 2022), (Hegazy & Saleh, 2023), (Almaz et al., 2024), (Karadag & Yıldız, 2024), (Karimi et al., 2024), (Tellios et al., 2023), (Caliskan, 2023).
7. Lack of AI Training and Proficiency for Educators.	(Yıldırım, 2023), (Hegazy & Saleh, 2023), (Li, Ng, & Lee, 2021), (Jin et al., 2024), (Rane et al., 2023), (Karimi et al., 2024), (Sadek, 2023).
8. Generality, Inaccuracy, and Misinformation.	(Caliskan, 2023), (Fareed et al., 2024), (Zhang et al., 2023)
9. Unsystematic Use and Superficial Integration.	(Ji, 2022), (Tellios et al., 2023), (Sadek, 2023), (Basarir, 2022)
10. High Financial Barriers and Cost Constraints.	(Ji, 2022), (Karadag & Yıldız, 2024), (Desouki et al., 2023), (Sadek, 2023).
11. Gap Between Educational and Professional Tools	(Yıldırım, 2023), (Rafsanjani & Nabizadeh, 2023).

2.7 Conclusion of literature

An extensive literature review was conducted on a wide range of relevant topics. By reviewing the contributions of leading scholars and researchers in the field, it was found that previous studies provided insights into developments in architectural design education methodologies, technological transformation, and the emergence of AI integration. The

review highlighted current trends in architectural pedagogy, the growing influence of AI in architectural design, and the potential transformations that AI could bring to traditional pedagogy.

However, there is still a gap in understanding AI's impact on architecture design education, its opportunities and contributions to design processes and stages, its influence on students' creativity, and the challenges and risks this adoption may face. Although GenAI tools are rapidly advancing, educators face challenges integrating AI into their education. This results in a gap between academic learning and professional real-world application.

Another notable gap is the limited research on the long-term effects of AI adoption in architecture education. While studies have begun to explore the potential benefits of AI, such as enhancing creativity and efficiency, there is still insufficient data on how AI tools affect students' creativity and practical skills. This calls for more in-depth investigations into balancing AI tools with traditional design education to ensure a holistic approach to provide practical, evidence-based insights, address key opportunities and challenges that universities may encounter, and propose a strategic framework and recommendations for the responsible integration.

Accordingly, the study provided a framework, as demonstrated in *Figure 2.27*, for utilizing AI tools at each architectural design stage of architecture design from the education perspective. By reviewing the contributions of key scholars and researchers and the latest technological advances in AI adoption, this chapter thoroughly examined the most common generative AI tools and how AI is currently being integrated into architectural education.

Lastly, this literature review served as a foundational basis for the subsequent methodology chapter, where the theoretical insights gained were applied to the practical aspects of research design.

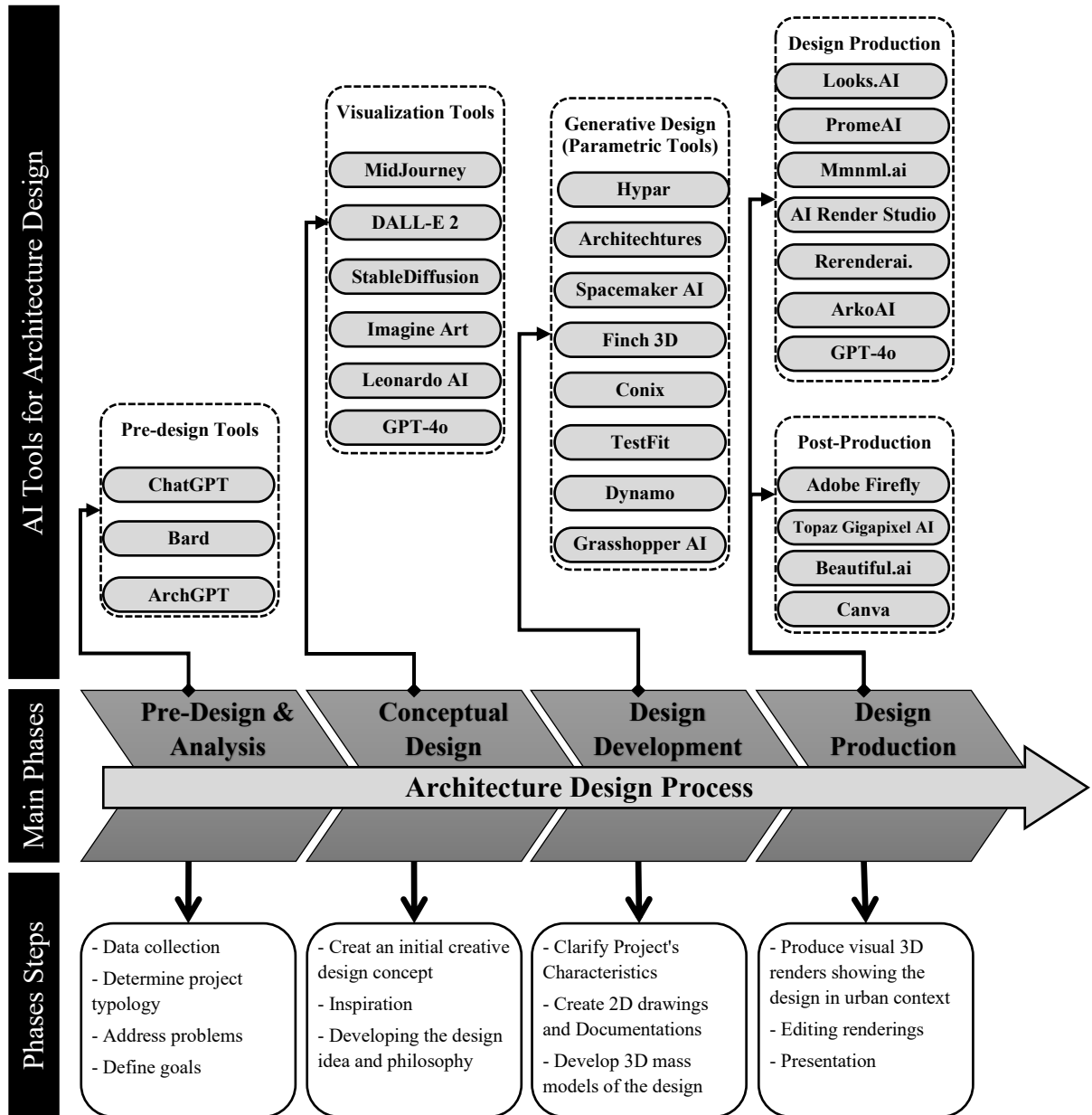


Figure 2.27: Conceptual framework of AI application in architectural design education

Chapter 3 : Research Methodology

3.1 Introduction

Chapter 3 provides an in-depth overview of the research methodology as illustrated in *Figure 3.1*, which aims to explore the potential impact of generative AI in architectural design education by bridging theoretical knowledge with practical realities, providing useful insights into the opportunities and challenges of integrating AI into architectural education. The research methodologies were designed to achieve the main objectives of the study, which, as previously mentioned, include: Objective 1: Determining the role of GenAI in architectural education, focusing on the architectural design process, and Objective 2: Developing recommendations and strategies for integrating GenAI technologies into architectural design education.

To achieve these objectives, the structure of this chapter was divided into four main parts: a comprehensive literature review, which contributed to achieving Objective 1 by identifying key themes, defining the research gap, and establishing the conceptual framework for AI applications. Interviews with professors and questionnaires were conducted with architects, which contributed to achieving Objectives 1 and 2 by gathering perspectives on the role of AI in design education and strategies for its integration. A field experiment was also conducted with architectural students, primarily designed to achieve Objective 1 by observing the practical use and impact of AI tools within the design process. Methodological triangulation was employed in this study, which refers to the use of at least two methods, usually qualitative and quantitative, to address the same research problem, capture diverse perspectives, and increase the validity of the results (Valencia, 2022). By combining these research methods, the study aimed to improve the accuracy and credibility

of the findings, offer a more comprehensive understanding of the potential impact of integrating Gen AI into architectural education, and support the development of practical strategies and recommendations.

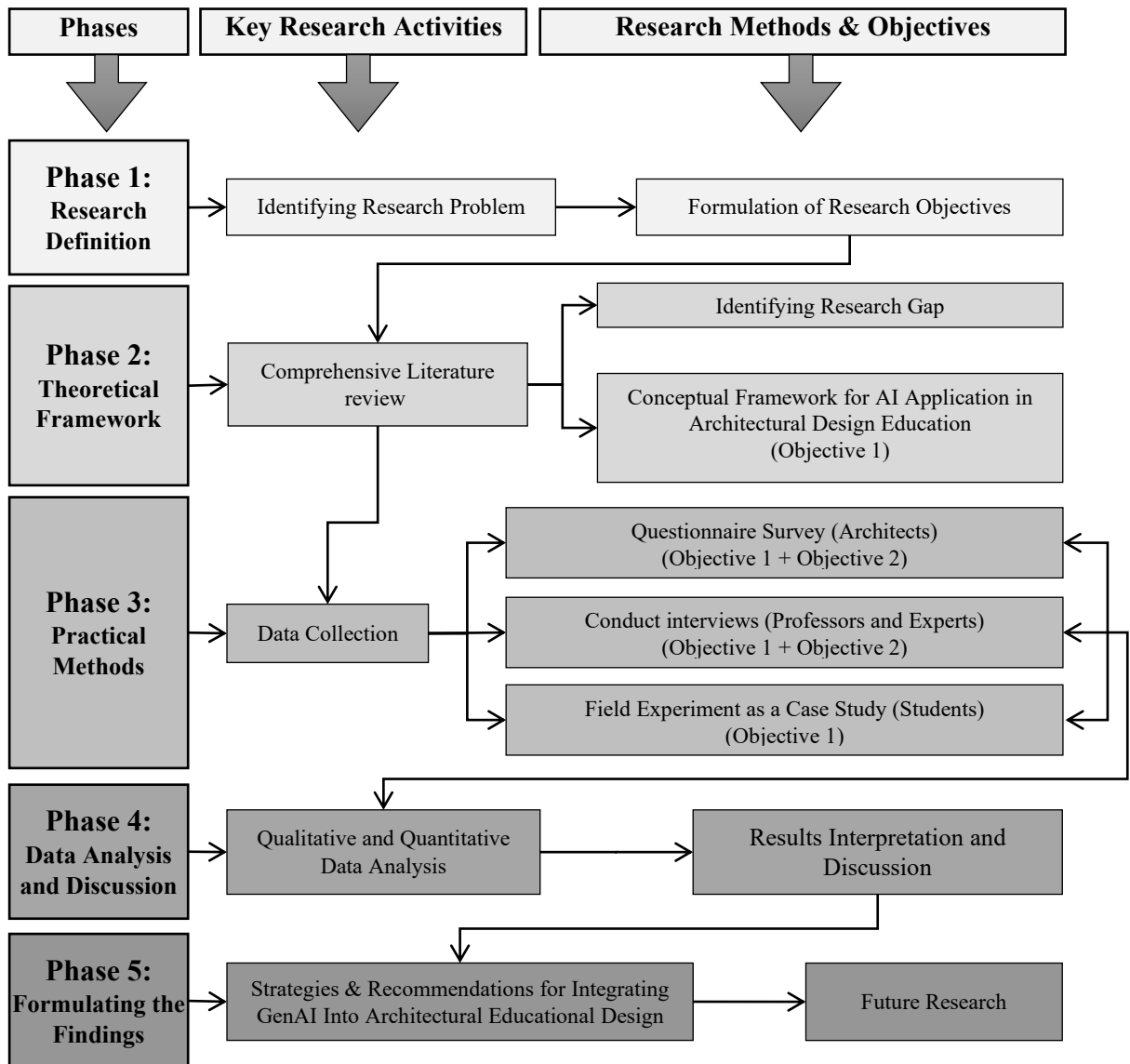


Figure 3.1: Methodological framework of the study

3.2 Literature Review

The literature review supported the study methodology by offering an extensive review of the current state of various topics related to the main subject and the research objectives. Its results and output, including compiled summaries and frameworks, served as essential tools for developing survey questionnaires, crafting interview questions, and designing field experiments. The literature review in the previous chapter provided a comprehensive overview of the current state of conventional architectural design education, the advancements in digitalization within architectural design education, and a concise definition, history, and general concept of AI. This foundation paved the way for discussing and analyzing the current AI tools employed in architectural design.

However, the findings and conclusions of the literature review established two primary frameworks. First, a detailed framework for examining the various stages of architectural design was developed by synthesizing findings from multiple studies, *Figure 2.23*. Second, a framework categorizing the AI tools utilized in architectural design, specifically tailored to align with the different stages outlined in the first framework, *Figure 2.22*. Subsequently, both frameworks were integrated to provide a cohesive structure for the study. The following chapter utilized this integrated framework to conduct an in-depth study of the impact of AI integration at each architectural design stage from an educational perspective, providing guidelines for effectively incorporating AI tools into architectural design education and investigating how this implementation affects students' innovative thinking and creativity.

In addition to the above, a brief literature review was conducted to investigate the benefits, challenges, and risks of utilizing AI in architectural design from an educational perspective, which can later assist in developing the survey questionnaire and conducting interviews.

3.3 Questionnaire Survey

3.3.1 Questionnaire Aim

The research methodology involves conducting a questionnaire survey among architects currently working in Saudi Arabia's labor market to explore their perceptions and views on using AI in the architectural design process. The primary objective of this survey is to investigate how AI may influence architects' creativity, productivity, and decision-making, and to identify opportunities and risks associated with adopting AI in practice. Consequently, measuring the extent of AI use in the market helps determine whether universities should incorporate AI skills to better prepare students for the professional demands they will face after graduation. The study also identifies AI-driven tasks in practice, highlighting areas that may require less focus in education, allowing universities to emphasize skills that complement AI's utilization.

3.3.2 Sampling and Distribution Methods

The survey's target population consisted of architects in Saudi Arabia who are actively engaged in the architecture industry and working in architecture firms. Due to the unavailability of precise data on the actual population size, the global population was used as a reference point in the sample size calculation. According to the Australian Bureau of Statistics (ABS) sample size calculator, for a 95% confidence level and a proportion of 0.5, a confidence interval of $\pm 5\%$ results in a recommended sample size of 385. This interval

implies that the true population proportion is expected to fall between 0.45 and 0.55. However, using a slightly wider confidence interval of $\pm 5.55\%$, the required sample size is reduced to 312, which aligns with the number of participants in this study. This is further discussed in Chapter 4, Section 3.

3.3.3 Questionnaire Structure

The questionnaire included closed-ended questions using a 5-point Likert scale, where responses ranged from 5 (Strongly Agree) to 1 (Strongly Disagree), capturing participants' familiarity with and opinions on integrating AI technology into the architectural design process. The final section of the survey invited respondents to share recommendations and insights on how AI could be effectively integrated into architectural education and how students should be prepared to enter the market, ensuring educational programs align with market needs. The findings were considered in the study recommendation.

The formulation of the survey questions was carefully structured based on the major aspects highlighted in the thorough literature review, for the influence of GenAI in both practice and architectural education. To collect reliable and valid data, the survey design followed a set of criteria defined by extracting the key insights from relevant and recent studies, which shaped the investigation of the multifaceted impact of AI. These criteria were categorized into four main categories: First section is the Sample Characteristics and the participants' experience, familiarity, and usage of digital and Generative AI tools. This section collected information about the respondents' professional background, years of experience, familiarity with digital design tools and parametric design software, and willingness to use AI tools, as well as their familiarity with GenAI tools which evaluated architects' awareness and personal experience with AI tools in architectural design and

assessed the extent of influence of AI integration across different design stages. Second, opportunities and benefits of adopting the AI: which explored respondents' views on whether AI is capable of producing high-quality designs and whether this might affect job opportunities, productivity, creativity, innovation, improve teamwork, cost, enhance appearance and aesthetic aspects, and contribute to sustainability in architectural projects. Following this, the third category discussed risks and challenges of AI utilization, focusing on the threats and barriers associated with its integration, identified in the literature review to address practical limitations and ethical concerns. Finally, educational integration included insights on how AI should be incorporated into architectural education, focusing on the integration of the GenAI in every architecture design stage, to bridge the gaps between education and professional practice and ensure the preparation of future architects for a technology-driven industry (Appendix A: Questionnaire Questions). The following *Figure 3.2* summarizes the design of the survey questions.

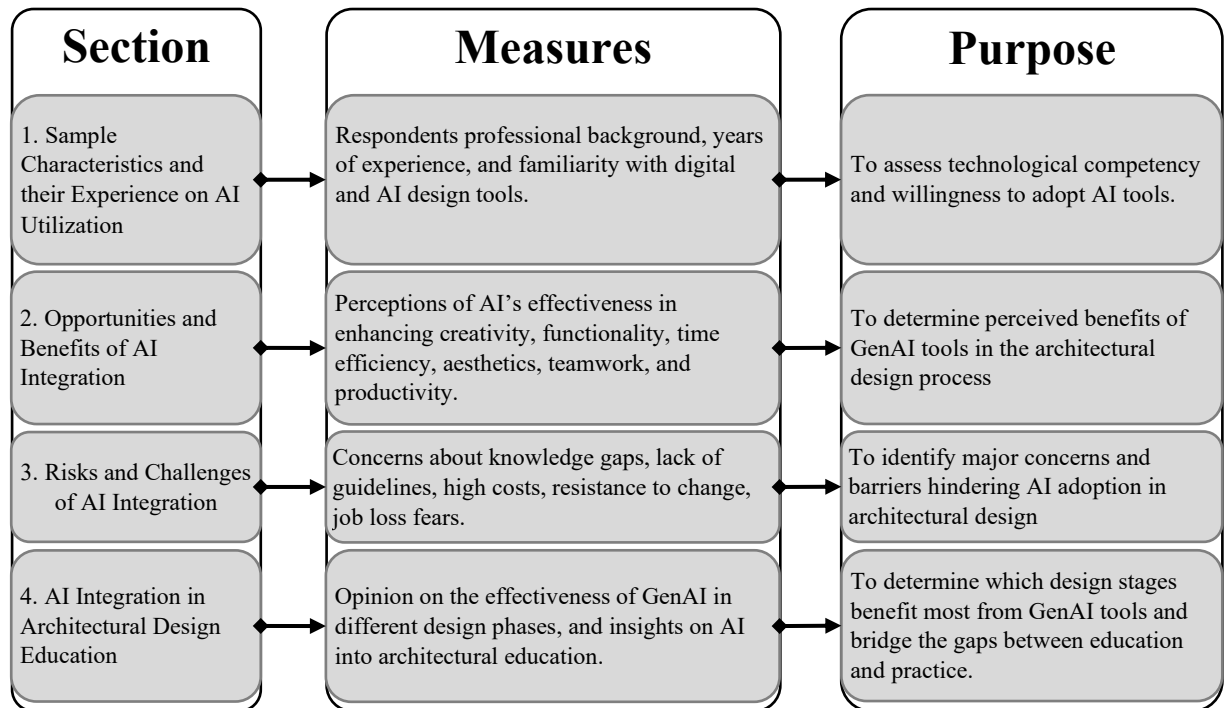


Figure 3.2: The design of the questionnaire questions

3.3.4 Data Analysis Methods

The survey was developed using Google Forms and distributed via email and professional networking platforms, such as LinkedIn, to reach a broad audience, as well as to architecture companies and consultants' offices in Riyadh, Saudi Arabia. Several statistical analyses were conducted on the questionnaire data collected using SPSS software. Beginning with the descriptive statistics, which summarized demographic and professional characteristics of the participants, including their gender, education level, years of professional experience, frequency of using digital tools, and their familiarity with AI-based tools. A reliability test was then performed using Cronbach's Alpha to evaluate the internal consistency within the questionnaire sections addressing opportunities, challenges, and the use of AI in architectural education.

In addition to the above, comparative analyses, such as independent samples t-tests, were employed to compare independent groups, such as gender, to examine differences in participants' perceptions and to determine whether there is a statistically significant difference between them regarding a specific variable. The analysis included Levene's Test for Equality of Variances, which assessed whether the variances between the groups are equal, followed by the t-test for Equality of Means, which examined differences in mean value (Delacre et al., 2017). This test was essential to help determine whether differences between groups reflect actual trends or are due to random chance, and this study applied it to understand differences in participants' perceptions of AI opportunities in architectural design processes and AI utilization in architectural education. Moreover, Analysis of Variance (ANOVA) was employed to identify differences in perceptions based on educational level and professional experience to compare the means of three or more

independent groups to determine whether they have statistically significant differences (Gelman et al., 2005).

Lastly, to gain a deeper understanding of how GenAI is perceived in architectural design and education, a detailed analysis was conducted to identify and prioritize key benefits, challenges, and integration strategies. The Relative Importance Index (RII) was employed to evaluate and rank participants' perceptions of the benefits and challenges associated with adopting Generative AI in architectural design, highlighting priority areas for its effective integration into architectural education (A. Kassem et al., 2020).

3.4 Interviews with Experts

This method involves managing online personal interviews with architecture professors from various universities worldwide. The primary objectives are to gather insights into the integration of GenAI in architectural education, deepen the understanding of the opportunities and challenges of AI in educational and academic settings, and explore its impact on student outcomes.

The expected outcome of these interviews is to benefit from the expert professors' experiences, insights, and recommendations, which may contribute to the development of guidelines and recommendations for effectively integrating generative AI techniques into architectural design education.

3.4.1 Selection of Interviewees

The sample consisted of 18 professors of architecture from various universities across different regions of the world, aiming to identify regional differences and commonalities in the adoption of AI. This ensured that the findings were applicable across diverse

educational contexts. The professors were selected based on their expertise in architectural education, with a focus on those who are knowledgeable about or involved in the integration of AI technologies into their teaching and research practices.

3.4.2 Data Analysis Methods

The interview data were analyzed qualitatively to identify repeated themes, patterns, and insights. Content analysis was utilized to categorize the views expressed by professors on the adoption of AI, opportunities, and challenges, as expected, as well as their recommendations for integrating AI into architectural education. The interviews were recorded and transcribed, after which the data were analyzed to identify common themes and key insights, categorized, and transformed based on the frequency of response into statistical form using a thematic analysis and statistical comparison.

3.4.3 Interview Structure

The interviews covered key significant areas of the study. The interview questions aimed to explore the respondents' perspectives, challenges, and recommendations related to AI in architectural education, ensuring that their answers contribute to the development of practical guidelines for integrating AI into architectural design education. Open-ended questions enabled valuable insights to be obtained during these interviews, while follow-up questions were added based on participants' responses to delve deeper into certain perceptions.

The interview questions were designed to explore the potential impact of GenAI on architectural design education (Appendix B: Interview Questions). The first part focused on understanding participants' perspectives on the current role of AI in educational settings

and whether they have observed any changes in its use over time. It also invited them to share their expectations for how AI tools might develop in the future within the context of architectural education. The second part explored how GenAI may influence the design process and student learning outcomes, particularly in relation to creativity, innovation, problem-solving, and productivity within studio-based learning. The third part of the interview addressed the potential challenges and ethical concerns involved in adopting GenAI in architecture programs, such as limited technical knowledge, lack of training, cost, and the risk of over-reliance on AI tools. The final part asked participants to reflect on their own teaching experiences, highlighting the stages of the design process where GenAI has the most noticeable impact. They were also encouraged to share practical examples and offer suggestions for how GenAI can be effectively and responsibly integrated into architectural design education, *Figure 3.3*.

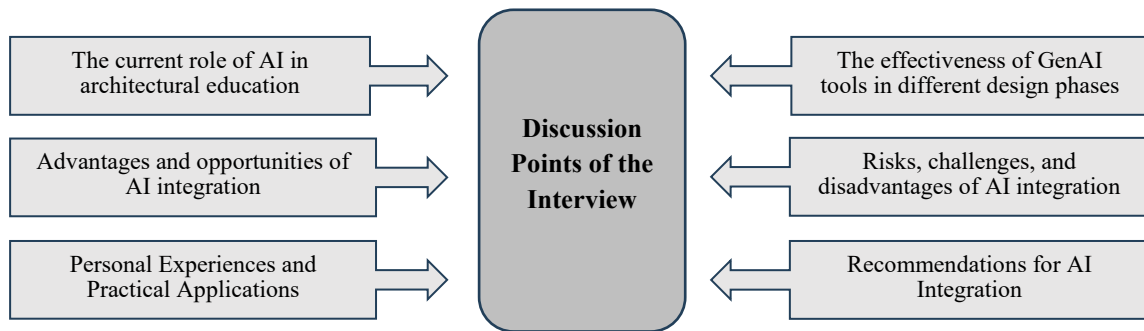


Figure 3.3: Interview discussion points on AI in education and architecture

3.5 Field Experiment

Conducting a field experiment is essential to evaluate the potential impact of integrating GenAI tools into architectural design studios through practical application. The main purpose of the field experiment is to evaluate the effect of integrating generative AI tools on architectural design education and the design process among undergraduate students.

This includes evaluating their impact on design quality, student creativity, and efficiency, as well as identifying challenges and opportunities to better prepare future architects for the evolving demands of the profession.

These tools were adapted and employed as design assistance and sources of inspiration based on the framework presented previously in *Figure 2.27* for linking AI tools with design processes. Furthermore, this experiment aimed to identify differences in outcomes between students who use AI tools and those who follow traditional design methods. Based on the students' outcomes and feedback, the experiment provided practical insights into the potential benefits and challenges of integrating AI into architectural education.

3.5.1 Participants in the Field Experiment

The experiment was conducted at King Fahd University of Petroleum and Minerals with senior undergraduate architecture students under the supervision of the design studio course instructor. A total of 10 students participated and were randomly assigned to two main groups: the AI group, which utilized only the GenAI tools provided by the author (e.g., ChatGPT, Midjourney, Lookx.AI), and the control group, which relied on traditional design methods without any AI tools. The goal is to compare the results between AI-assisted design methods and traditional methods.

Furthermore, participants were randomly assigned to either the AI-supported group or the control group to reduce any potential bias. This randomization ensured that the two groups were comparable regarding skill level, creativity, and familiarity with digital tools.

3.5.2 Analysis Tools and Methods

To collect data, the final design submissions from both groups were gathered for a structured evaluation by the supervising instructor. The students of the experimental group used some of the AI tools depicted in *Figure 2.22* in their task, under the instructor's supervision and approval.

By the end of this experiment, the study gathered students' feedback regarding their experiences and challenges they encountered in utilizing AI tools during the process. Observational techniques were also utilized to monitor the design process, allowing for an analysis of differences in approach and methodology between the two groups.

In terms of analysis, statistical tests were applied as part of a comparative analysis to compare the performance and outcomes between the two groups. Furthermore, qualitative analysis was conducted on open-ended feedback responses to provide deeper insights into the students' perceptions toward the integration of AI in the design process. The analysis concluded by reporting the findings in terms of statistical significance.

3.5.3 Experiment Design

Both groups of students participated in the same design studio workshop, which featured the same assignments and timeframes. The only difference between the two groups was the tools they used. The AI group was provided with access to specific AI tools to assist in their design process, while the Control Group worked without any AI assistance, relying solely on traditional design methods. Before the experiment began, the educators determined the type of architectural projects assigned to both groups. They were asked to design a small pavilion for a public space, which can be defined as a small structure in an

urban area designed as a multi-purpose space for community gatherings, events, or relaxation, often featuring unique and innovative designs.

The experiment lasted approximately two weeks, beginning at the start of the second semester of the 2024/2025 academic year. On the first day, participants received an introductory presentation outlining the study's objectives and the tasks required of them. Furthermore, to ensure that students reach an acceptable level of proficiency in handling these tools, three days before the experiment were provided for the AI group, accompanied by supportive basic tutorials. The study observed and examined the impact of AI tools on students' creativity, problem-solving abilities, and productivity.

Finally, the students provided their feedback at the end of the experiment through a survey to capture their experiences (Appendix C: Student Survey for the Experiment). As demonstrated in *Figure 3.4*, the experiment was conducted using several procedure steps.

Procedure of Experiment	
1. Introduction Session	• All participants introduced to the objectives and the procedures.
2. Random Assignment	• Students were randomly assigned to either group to avoid preconceptions and bias.
3. Design Phase	• AI-supported group had 3 days before the experiment to review tutorials, then began their project. They used AI tools, while the control group used traditional design methods.
4. Submission	• All submissions were collected after completing the design projects for evaluation.
5. Evaluation	• Design submissions of both groups were evaluated by the supervising instructor, with defined criteria.
6. Data Analysis	• Statistical tests using SPSS were applied to compare group performance and outcomes.
7. Feedback Collection	• Student feedback were gathered at the end of the experiment to capture their experiences.

Figure 3.4: Procedure of experiment

This chapter outlined a systematic approach to investigating the potential impact of AI in architectural design education. As shown in Table 3.1, a combination of research methods was specifically and carefully employed to achieve the main objectives outlined in the first chapter of the study. This robust methodological foundation is essential for developing actionable guidelines to shape the impact of Generative AI on architectural design education.

Table 3.1: Research methods, analysis techniques, and purpose

Research Objectives	Research Tools	Justification
1- Determining the role of GenAI in architectural education, focusing on the architectural design process.	• Literature Review • Expert Interviews • Field Experiment • Questionnaire	• Establish a foundational understanding of the potential impact of AI tools on students' creativity and outcomes. • Identifying the opportunities and challenges of utilizing GenAI in architectural pedagogy.
2- Developing recommendations and strategies for integrating GenAI technologies into architectural design education.	• Expert Interviews • Questionnaire	• Develop practical, effective, and adaptable guidelines for integrating AI technologies into architectural education contexts.

Chapter 4 : Results and Discussion

4.1 Introduction

This chapter presents and discusses the findings collected through the study's three primary research methods: the questionnaire, expert interviews, and the field experiment. Each method explores different dimensions of generative AI integration in architectural design education, offering quantitative and qualitative insights. The results are organized into three main sections: quantitative analysis of trends from professionals in the field, expert perspectives on integrating AI into architecture education, and practical outcomes observed during a design studio experiment. The synthesis of these findings offers a comprehensive understanding of the potential influence of Gen AI in architectural pedagogy.

4.2 Questionnaire Analysis

This section presents and discusses the findings from the questionnaire, which gathered responses from a diverse group of architects in the Saudi Arabian labor market. The questionnaire was prepared and shared as an online Google Form with about one thousand participants. A total of 312 completed the questionnaire, which presents a response rate of 31.2%. However, out of them, 264 respondents indicated, in question number 1.6, which measures the familiarity level of the participants with AI, that they are familiar with AI tools in architectural projects and therefore proceeded to complete the full questionnaire. The remaining 48 respondents (representing 15% of the total responses) indicated no familiarity with AI tools and were consequently excluded from the data analysis. Questionnaire analysis examined several key factors, including the characteristics of the sample, opportunities, challenges, and levels of AI integration in architectural education, providing statistical insights into trends and prevailing attitudes. This section employs

quantitative methods using SPSS software to offer a structured evaluation of participants' views and understanding of the impact of GenAI tools on architectural practice and education.

4.2.1 Descriptive Statistics

Frequency analysis was employed to examine data related to various demographic characteristics and practices associated with the use of digital and GenAI tools in architectural projects. This analysis enables the assessment of the distribution of various variables, including gender, education level, years of experience in the field of architecture, use of digital design tools, willingness to utilize AI-based tools, and participants' familiarity with AI tools. Through this analysis, it is possible to identify key trends and prevailing patterns in the data, thereby creating a clear picture of the participants and their tendencies toward the use of modern technology in the field of architecture.

The descriptive statistics for the participants' genders indicated that the sample consists of 58% males and 42% females, suggesting a slight male predominance in the study population. This distribution provides a nuanced perspective on the study's findings, ensuring that both viewpoints are considered when analyzing the use of digital and AI tools in architectural design. For the education level, the results indicated that the majority of the participants hold a Bachelor's Degree, with 82%, suggesting that the participants possess basic academic qualifications in the field. Next, the Master's Degree holders with 16% of the participants, and only 2% hold a Ph.D. These results suggest that the sample consists mostly of individuals with undergraduate education, with fewer holding advanced academic degrees. Additionally, the results illustrated that the majority of participants have less than six years of experience, with a participation percentage of 69%. Specifically, 36%

have under three years of experience, and 33% have between three and six years of experience. A smaller proportion has six to nine years of experience, at 14%, while 17% have nine or more years of experience. This indicates that the sample primarily comprises early-career professionals, which may shape their familiarity and openness to adopting digital and AI tools in architectural design.

Moreover, the results of utilizing digital design tools in architectural design showed that most participants regularly use digital design tools, with 62% always relying on them and 14.0% using them often or sometimes. In contrast, only 8% of architects rarely use these tools, and 2% never use them at all. This highlights a strong integration of digital tools in architectural design projects and their essential utilization in modern practice. Next, regarding the willingness to use AI-based tools, the results demonstrate a positive attitude toward AI-based tools in architectural design, with 40% strongly agreeing and 45% agreeing to their current or future use. A smaller proportion remains neutral (13%), while only 2% express disagreement. This suggests a high level of acceptance and willingness among architects to integrate AI into their design processes, as shown in Table 4.1 and Figure 4.1.

Table 4.1: Sample characteristics

		Frequency	Percentage
Gender	Male	181	58%
	Female	131	42%
Education Level	Bachelor's Degree	256	82%
	Master's Degree	50	16%
	Ph.D. Degree	6	2%
Years of Experience	Less than 3 years	112	36%
	3 to less than 6 years	103	33%
	6 to less than 9 years	44	14%
	9 years and more	53	17%
	Always	193	62%

Utilizing Digital Design in Architectural Design	Often	44	14%
	Sometimes	44	14%
	Rarely	25	8%
	Never	6	2%
Using, or willing to use, AI-based tools in architectural design	Strongly Agree	125	40%
	Agree	140	45%
	Neutral	41	13%
	Disagree	6	2%
Familiarity with AI tools in architecture	Very Good	25	8%
	Good	81	26%
	Average	88	28%
	Low	70	23%
	Not familiar (Excluded)	48	15%

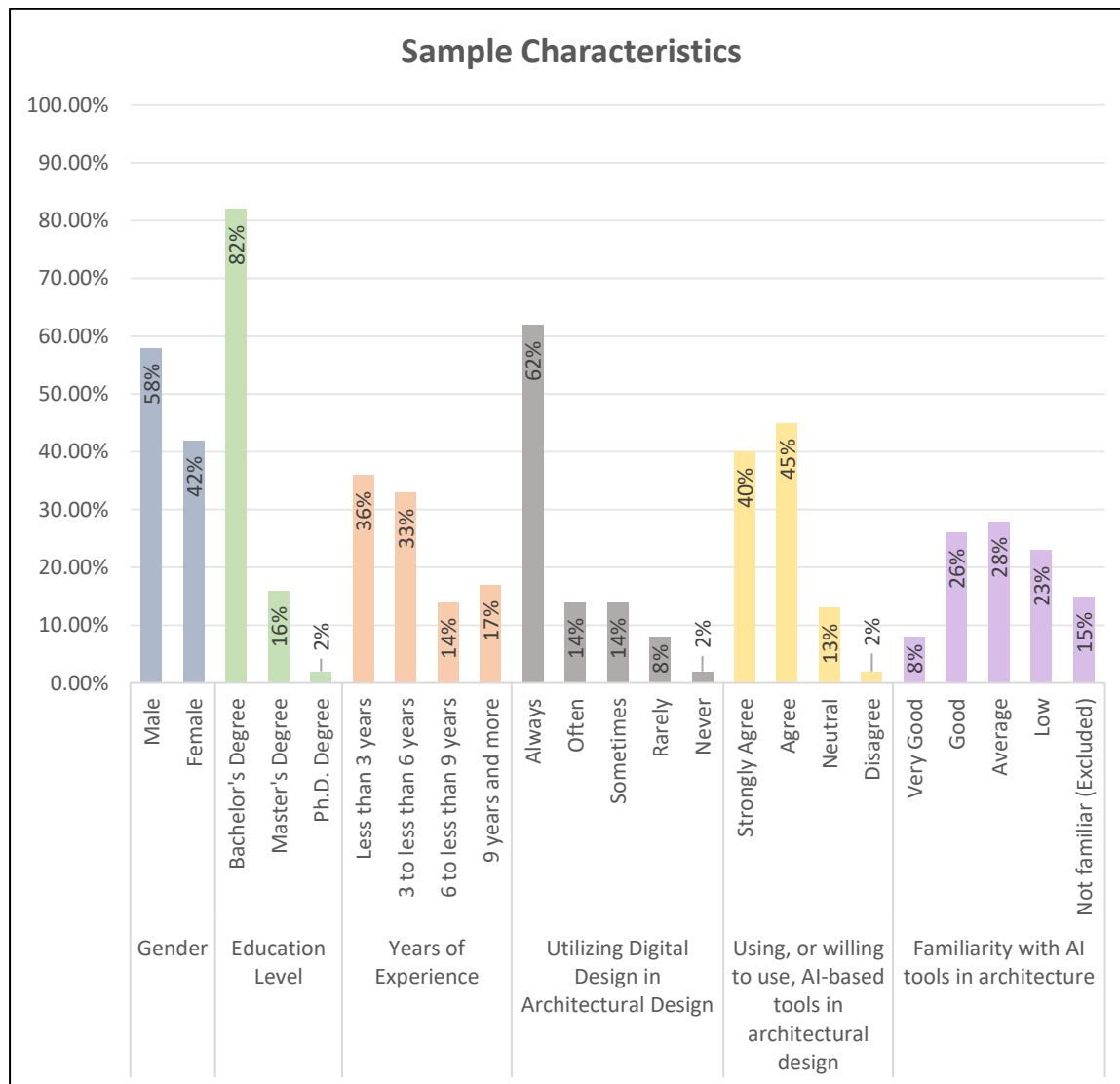


Figure 4.1: Sample characteristics

In addition to the above, the results also indicated a moderate level of familiarity with AI tools among participants. While a small portion rated their familiarity with AI tools as very good, 26% rated it as good, the largest group, at 28%, considered it average, and a notable 23% reported low familiarity. Only 48 participants reported being unfamiliar with AI tools, representing 15% of the total, and were excluded from further data analysis. This suggests that while many participants recognize AI tools, a noticeable percentage still has limited exposure, as shown in *Figure 4.2* below shows the result of the AI familiarity of the complete 312 participants.

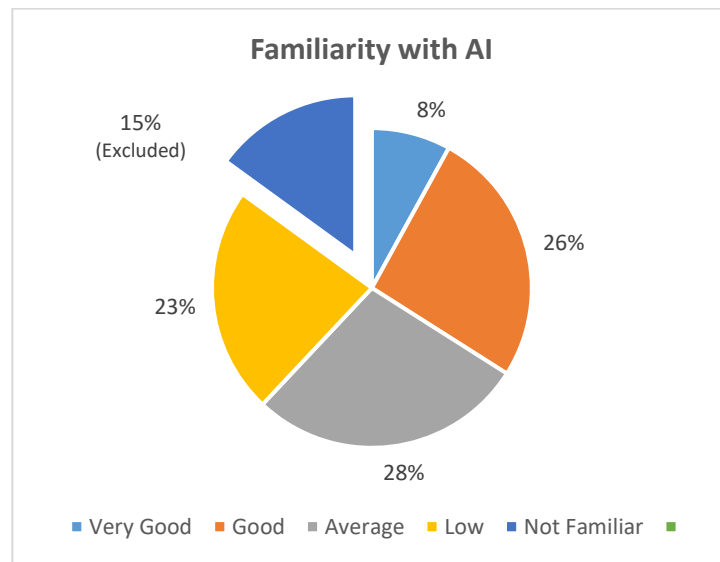


Figure 4.2: Distribution of AI tool familiarity levels among participants

4.2.2 Data Reliability

The reliability tests were conducted to assess the accuracy and consistency of the survey questions designed to measure participants' perceptions of AI. Reliability analysis involved calculating Cronbach's Alpha value, a metric used to determine the internal consistency of

questions within survey sections that measure a certain construct, namely Section 2 (S2) and Section 3 (S3). The values derived from the Cronbach's Alpha test indicate the strength of the relationship between the questions within the same section, where a value above 0.7 is typically considered an indicator of good reliability (Taber, 2018). The benefit of this analysis lies in ensuring that the questions designed to measure AI perceptions are not only relevant but also yield consistent responses aligned with overall AI adoption trends.

Cronbach's Alpha value for Section, which discusses the opportunities of utilizing AI in the architectural design process, is 0.832, indicating a high level of internal consistency reliability. This suggests that the questions in this section are well-structured and consistent in measuring the intended concept. Next, for Section 3, which addresses challenges associated with AI utilization in architectural design, the Cronbach's Alpha value became 0.701, indicating an acceptable level of reliability in internal consistency.

4.2.3 Analysis of Differences Between Groups Using the Independent Samples t-

Test: A Study on AI Perceptions in Architectural Design

To explore group differences in perceptions, Independent Samples t-tests were conducted to compare variables such as gender. The analysis includes tests for equality of variances and means to determine whether observed differences are statistically significant or due to random chance.

The results of the Independent Samples t-Test are presented in Table 4.2. Levene's t-Test for equality of variances showed a Sig. value greater than the significance level of 0.05 in Sections 2 and 4. This indicates that the assumption of equal variances holds. As for Section 3, Sig. value was less than the significance level, which indicates that equal variances are

not assumed. As for the t-Test results, the Sig. (2-tailed) value for S2 is 0.795, which is greater than 0.05. This means that there is no statistically significant difference between males and females in their perceptions of AI opportunities in architectural design. According to the descriptive statistics, the mean difference is - 0.13581, showing a minimal difference between the two groups. This similarity suggests that both genders share a common perspective on AI's potential to enhance architectural design, reflecting a mutual understanding of its utilization in fostering creativity and innovation in the field.

Moreover, the results of the Independent Samples t-Test illustrated in Table 4.2 indicates that the Sig. (2-tailed) value for S3 is 0.030, which is less than 0.05. This suggests a statistically significant difference between males and females in their perceptions of the risks and challenges associated with utilizing AI in architectural design. According to the descriptive statistics, the mean difference is 0.92669. This indicates that males tend to have a more positive perception of AI integration in architectural design compared to females. This difference could be attributed to various factors, such as differences in educational background, exposure to AI tools, or varying levels of openness to adopting new technologies in learning environments.

Regarding the use of AI in architectural design education, the results showed that, according to Table 4.2, the Sig. (2-tailed) value for S4 is 0.488, which is also greater than 0.05. This indicates that there is no statistically significant difference between males and females in their perceptions of AI's role in education. However, descriptive statistics show that the mean difference is - 0.43703, revealing only a slight difference between the two groups. This suggests a general agreement between males and females on the value of AI

in improving teaching and learning methods in architectural design, with no notable gender-based differences in evaluating its impact on education.

Table 4.2: Independent samples t-test

		Levene's t-Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
S2	Equal variances assumed	.304	.582	-.260	262	.795	-.13581	.52284	-1.16531	.89369
S3	Equal variances not assumed	3.904	.049	2.185	262	.030*	.92669	.42406	.09168	1.76170
S4	Equal variances assumed	.113	.737	-.695	262	.488	-.43703	.62884	-1.67526	.80120

Note: * indicates a statistically significant difference at the $p < 0.05$ level.

4.2.4 Examining the Influence of Educational Level and Work Experience on Perceptions of AI Utilization in Architectural Design Education

In this study, ANOVA is applied to assess how educational level and years of experience could influence respondents' perceptions of AI opportunities, challenges, and its role in architectural design and education, determining whether professionals with different backgrounds perceive AI differently.

1. Educational Level and Perceptions of Opportunities and Benefits in Utilizing AI in the Architectural Design Process (S2)

Regarding the analysis by educational level, the results for the variable Opportunities in Utilizing AI in the Architectural Design Process (S2) show a Sig. value of 0.072, greater than 0.05, indicates no statistically significant differences between the different educational levels in their perceptions of the opportunities available for utilizing AI in architectural

design, Table 4.3. This suggests that professionals across all educational levels, whether they have undergraduate degrees, postgraduate degrees, or different academic backgrounds, have similar perceptions about the potential opportunities for AI in architectural design. Although there is no clear statistical significance, a slight trend is observed in the mean differences, indicating that individual views may vary depending on their educational background.

2. Educational Level and Perceptions of Risks, Challenges in Utilizing AI in the Architectural Design Process (S3)

For the result of the Risks, Challenges, and Concerns in Integrating AI into Architectural Education (S3), the Sig. value is 0.301, which is greater than 0.05, Table 4.3. This indicates that there are no statistically significant differences between the different educational levels in their perceptions of how GenAI contributes to the design process and learning outcomes. This suggests that professionals and students, regardless of their level of education, share a common perspective on the advantages and opportunities presented by GenAI in architectural design. While the results do not reveal a significant difference, subtle variations in opinions may exist, implying that individuals' experiences and exposure to AI-driven tools could influence their perceptions of its benefits in design and education.

3. Educational Level and Perceptions of Utilizing AI in Architectural Design Education (S4)

For the variable Utilizing AI in Architectural Design Education (S4), the Sig. value is 0.148, indicating no statistically significant differences between the different educational levels in their perceptions of the role of AI in architectural design education, Table 4.3. Thus, it

can be concluded that all educational levels generally agree on the positive impact of AI in improving architectural design education.

Table 4.3: ANOVA results comparing perceptions across different educational levels regarding various aspects of AI in architecture (S2, S3, and S4)

		Sum of Squares	df	Mean Square	F	Sig.
S2	Between Groups	92.212	2	46.106	2.658	.072
	Within Groups	4527.409	261	17.346		
	Total	4619.621	263			
S3	Between Groups	28.332	2	14.166	1.206	.301
	Within Groups	3065.289	261	11.744		
	Total	3093.621	263			
S4	Between Groups	97.287	2	48.644	1.925	.148
	Within Groups	6596.031	261	25.272		
	Total	6693.318	263			

4. Work Experience and Perceptions of Opportunities and Benefits in Utilizing AI in the Architectural Design Process (S2)

Regarding the analysis by years of experience, the variable Opportunities in Utilizing AI in the Architectural Design Process (S2) results show a Sig. value of 0.018, which is less than 0.05, indicates statistically significant differences between professionals with years of experience in their perceptions of AI opportunities in architectural design, Table 4.5. This demonstrates that participants' perceptions vary based on their experience level, with more experienced professionals potentially having different perspectives than those with limited or medium-sized experience.

To further investigate these differences, a Tukey HSD post hoc test was conducted. The results showed a significant difference between participants with less than 3 years of experience and those with 9 years or more ($p = .027$). Participants with 9 or more years of experience reported higher perceptions of AI opportunities compared to those with less

than 3 years of experience. This suggests that professionals with longer experience tend to be more optimistic or more aware of the potential applications of AI in architectural design, Table 4.4.

Table 4.4: Tukey HSD results for S2 by years of experience

		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
(9 years and more)	Less than 3 years	2.11064	.74940	.027	.1729	4.0484
	3 to less than 6 years	.58864	.75763	.865	-1.3704	2.5477
	6 to less than 9 years	.81622	.91744	.810	-1.5560	3.1885

5. Work Experience and Perceptions of Risks, Challenges in Utilizing AI in the Architectural Design Process (S3)

For the variable Utilizing AI in Architectural Design Education (S3), the Sig. value is 0.118, which is greater than 0.05, indicating no statistically significant differences based on years of experience, Table 4.5. This suggests that professionals, regardless of experience level, generally share similar perceptions about the utilization of AI in architectural education. While experienced professionals may have encountered AI differently in their careers compared to newcomers who are more accustomed to digital tools, their overall evaluation of AI's impact on education remains consistent.

6. Work Experience and Perceptions of Utilizing AI in Architectural Design Education (S4)

Similarly, for the variable Utilizing AI in Architectural Design Education (S4), the Sig. value of 0.138 indicates that there are no significant differences across experience levels, Table 4.5. This reinforces the idea that professionals, whether early-career, mid-career, or

highly experienced, have a common understanding regarding the utilization of AI in enhancing architectural education.

Table 4.5: ANOVA results comparing perceptions across different work experience regarding various aspects of AI in architecture (S2, S3, and S4)

		Sum of Squares	df	Mean Square	F	Sig.
S2	Between Groups	176.073	3	58.691	3.434	.018*
	Within Groups	4443.548	260	17.091		
	Total	4619.621	263			
S3	Between Groups	68.867	3	22.956	1.973	.118
	Within Groups	3024.754	260	11.634		
	Total	3093.621	263			
S4	Between Groups	140.216	3	46.739	1.854	.138
	Within Groups	6553.102	260	25.204		
	Total	6693.318	263			

Note: * indicates a statistically significant difference at the $p < 0.05$ level.

4.2.5 Participants' Recommendations for Integrating AI into Architectural Education

Most respondents strongly supported the integration of AI into architectural education, recognizing its potential to enhance efficiency, creativity, and workflow optimization. However, many participants emphasized that this integration should be responsible, structured, and utilized as a supportive tool rather than replacing fundamental architectural skills.

Many recommended a phased approach, introducing AI tools in later years after students develop foundational design skills. AI was particularly useful in brainstorming, generative design, site analysis, and research, allowing students to explore multiple ideas efficiently. However, concerns were raised about over-reliance on AI, the loss of critical thinking, and the importance of maintaining traditional design methods.

To address these concerns, respondents suggested dedicated AI courses, faculty training, and workshops to ensure students and educators can effectively use AI tools. Some advocated ethical guidelines on AI usage, ensuring students critically evaluate AI-generated outputs rather than passively accepting them.

Others stressed the need for industry collaboration, integrating AI-driven workflows into studio projects and real-world applications. Ultimately, participants agreed that AI should enhance, not replace architectural thinking, and universities must adapt their curricula to prepare students for the evolving design industry.

4.2.6 Analysis of the Importance, Benefits, and Challenges of Generative AI in Architectural Design Using the Relative Importance Index (RII)

The following analysis utilizes the Relative Importance Index (RII) to rank participants' perceptions of Generative AI in architecture, focusing on its benefits, challenges, and integration into educational settings. To structure this evaluation, the analysis is divided into three key areas: benefits (S2), challenges (S3), and integration of Generative AI into architecture design education (S4).

1. Benefits of Generative AI in Architectural Design (S2)

This section aims to assess the extent to which respondents agree that integrating Generative AI into architectural design is beneficial and useful.

The results indicate that the most significant perceived benefit of Generative AI in architectural design is saving time and improving productivity among architects (RII = 0.862), reflecting the understanding that AI can help accelerate the design process and enhance efficiency. The second highest-rated benefit is exploring more innovative

variations and aesthetics (RII = 0.820), suggesting that AI can effectively enhance the aesthetic qualities of designs.

On the other hand, benefits related to enhancing teamwork and collaboration (RII = 0.576) and improving design functionality (RII = 0.726) received the lowest rankings. This indicates skepticism about AI's ability to fully replace human collaboration in design teams or improve the technical functionality of designs at the same level as human interaction, Table 4.6.

Table 4.6: RII analysis of participants' perceptions of opportunities in utilizing Generative AI in the architectural design process (S2)

	Weighted Mean	RII	Ranking
S2 (Opportunities in Utilizing AI in the Architectural Design Process)			
1- I believe that Generative AI could be used effectively in architectural design projects to foster creativity and inspiration	4.06	0.812	3
2- I believe that Generative AI could be used effectively in architectural design projects to optimize design functionality	3.63	0.726	4
3- I believe that Generative AI could be used effectively in architectural design projects to explore more innovative variations and aesthetics	4.10	0.820	2
4- I believe that Generative AI could be used effectively in architectural design projects to enhance teamwork and collaboration	2.88	0.576	6
5- I believe that Generative AI could be used effectively in architectural design projects to save time and, therefore, improve productivity	4.31	0.862	1
6- I believe that Generative AI could be used effectively in architectural design projects to reduce design costs	3.56	0.712	5

2. *Challenges of Generative AI in Architectural Design (S3)*

This section examines the extent to which respondents perceive challenges in integrating Generative AI into architectural design. The most significant challenge identified by participants is the lack of knowledge and training (RII = 0.818), indicating that insufficient familiarity with AI tools is a major barrier to their adoption in the architectural design

profession. The absence of clear regulations and guidelines for AI use (RII = 0.788) ranked as the second most pressing concern, highlighting the need for well-defined policies to facilitate AI integration. Meanwhile, resistance to change among stakeholders (RII = 0.722) and fear of job loss (RII = 0.608) were considered moderate challenges, meaning they were not seen as the most significant concerns.

However, the high cost of Gen AI tools (RII = 0.558) was ranked as the least significant challenge, implying that while financial constraints exist, they may not be the primary barrier to AI adoption in architectural design, Table 4.7.

Table 4.7: RII analysis of participants' perceptions of risks and challenges associated with the use of Generative AI in architectural design (S3)

	Weighted Mean	RII	Ranking
S3 (Risk and Challenges of Generative AI in Architectural Design)			
1- I believe that one challenge that faces the effective use of Generative AI in architectural design projects is the lack of knowledge and training	4.09	0.818	1
2- I believe that one challenge that faces the effective use of Generative AI in architectural design projects is the high costs of AI tools	2.79	0.558	5
3- I believe that one challenge that faces the effective use of Generative AI in architectural design projects is the resistance to change among stakeholders	3.61	0.722	3
4- I believe that one challenge that faces the effective use of Generative AI in architectural design projects is the fear among designers of job loss	3.04	0.608	4
5- I believe that one challenge that faces the effective use of Generative AI in architectural design projects is the absence of clear regulations and guidelines of AI use	3.94	0.788	2

3. Integration of Generative AI Across Different Stages of the Architectural Design Process (S4)

This section examines how respondents perceive the effectiveness of GenAI applications across various stages of the architectural design process. The most highly rated application

was using AI in the Conceptual Design stage to generate creative design concepts, with an RII of 0.844. This suggests that participants recognize AI's strong potential to foster inspiration and creativity during the early design phases. The use of AI in the Design Production stage for rendering, design refining, and presentation was ranked second (RII = 0.836), reflecting the growing acceptance of AI-powered visualization tools in enhancing the presentation quality of architectural projects. The application of AI in the Pre-Design and Analysis stage for data collection and project requirements analysis followed closely, with an RII of 0.820, indicating its perceived effectiveness in optimizing research and preparatory work.

While these top three stages received similarly high evaluations (all above 4.0 out of 5 in weighted mean), the Design Development stage lagged noticeably behind with an RII of 0.720. This gap suggests that GenAI is perceived as less effective in this intermediate phase, which often requires deeper manual skills, iterative refinement, and detailed decision-making. These results highlight that GenAI is seen as most beneficial in the early and final stages of the design process. Table 4.8.

Table 4.8: RII analysis of participants' perceptions on integrating Generative AI into architectural education, including design stage applications (S4)

	Weighted Mean	RII	Ranking
S4 (Design Stage Applications)			
1- I believe that Generative AI could be effectively used in the Pre-Design and Analysis stage for data collection and project requirements analysis	4.10	0.820	3
2- I believe that Generative AI could be effectively used in the Conceptual Design stage to generate creative design concepts (Conceptual Design)	4.22	0.844	1
3- I believe that Generative AI could be effectively used in the Design Development stage for schematic planning and preliminary 3D massing (Design Development)	3.60	0.720	4

4- I believe that Generative AI could be effectively used in the Design Production stage for rendering, design refining, and presentation (Rendering)‘	4.18	0.836	2
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4.2.7 Summary of the Questionnaire Analysis

This section summarizes the key findings from the questionnaire across four main axes: the current utilization and acceptance of AI in architectural education, the advantages and opportunities of integrating AI in architectural design education, its risks, challenges, and disadvantages, and the effectiveness of GenAI tools in various design phases.

A. The current role and acceptance of AI in architectural education

- 85.6% of architects in the Saudi labor market are using or willing to use GenAI tools in design, showing a widespread acceptance of these tools in the labor market.
- 84.62% reported familiarity with AI tools, reflecting a strong level of awareness and readiness for further integration into both professional and educational settings.
- Proficiency levels varied from basic to very good.

B. The advantages and opportunities

- The most significant perceived benefit is improving time efficiency and productivity, as these tools are valued for their ability to streamline the design process.
- Other benefits mentioned include exploring more innovative variations and fostering creativity and inspiration.
- The least benefit is improving teamwork and collaboration in architecture practice.
- More experienced professionals perceived the benefits of GenAI more positively than those with less experience.

C. The risks, challenges, and disadvantages

- The most significant challenge identified is the lack of knowledge and training in GenAI tools, remaining as a primary barrier within the profession.
- Absence of clear guidelines and regulations was a major concern, emphasizing the need for structured policies to ensure responsible and consistent use.
- The least ranked concern is the cost of GenAI tools, showing that financial constraints are less of a hindrance
- Male participants reported more positive views than females regarding AI-related risks and challenges.

D. The effectiveness of GenAI tools in different design phases

- The most effective phase is the conceptual design stage, where GenAI is highly valued for supporting creative ideation and inspiration.
- The second most effective is design production and rendering, which enhances refinement, rendering, and presentation quality in later phases.
- Third: Pre-Design and Analysis, supports research, data collection, and planning.
- Least effective: Design Development, which requires deeper manual skills and detailed decisions, making GenAI tools less suitable.
- The results show that the top three stages had similar high scores (above 4 out of 5), while the Design Development stage scored much lower, showing it's the least suitable for GenAI use.

In addition to the above, the findings also emphasized that continuous faculty training is seen as the most critical requirement for integrating Generative AI into architectural education. Most participants also agreed that AI should complement, rather than replace, traditional methods, indicating a clear preference for a balanced integration.

4.3 Experts Interviews

This section presents and discusses the findings from interviews with expert academics on the evolving role of AI in architectural education. The insights revealed the potential opportunities of AI in design processes, its positive and negative influence on students, and the risks and challenges it introduces. Experts offered diverse perspectives, which are thematically analyzed and synthesized to provide a better understanding of how AI influences architectural pedagogy and the considerations necessary for its responsible integration.

The study involved 18 academic professionals specializing in architecture, drawn from various universities across different countries and regions. The highest representation was from the Middle East (7 participants), followed by the Asia-Pacific region (4), North America (3), and one participant each from Europe and Africa. These experts were selected based on their knowledge, research contributions, and professional experience in architectural education, innovation, and the integration of artificial intelligence. Participants held a variety of academic and leadership roles, including professors, associate professors, assistant professors, and researchers, many of whom also serve as program chairs, directors, or editors in academic and professional contexts. For clarity, they have been organized according to their academic ranking in (Appendix D: List of Interview Participants and Academic Affiliations). The regional distribution of participants is visually represented in *Figure 4.3*.



Figure 4.3: Geographic distribution of interview participants by country

4.3.1 The Current Role and the Evolution of AI in Architectural Education

There is a consensus among experts that AI is rapidly evolving and shifting from specialized tools to a core element of architectural education. However, the extent of AI's integration and its future trajectory remain subjects of debate. While some view AI as a fundamental tool reshaping the design process, others see it as still in an exploratory phase, with concerns about ethical implications and long-term impact.

1. AI as an Assistive and Transformative Tool in Architectural Education

Experts widely recognize AI's potential in architectural education, emphasizing its applications in the design process. Most of the interviewees highlighted how AI automates repetitive tasks and enhances decision-making, making it a valuable asset for both students and educators. Others described GenAI tools as an evolution in technology that has been transformed from being a simple technical assistant to an active collaborator that engages in design thinking. Beyond assisting with technical tasks, many interviewees mentioned that they believe that AI can improve the learning process more effectively by facilitating

ideation, generating design variations, and supporting visualization through text-to-image tools. Additionally, they emphasized that AI serves as an assistant tool that can guide students through problem-solving as if they had a personal guide explaining each step.

2. Uncertainty and Ethical Concerns

On the other hand, some interviewees noted that AI in architectural education is still in an exploratory phase, and further structured research is required before it can be fully integrated into architectural education. However, Interviewee 3 mentioned that:

“AI remains largely experimental, driven by individual initiatives rather than guided by a structured methodology. While its future role, particularly within design studios, holds significant promise, its integration is still in progress and lacks a well-defined, standardized framework.”

Additionally, Interviewee 12 described AI as a “*double-edged sword*.” He indicated that while AI holds great potential, it also raises ethical concerns, highlighting the need for proper guidelines and regulations to ensure responsible use in academic settings. That is why most interviewees highlighted that AI should remain a complementary tool rather than a replacement for independent student thinking, as excessive reliance on AI outputs may diminish cognitive engagement by generating information from continuously vague and sometimes unverifiable sources.

3. Increasing Acceptance and Integration into Education

Several experts highlighted a shift in attitudes toward AI in education and observed that, despite initial resistance, AI adoption has rapidly increased among students and educators.

Interviewee 14 noted that:

“AI was initially viewed negatively, with many educators considering its use equivalent to academic dishonesty. However, AI is now more widely accepted, and students increasingly give credit to AI-generated contributions.”

Furthermore, Interviewee 11 shared her experience of integrating AI into architectural education, despite initial opposition from her faculty colleagues, who claimed that the use of AI was not permitted. In late 2024, she conducted several experiments with senior students, incorporating GenAI tools into the architecture design studio, specifically in sketching, design refinement, and 3D modeling. She reported that the results of her experiments received 75–85% positive feedback, and students indicated that using AI helped them become more innovative in their design process. Based on these findings, her university later officially integrated AI into the department’s curriculum, with a focus on research, form development, rendering, and sustainability.

4. Regarding the future of AI in architectural education

Several interviewees saw that it is moving toward deeper integration across various aspects of design learning. Interviewee 17 predicted that *“A shift from tool-centric applications to methodology-driven approaches, where AI supports human creativity rather than replacing it.”* Moreover, some interviewees suggested that AI will soon streamline complex design analyses, making them more accessible and intuitive, while others

mentioned that AI capabilities will extend beyond generative text, covering modeling, rendering, and optimization, which could revolutionize architectural education.

4.3.2 The Effectiveness of GenAI Tools in Different Design Phases

In this section, the interviewees were asked to share their perspectives on which stage of the design process the GenAI tools have the most significant impact. Most responses by interviewees agreed that the best fit for GenAI tools in the design process is at the early stages, which are the pre-design stage and the concept design stage, where AI tools have the most significant impact. Interviewee 12 mentioned that:

“AI is highly suitable for the initial phase of architectural design, specifically the Conceptual Design Stage, as well as the following phase, which includes Rendering and the required visualization details, except for the design development phase, as this stage needs architects to rely more on their manual design skills because it has a lot of deep details and spatial analysis”

On the other hand, other interviewees believed that the biggest impact is seen in the final presentation stage, as this phase requires rapid idea testing, rendering, and generating multiple alternatives, where AI can provide significant assistance. They suggested that students develop their ideas through sketching and utilize digital tools with AI-powered capabilities to further refine and enhance their designs.

That is why some of them suggested restricting AI use during the pre-design stage, while encouraging students to explore its potential in the later stages of the design process. However, this view is contrasted with Interviewee 10 pointed out that:

“Utilizing and integration of the GenAI tools in later stages, such as design development and design production, where AI can still be useful, is more sophisticated and requires more experience, advanced technical knowledge, higher costs, and more advanced technology.”

Some other interviewees indicated that AI tools can significantly impact all stages of the design process, and their effectiveness depends on the student's ability to use them efficiently. They indicated that GenAI tools can be effectively utilized in all stages, but they differ in the level of complexity involved. For example, as raised by Interviewee 3, the design development and conceptual design stages are the most challenging and require more advanced AI tools. Meanwhile, the design production stage is efficient, straightforward, and seamless. In this context, Interviewee 1 responded to this question by pointing out that:

“Students tend to engage less deeply in the design phase, relying instead on collecting images without fully considering the underlying design philosophy. In some cases, the design process moves directly to the planning phase, with images being refined using AI tools. While this approach produces visually striking results, it often leads to designs that are functionally weak and lack cultural and contextual relevance. For this reason, I believe that AI tools should be used immediately after concept development or during the Concept Stage.”

Additionally, Interviewee 11 highlighted, based on three experiments she conducted with her students, the importance of defining clear focus points when integrating GenAI tools into architectural education, such as sketch development, sustainability, and material integration. AI can then be used more effectively to enhance students' learning experiences,

ensuring that AI serves as a complement to design education. In line with this perspective, Interviewee 3 recommended that:

“Educators should monitor the entire design process with students to ensure they do not become overly reliant on GenAI tools. Instead, they should integrate these tools in a way that enhances their design abilities rather than replacing them.”

Figure 4.4 and Table 4.9 present the frequency and percentage of responses from academic experts and their corresponding rankings, reflecting their evaluation of GenAI tools’ effectiveness across architectural design phases. They summarize the Interviewees’ opinions about the most significant impact of GenAI tools on the design process stages. The results indicate that the utilization of GenAI tools has the most significant impact on the initial stages, such as the conceptual design stage, which ranked highest with 12 mentions and a 67% percentage of responses. However, this recommendation was given under certain conditions, such as educators monitoring the entire design process, applying academic guidelines, avoiding overreliance, considering the philosophy of the design and its functionality, and engaging with the local culture and context.

The second highest is the pre-design stage, also considered an initial stage, with 9 mentions and a 50% percentage of responses. In this stage, GenAI tools can assist with repetitive tasks, data collection and analysis, and highlight key aspects that students should consider, making design decisions more data-driven.

Moreover, the design development stage was the least mentioned by the interviewees, with only two references and a response percentage of 11%, as some interviewees highlighted that utilizing AI at this stage requires more experience, advanced technical knowledge, and incurs higher costs.

Additionally, the design production stage was mentioned four times, ranking third, with a response percentage of 22% of the academic experts, indicating that it has a significant impact, particularly for tasks such as rendering and optimization. Lastly, four interviewees, 22% response percentage, noted that GenAI tools can be applied across all design stages, depending on students' usage, technical knowledge, and level of education.

Table 4.9: Results from expert interview analysis on the effectiveness of utilizing AI across different architectural design phases, based on response frequency, percentage, and ranking

Experts' perspective on the effectiveness of utilizing GenAI tools across different design stages	Experts Interviews		
	Freq.	Percentage	Ranking
Pre-Design & Analysis	9	50%	2
Conceptual Design	12	67%	1
Design Development	2	11%	4
Design Production & Rendering	4	22%	3

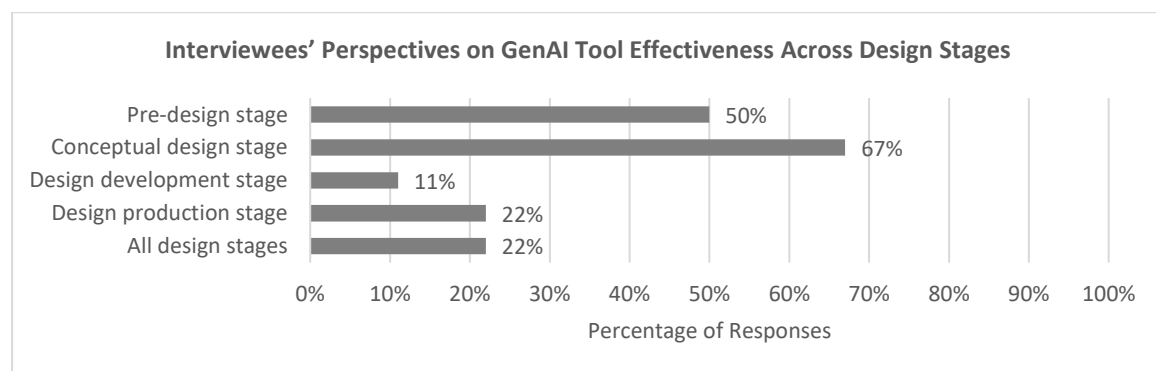


Figure 4.4: Interviewees' responses in percentages on the effectiveness of AI utilization across architectural design stages

4.3.3 Opportunities and Benefits of Utilizing GenAI Tools on the Design Process and Learning Outcomes

Most of the interviewees' responses to this section agreed that the GenAI tools have both positive and negative impacts on students. Interviewee 4 said:

"We all know that AI will reshape the nature of work, and as a result, it will inevitably change the way we approach education."

Moreover, they all emphasized that AI should be viewed as just a tool, and students could benefit the most from it by using it effectively, where it could serve as a great collaborator in the creative process and during brainstorming. It can act as a virtual friend or colleague with whom you can collaborate and generate ideas. Interviewees mostly indicated that GenAI tools can become instruments for enhancing creativity and innovation, and their impact on students is mainly positive, depending on how wisely and effectively students utilize them, especially by mastering the right prompts. From their perspective, students should first acquire fundamental architectural skills and knowledge before being introduced to AI tools, as they could start relying solely on AI without fully understanding the core principles of architecture, which could lead to a disconnect from its foundational aspects. In addition, Interviewee 5 stated that:

“It is perfectly fine to incorporate AI-generated ideas, but students still need to refine them and make them more precise, comprehensive, and detailed, as this refinement process is a crucial part of learning.”

1. Time Saving and Improving Productivity

In response to this point, all participants demonstrated that using GenAI tools reduces the time required for studio work compared to traditional methods, particularly in the pre-design phase, the idea generation stage, and design visualizations. With these time savings, students can allocate their time more efficiently to other important aspects of the design process, leading to improved productivity. Interviewee 16 noted that:

“Students can generate multiple design concepts and explore different ideas within a single day, thereby significantly enhancing the efficiency and speed of

the design process. Rather than spending excessive time on manual processes, students can focus more on developing their ideas, allowing for more time on critical positioning and design resolution instead of spending hours drawing plans and exploring massing concepts.”

However, interviewees mentioned that AI-based tools change the nature of the work done by students, allowing them to focus on more efficient studies of the design process, problem definition, and decision-making processes.

2. Foster students' creativity and inspiration

This is an interesting point raised by multiple interviewees, where most of them agreed that AI enhances creativity and inspiration by providing quick iterations and assisting students in the design process. They also indicated that utilizing GenAI tools helps students develop their ideas quickly, as they open up new possibilities they might not have considered independently. As Interviewee 6 described:

“It feeds human creativity, giving them more chances to improve imagination, and rapidly materializes conceptual possibilities that might otherwise remain unexplored.”

3. Explore more innovative variations & aesthetics

More than two-thirds of the interviewees highlighted AI's advantage in enabling students to explore numerous design variations and design solutions more easily, enhancing their design thinking and allowing them to develop more advanced and innovative concepts, while also supporting data-driven decision-making through access to vast amounts of

information. These tools allow them to generate multiple design variations, with the goal of broadening their perspectives and enhancing their imagination. Interviewee 8 said:

“AI could become a fundamental part of project evaluation, enabling designs to be analyzed for diversity, sustainability, and aesthetics, while offering precise feedback based on global standards.”

Moreover, the interviewees noted that Generative AI tools can be used for visual or aesthetic representation, such as sketch-to-render or model-to-render processes, rapidly generating formal variations and compressing visualization workflows that once required significant technical expertise. Similarly, some of them highlighted that Autodesk Revit has integrated generative AI design tools over the past few years, allowing architects to explore multiple design solutions more efficiently. In this context, Interviewee 4 mentioned:

“AI is currently focused on prediction, helping students visualize possibilities and expand their design space.”

4. Acceleration and Automation

Interviewees illustrated that GenAI tools accelerate architectural design processes by rapidly generating multiple formal variations, automating repetitive documentation tasks, and streamlining visualization workflows, particularly when students work with large datasets. AI helps them quickly compare and analyze information, assists in data collection and review, and highlights key aspects that students should consider. According to Interviewee 9, who mentioned that:

“These tools accelerate the design process by eliminating repetitive tasks, allowing students to focus more on creativity and problem-solving.”

Furthermore, interviewees also reported that utilizing GenAI tools in architectural design accelerates design iterations and speeds up the design process, enabling faster exploration of ideas. They stated that GenAI tools offer instant analysis of spatial configurations, materials, and sustainability, enabling more data-driven design decisions rather than relying solely on intuition.

5. Enhancing Learning Outcomes and Students' Performance

Most of the interviewees advised that AI tools should be used as an assistant, supporting, and complementary tool, not a replacement for human critical design thinking and creative decision-making processes. They pointed out that it is essential for students to learn how to utilize AI tools and integrate them with traditional methods to achieve a balanced and comprehensive understanding that bridges modern technology with classical architectural principles. Interviewee 2 emphasized that:

“The impact of GenAI tools on student learning depends on how they are utilized. When applied solely for quick visual outputs, AI risks weakening creative thinking. However, when integrated as a tool for testing ideas, solving technical challenges, and refining design decisions, it enhances students' analytical skills and deepens their understanding of the design process.”

A practical example of this comes from Interviewee 11, who conducted multiple experiments over three consecutive semesters with different student groups, focusing on analyzing AI's effective applications in architectural education. As part of this analysis,

she compared the first and second research projects in one of the courses and observed a noticeable improvement in learning outcomes. As a result, she found that AI enhances student performance, improves imagination and innovation skills, and ultimately leads to significant improvement in learning outcomes. This highlights the importance of structured AI integration in education, aligning with Interviewee 5's perspective that academia should develop clear guidelines on AI usage in architectural education to ensure it not only benefits students but also enhances their overall learning experience. Taking into consideration Interviewee 3's perspective who said that:

“AI is a powerful tool, as it can generate both reliable and unreliable information, as well as valid and invalid data. It can also produce relevant and irrelevant results, making filtering a necessary step. In fact, AI itself can be used for filtering, but it must be given clear instructions and well-defined parameters.”

Additionally, interviewees emphasized that the more precise and clear the guidance provided to GenAI tools, the more accurate and useful the results will be. The quality of the output is directly dependent on the input: when directed properly, GenAI can produce highly accurate outcomes; however, poor or vague guidance inevitably leads to flawed results.

6. Optimize design functionality

Lastly, around half of the interviewees noted that the AI is increasingly seen as a powerful tool for optimizing design functionality in architectural education. It enables students to analyze and refine their work more effectively by offering feedback on the architecture design and performance evaluations based on architectural criteria. This can enhance the

quality of models generated, improve renderings, and facilitate the selection of the most suitable design forms, thereby helping students make informed and functionally sound design decisions. Interviewee 8 said that:

“AI-powered programs can provide instant feedback on designs, suggest improvements based on architectural criteria, and offer optimized design solutions. They have the potential to become a fundamental part of project evaluation by enabling analysis in areas such as sustainability, thermal performance, and aesthetics.”

7. Frequency of opportunities and benefits

Based on *Figure 4.5* and *Table 4.10*, showing the response frequency, percentage, and ranking, reported by academic experts, reflecting their evaluation of GenAI’s advantages and opportunities in the architectural design process. The result revealed that all interviewees agreed that the most notable benefit of using GenAI tools in architectural design is saving time and improving productivity, as reflected by 18 references. They emphasized that AI helps reduce the time spent on tasks such as idea generation and visualization, allowing students to manage their time more efficiently and focus on other important aspects of the design process. This shift improves students' productivity and supports more effective project development.

Another highly reported benefit, with 16 mentions and an 89% response percentage, is fostering students’ creativity and inspiration, as they noted that GenAI tools help students generate multiple iterations quickly and explore new ideas they might not have considered, especially in the early design stages.

A key benefit emphasized by the interviewees and mentioned 13 times, with a response percentage of 72% among academic experts, is the ability of GenAI tools to support the exploration of more innovative design variations and aesthetic outcomes. These tools enable students to generate multiple formal alternatives, broadening their design perspectives and aiding in visual experimentation and enhanced imagination. Interviewees also noted that GenAI contributes to design evaluations in areas like sustainability and aesthetics, offering data-driven insights that enrich the creative process.

Another frequently mentioned benefit, reported 11 times with a response percentage of 61%, is the acceleration of the design process. Interviewees explained that AI tools support quicker generation of design iterations, automate repetitive tasks, and assist in analyzing spatial configurations and materials. This allows students to make faster, more informed design decisions.

Next to this, enhancing learning outcomes and student performance was mentioned 9 times, with a response percentage of 50%. Interviewees emphasized that GenAI tools, when integrated alongside traditional methods, can deepen students' understanding of the design process. They agreed that AI should act as a support tool, refining ideas, aiding problem-solving, and improving overall academic performance, rather than replacing critical design thinking. Structured guidance and clear educational frameworks were seen as essential for maximizing the benefits of AI integration.

Finally, optimizing design functionality was highlighted 8 times by the interviewees, with a 39% response percentage. The experts noted that GenAI tools can assist students in refining their architectural designs by providing feedback based on performance evaluations and architectural criteria. This helps enhance the quality of outputs, supports

better decision-making, and enables students to select the most suitable design solutions based on sustainability, aesthetics, and thermal performance.

Table 4.10: Results from expert interview analysis on AI-related advantages and opportunities in architectural design, based on response frequency, percentage, and ranking

Experts' perspectives on the opportunities of utilizing GenAI tools in architectural design	Experts Interviews		
	Freq.	Percentage	Ranking
Save time & improve productivity	18	100%	1
Foster students' creativity and inspiration	16	89%	2
Explore more innovative variations & aesthetics	13	72%	3
Improve acceleration and automation	11	61%	4
Enhance learning outcomes and student performance	9	50%	5
Optimize design functionality	7	39%	6

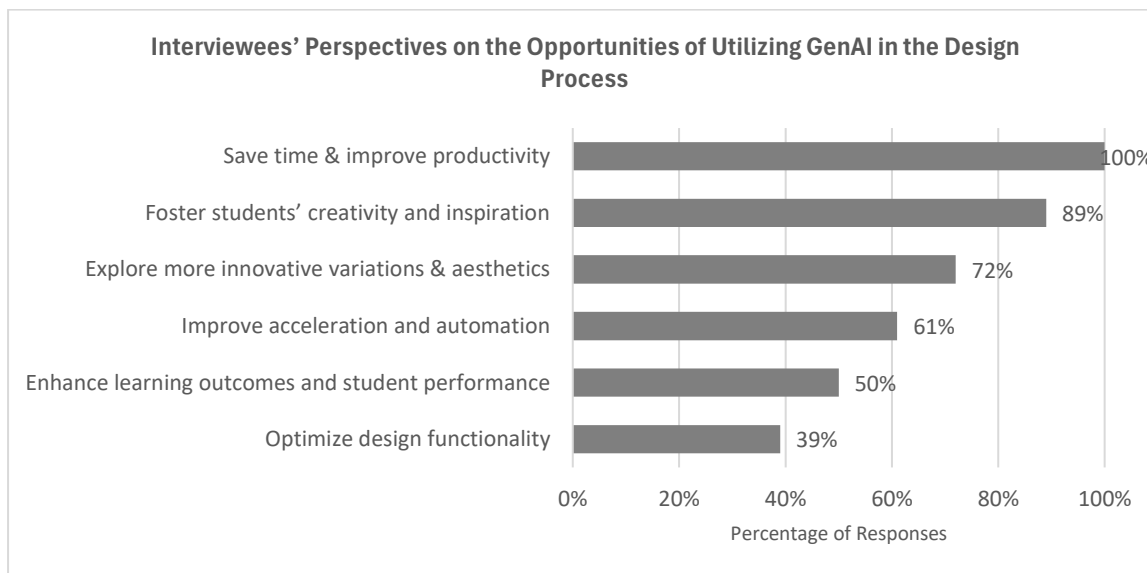


Figure 4.5: Interviewees' responses in percentages on the opportunities and benefits of GenAI utilization in the architectural design process

4.3.4 Risks, Challenges, and Concerns in Integrating GenAI Tools Into

Architectural Education and Design Process

Although AI offers considerable benefits in architectural education, its integration presents notable challenges and disadvantages, as highlighted by interviewees from various

international institutions. Many acknowledged that using Generative AI tools can enhance students' imagination and creativity in the short term by opening up new possibilities and design variations.

However, concerns were raised about the long-term implications: excessive reliance on AI may hinder students' creative instincts and reduce opportunities for independent exploration and experimentation. As Interviewee 10 noted,

“Utilizing AI could negatively impact students in the long term if they over-rely on AI, which could limit their creativity, and an excessive dependence may reduce their critical design thinking.”

These challenges and disadvantages can generally be categorized as follows:

1. Lack of Technical Knowledge and AI Training

The most frequently cited challenge and barrier across interviews is the lack of technical knowledge and AI-focused training among educators. Interviewees emphasized the need for qualified faculty members who can guide students through the complexities of AI. They noted the shortage of qualified academic staff proficient in AI and called for substantial institutional investment in specialized training programs. Additionally, interviewees mentioned that faculty preparedness is critical, as many educators experience tension between their established expertise and emerging computational paradigms, leading to hesitation in incorporating tools they have not yet fully mastered.

Moreover, interviewees believed that there is a growing gap between educators and students, which prevents the effective integration of AI tools into education. This real barrier is not the technology itself, but rather whether educators are well-versed in AI,

actively using it, and exploring its theoretical and practical applications. This was supported by Interviewee No. 6, who stated that:

“The most significant challenge would be educating educators so that they can effectively evaluate the AI-assisted work presented by students. However, they must first be convinced that AI has a positive impact on architecture and architectural education.”

2. Ethical Concerns in AI Use

Ethical concerns are frequently raised by multiple interviewees, particularly regarding intellectual property, transparency, and responsible deployment. They emphasized the ethical misuse of existing work without proper credit. Interviewee 11 highlighted that:

“Once an idea is entered into an AI system, it is stored on the program’s servers, which means that it could potentially be accessed, reused, or even modified by others without proper attribution to the original creator.”

The interviewees also stressed the importance of students understanding the sources behind AI-generated content, particularly in image creation. Cases like students unknowingly presenting AI-altered designs as their work highlight critical gaps in intellectual property awareness. According to many interviewees, such ethical concerns can be addressed through the educator’s role as a leader, who can establish a clear plan for students on how to utilize AI in their learning process. They suggested a transparency-based approach for student projects, proposing that when students submit their final studio project posters, they should clarify whether the design was created solely by them or with the assistance of AI tools. This would foster academic integrity and accountability, ensuring that the utilization

of AI in the design process is openly acknowledged and preventing misrepresentation of AI-generated content as purely original work. Interviewee 14 highlighted that:

“Broader AI-related ethical challenges, including transparency, responsible deployment, and long-term implications in education, underscore the need for clear ethical guidelines for responsible AI deployment within universities.”

3. The Absence of AI Governance Policies and Guidelines in Universities

The majority of interviewees expressed the need for clear AI regulations and guidelines to govern the use of AI in education. They agreed that while completely preventing students from using AI is unrealistic. Universities must take responsibility for establishing clear guidelines and restrictions. Interviewee 15 strongly advocated that:

“Establishing clear governance policies for the responsible use of AI within universities, which define structured institutional guidelines, ethical boundaries, and accountability is essential, and holding regular training sessions for faculty and students ensures informed and ethical AI practices.”

Interviewee 3 supported this need by providing an example of how his university is addressing AI governance gaps. He explained that their institution openly discussed the issue with the deanship and decided to incorporate AI usage guidelines into course syllabi. Two potential approaches were considered: completely prohibiting AI, which would drive students to use it secretly, or promoting transparency and providing clear guidance. The university chose the latter to enhance monitoring and direct students' use of AI, which can be implemented by including a section in each course syllabus outlining AI usage regulations, with different rules for theoretical courses and design studios. This approach

enables universities to develop AI policies that balance between regulation and innovation, ensuring the responsible use, transparency, and academic integrity.

4. Maintaining the Balance between AI Utilization and Students' Critical Skills

Another frequently mentioned challenge is balancing the use of AI with the creative and critical thinking skills. Several experts have clearly articulated the importance of striking a balance between AI usage and the preservation of core creative and critical thinking abilities. They underscored the importance of carefully managing AI integration and maintaining the right balance, ensuring it enhances rather than diminishes students' creativity and capabilities. Building on this idea, Interviewee 4 emphasized that:

“Students should be actively trained to evaluate AI outputs rather than passively accepting them critically. He urged educators to shift students away from passive consumption toward creative and critical engagement with AI’s role in architecture.”

Moreover, some interviewees stated that the impact of GenAI depends on the student's level of education. While others pointed out that if AI is introduced at the early stages of education without considering architectural fundamentals, may result in students lacking essential skills and negatively impact their creativity by providing solutions without a strong foundational understanding. Interviewee 3 mentioned that:

“If students leave the design decisions to AI judgment, the results may be negative or, at the very least, unreliable.”

However, The interviewees emphasized the need to limit the use of AI tools and encourage students to thoughtfully evaluate and engage with AI-generated designs rather than blindly trust them. Additionally, some interviewees suggested that professors can designate specific parts of the projects where AI is allowed, while ensuring that other sections rely entirely on students' personal efforts, thereby emphasizing the importance of fostering critical thinking. Interviewee 2 pointed out the role of studio instructors in maintaining this balance by engaging students to understand their thought processes, research, and design intentions. He said that

“The final design should reflect deep intellectual exploration rather than being driven solely by aesthetics or AI-generated outputs.”

Similarly, Interviewee 1 expressed concern that AI is diminishing meaningful discussions between students and professors, leading to a decline in the depth of design philosophy and critique, which indicates the need for structured implementation rather than unrestricted AI use.

5. Resistance to AI Adoption among Faculty

Faculty resistance to adopting AI tools was identified as another considerable obstacle. This issue was addressed by many interviewees who state that educators often show reluctance to embrace technological shifts due to the accompanying pedagogical and methodological changes. This hesitation and resistance to change are significant barriers slowing AI adoption. Moreover, the interviewees emphasized that ignoring AI is not an option; professors' responsibility is to adapt their methods to align with these changes

rather than resist them, ensuring they stay engaged with evolving student needs. Interviewee 1 outlined that:

“Many instructors are opposed and skeptical about the effectiveness of AI tools, and show resistance to change. Some of them highlighted that we are experiencing a shift similar to the one that occurred when computers were first introduced, where tools like CAD faced criticism but eventually became indispensable.”

In addition to the above, some interviewees mentioned that resistance to change exists among educators, especially from older generations, who may be reluctant to integrate AI into education because it could change their role in teaching or contradict the principles they aim to instill in students, which is understandable. However, as Interviewee 9 explained, citing the example of Italy initially banning ChatGPT in its universities but soon reversing its decision, some academic institutions are also attempting to detect AI-generated content. Rather than resisting it, educators and professionals should, instead, embrace its potential while maintaining critical oversight.

6. Lack of AI-specific Courses in the Academic Curriculum

Experts advocated for integrating AI education into architectural curricula to ensure students gain a basic understanding of AI in architectural design. However, there are differing perspectives on the optimal timing for AI integration in architectural education.

Interviewee 16 emphasized that:

“AI should be introduced in later years of study, allowing students to first develop fundamental architectural and design skills before leveraging AI tools, thereby

building a strong foundation in traditional architectural principles. This is essential for students to utilize AI effectively in the advanced stages of their education.”

In contrast, other interviewees advocated for integrating well-defined AI courses from the early stages of education, as delaying AI exposure may hinder students’ understanding of key concepts, such as generative design, parametric design, computational tools, Grasshopper, and coding. Interviewee 10 illustrated that:

“As a department chair, I am currently developing a new curriculum that will introduce AI and computational tools into architectural design education starting in the fall of 2025, ensuring that students are equipped with essential digital skills early on.”

Furthermore, interviewees also highlighted a broader challenge regarding the lack of interdisciplinary focus in architectural education. They explained that architecture inherently relies on multiple disciplines, including mathematics, statistics, programming, and artificial intelligence, which should be included alongside architectural subjects to provide students with the technical skills essential for AI-based design. Providing an example of existing AI integration. Providing an example of existing AI integration, Interviewee 1 noted that:

“AI has already been incorporated into some architectural curricula at his university. Courses such as “Parametric AI Design” at the undergraduate level and “Advanced AI” at the master’s level have been introduced to train students in using AI tools. This demonstrates that some institutions have already taken

steps toward integrating AI into architecture education, thereby bridging the gap between theory and practical application.”

7. Students’ Overreliance on Gen AI Tools and a Decline in Their Skills

Students’ overreliance on AI tools is one of the most significant concerns that experts have expressed, as it could hinder their creative and intellectual growth, as well as their manual skills. Interviewee 3 stresses that:

“Students must develop fundamental skills before leveraging AI tools, ensuring that AI does not replace but rather complements their creativity. Without this foundational knowledge, students may struggle to engage in deep, meaningful thinking.”

Moreover, some interviewees also mentioned that since AI is trained to generate responses, whether correct or not, it can lead students to rely blindly on its outputs rather than using critical thinking. In this context, Interviewee 10 said that:

“Utilizing AI could negatively impact students in the long term if they overreliance on AI, which could limit their creativity, and an excessive dependence may reduce their critical design thinking.”

They strongly emphasized that students tend to grant AI excessive creative freedom, which risks reducing originality and may lead to mental stagnation, with students simply waiting for the computer to generate results without making an effort in essential stages such as brainstorming, critical analysis, and meaningful design exploration. Offering an opposing viewpoint.

Interviewee 18 indicated that:

“Over-reliance on AI may diminish over time, as students continue using AI, they will start noticing recurring patterns and similarities in its outputs. This awareness could prompt them to engage more critically with AI, treating it as a design aid rather than a crutch.”

These concerns underscore the need to strike a balance between the use of AI and students’ creativity and critical thinking, a topic discussed in the next point.

8. Data Bias Concerns in AI-generated Content

Data bias in AI-generated content is another critical issue raised by multiple interviewees, who mentioned that they have noticed a bias that skews knowledge toward Western perspectives, creating a gap that needs to be addressed. For example, Interviewee 12 explained that he encountered data bias in AI-generated content, particularly in the field of architectural history. He observed that while AI provides extensive and detailed insights into Greek and Roman architecture, information on Arab and Islamic architecture is significantly limited and lacks depth. Building on this concern, Interviewee 15 suggested that:

“Institutions should invest in locally hosted AI models as a strategy to reduce bias and maintain local contexts. By training AI on regionally diverse datasets, educational institutions can ensure students receive a more balanced architectural perspective.”

Furthermore, the interviewees pointed out that poor data validation and a lack of critical understanding among students contribute to the unreliability of AI-generated outputs, thereby reinforcing architectural misconceptions. Interviewee 8 emphasized that:

“Addressing data bias necessitates a continuous review of the AI tools employed and the need for AI models to be built on diverse datasets to prevent them from imposing a specific design approach on students.”

9. High Cost of AI Tools and Infrastructure

Regarding cost-related barriers, although several experts stated that it was affordable and not a major obstacle, it was not a decisive factor in their decision. However, other experts considered it a factor that could not be ignored. They confirmed that high infrastructure costs could significantly restrict access to advanced and effective AI tools, particularly in developing regions. Interviewee 10 acknowledged that:

“Advanced AI software and computing infrastructure remain financially prohibitive for many institutions. Without sufficient funding, universities may struggle to provide students with access to cutting-edge AI tools, restricting their ability to integrate AI into the learning process.”

Comparably, Interviewee 17 highlighted resource inequities at both institutional and individual levels. She noted that well-funded programs offer state-of-the-art infrastructure and AI expertise, while resource-limited institutions risk deepening digital divides among students. This imbalance, according to her opinion, risks deepening digital divides among students, further exacerbating disparities in architectural education and professional readiness.

Moreover, Interviewee 15 pointed out that:

“Institutions are often reluctant to invest in AI technology without a clear cost-benefit justification. The uncertainty regarding AI’s long-term impact on education and job markets further discourages decision-makers from allocating substantial budgets toward AI infrastructure.”

10. Incompatibility with Traditional Design Methods

Incompatibility with Traditional Design Methods was raised by a few interviewees who indicated that a sharp tension between traditional architectural practices and AI methodologies. Interviewee 4 notes that:

“Students who rely heavily on AI-generated images often struggle to translate their designs into tangible, buildable models, suggesting a fundamental gap between traditional methods and new AI-generated techniques.”

Additionally, Interviewee 17 noted that:

“AI-generated models can sometimes be highly idealized or even fantastical, making them impractical for real-world implementation when combined with traditional methods. This leads students to focus on unrealistic designs rather than practical architectural solutions.”

These highlighted insights from diverse international perspectives illustrate the multifaceted nature of challenges involved in responsibly and effectively integrating AI into architectural education. Among the most frequently mentioned challenges, lack of

technical knowledge, AI training, ethical concerns, and the Absence of AI governance policies indicate the urgent need for clear AI integration guidelines in universities.

On the other hand, the least mentioned challenges were incompatibility with traditional design methods, and the cost-related barriers, which suggested that AI is not perceived as a direct threat to conventional architectural approaches but rather as an adjustment challenge. However, there are important factors to consider, such as data bias, resistance to change, and students' overreliance on Gen AI Tools, while prioritizing the most pressing issues in adapting AI to education. *Figure 4.6* and Table 4.11 illustrate the frequency, percentage, and ranking of these concerns, highlighting the key risks associated with AI adoption.

Table 4.11: Results from expert interview analysis on AI-related challenges and disadvantages in architectural design, based on response frequency, percentage, and ranking

Experts' perspectives on the challenges of utilizing GenAI tools in architectural design	Experts Interviews		
	Freq.	Percentage	Ranking
Lack of Technical Knowledge and Training	16	89%	1
Ethical Concerns	14	78%	2
Absence of Guidelines	12	67%	3
Maintaining Balance between AI Utilization and Students' Critical Skills	11	61%	4
Resistance to Change	10	56%	5
Lack of AI courses in the Curriculum	10	56%	6
Students' Overreliance	9	50%	7
Data Bias	9	50%	8
High Cost	6	33%	9
Incompatibility with Traditional Design Methods	4	22%	10

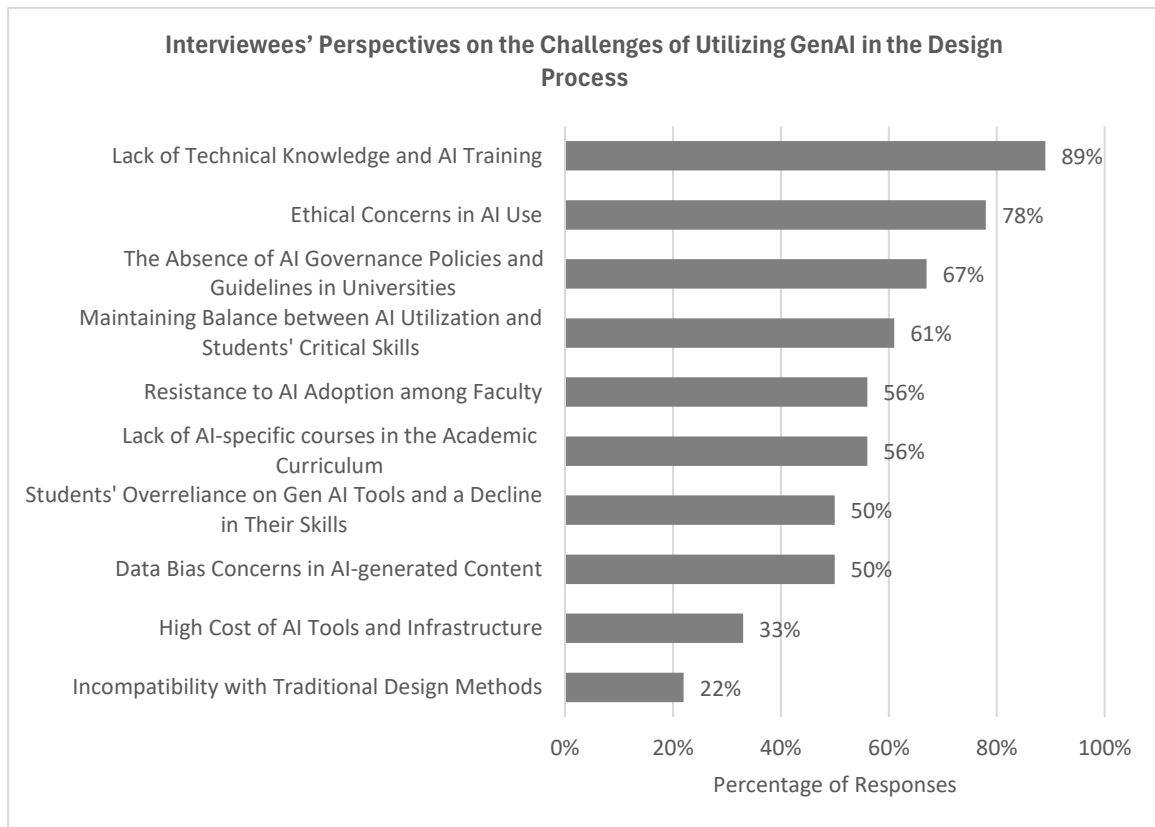


Figure 4.6: Interviewees' responses in percentages on the challenges and concerns of GenAI utilization in the architectural design process

4.3.5 Personal Experiences and Practical Applications of Experts

Moving on, academic professionals who have directly integrated AI tools into their teaching environments were asked about their diverse personal and practical experiences, and they shared their firsthand insights into how AI impacts their students' learning outcomes, creative processes, and engagement with design through real-world applications. These insights provide valuable reflections on the evolving role of AI in architectural pedagogy, highlighting the significant considerations.

5. Early Implementation and Engagement in Studio Courses

In several institutions, AI tools such as Midjourney were introduced in experiments and early-year studio courses, where students were encouraged to explore their potential in design visualization and conceptual development. These implementations varied in scope, from utilizing AI to generating visual design and iterations to applying it for specific tasks and style analysis. The interviewees reported that, leveraging these tools, students were able to rapidly produce and compare multiple design alternatives, which accelerated decision-making and supported the development of analytical and critical thinking among students.

A similar experiment was implemented with Interviewee No. 3, who applied AI in “Studio One” by combining physical modeling and AI image rendering tools. Students began by building a simple model to understand spatial elements and later used AI by taking pictures of it and inputting them into image rendering software to generate multiple design variations, as shown in their experiment in *Figure 4.7*. Interviewee No. 3 stated that:

“Students’ results were promising, and AI tools enabled them to visualize and discover new ways to manipulate form, light, and structures, as well as expand their ideas and enhance their imagination”.



Figure 4.7: Examples from Interviewee 3’s experiment with AI-assisted rendering of physical models at Effat University, Jeddah

6. Bridging Traditional and Digital Tools in Architectural Design Education

Several interviewees highlighted the empowerment of AI utilization and related digital technologies in supporting students who face challenges with traditional design techniques. Interviewee No. 12, for example, applied AI in a heritage-focused course, where students demonstrated strong engagement despite biases in AI-generated data. This experiment, which was academically published, used tools like Leonardo AI in History of Architecture courses. Through structured workshops, students visualized ancient architectural forms, reimagined lost heritage, and integrated various historical styles as illustrated in *Figure 4.8*. He added:

“Despite initial challenges such as bias in AI-generated outputs, this integration significantly enhanced creativity, critical thinking, and understanding of historical contexts”.



Figure 4.8: Examples of Interviewee 12’s workshop using AI in combining two different architectural styles

Source: (Fareed et al., 2024b)

Interviewee No. 4 shared a similar observation, recounting the case of a student lacking confidence in sketching. He explained that:

“Integrating physical sketches with AR and AI-generated enhancements helped the student evolve from rough drafts to complex visual narratives, deepening design thinking through a reflective, mixed-media process.”

Complementing these experiences, Interviewee No. 6, whose academic focus centers on virtual reality (VR), observed a marked improvement in students’ spatial awareness of their own design decisions when they engaged with immersive environments. He noted that:

“The most significant one is that students become more aware of their own design decisions when they experience it on a 1:1 scale.”

Although not strictly generative AI, his work highlights the broader digital landscape in which AI plays an influential role in architectural education.

7. AI Integration in Advanced Studios and Sustainable Design

At more advanced levels, educators have incorporated AI into comprehensive design and sustainable projects. Interviewee No. 1 described a senior-level studio focused on “Resilient and Sustainable Residential Buildings.” One of the Gen AI tools was selected for concept extraction, parameter definition, massing, and final rendering and presentation. He highlighted that:

“This approach was highly successful, with a streamlined design process and improved students’ ability to integrate sustainability and resilience into their concepts”.

Similarly, Interviewee No. 11 conducted extensive experiments across three studio courses. Her findings emphasized the utilization of Gen AI tools across multiple stages, from sketch development and form generation to structural aspects and material integration, as well as environmental analysis. Sustainability, in particular, was a recurring theme embedded within each studio course. She stated:

“The most commonly used AI tools by students were PromeAI, DALL-E, Midjourney, and ChatGPT.”

8. Faculty Cautionary and Perspectives on Gradual Integration

Faculty members shared varied approaches to integrating AI into their teaching, reflecting enthusiasm and caution. Interviewee No. 9 described full-scale adoption across his studios, where AI supports everything from concept development to visualization. He noted:

“ While AI reduces barriers, especially in rendering, excessive use could lead to shallow, less thoughtful outcomes“.

Similarly, Interviewee No. 18 adopted a step-by-step method in his parametric design studio. He began with manual modeling before introducing AI-generated forms, encouraging students to engage critically rather than rely on automation.

Others, like Interviewee No. 5, reported that while AI is not yet formally integrated into architecture studios, his students use it independently. He stated:

“I think AI should be introduced at the intermediate level, perhaps from the second year onward, rather than at the beginning of architectural education.”

He emphasized the importance of student reflection and explanation of design

choices, noting, “I asked them to explain, in detail, their understanding of the AI-generated design and demonstrate how they critically engage with the results rather than simply accepting them at face value.”

The diverse experiences shared by academic professionals reflect a wide range of insights and opportunities on integrating AI into architectural education, from early experimentation to advanced studio integration. These perspectives emphasize the importance of balancing innovation with pedagogical responsibility, guided by clear educational objectives.

4.3.6 Recommendations for AI Integration in Architectural Education

The interviewees indicated that if students are restricted from using it, they may react oppositely and rely on it even more. Therefore, they advised faculty members to recognize that AI tools are inevitable and will be used by students, whether we accept them or not. Interviewee 1 indicated that:

“There should be agreements among faculty members regarding the importance of AI tools in developing students’ skills, both technical and personal as they should not be limited to design courses alone; rather, it should be integrated into other subjects as well, ensuring that it serves as a practical application for theoretical courses.”

In this final section, participants share their recommendations for integrating AI into architectural education and architectural design, based on their experiences and practices in the field. These suggestions have been consolidated and categorized into the following

key points, accompanied by a supporting graph that illustrates their frequency, from the most commonly mentioned to the least:

9. Establish Clear Frameworks and Guidelines for Integrating AI into Architectural Education:

The majority of interviewees, approximately three-quarters, emphasized the importance of establishing clear frameworks, policies, and guidelines for integrating AI into architectural education, by both the educational institution and the educators themselves. Such regulations, as mentioned by Interviewee 13, would clarify the expectations from the students before the project begins. Interviewee 14 elaborated on this by stating that:

“Educators and higher education institutions should establish clear guidelines outlining when and how students can use AI in the architectural design process, as well as which AI tools are permitted.”

Furthermore, as suggested by Interviewee 1, this could begin with a framework outlining how AI can be implemented in the studio environment. From there, the framework could evolve into a more concrete curriculum, eventually leading to formal policies and institutional guidelines. For educators, now is the time to revise and update our existing syllabi, making the necessary amendments to align with the future of architectural education. He also pointed out that:

“This ensures that students do not commit violations or engage in unconscious or unethical use of these tools. As an instructor, it is my duty not only to support students but also to protect them from misuse.”

Additionally, the interviewees advised instructors to understand the risks and how GenAI tools work, providing solutions that prevent students from making mistakes and engaging in risky activities that may impact their learning curve, process, design thinking, and overall understanding of architecture. Supporting this recommendation, Interviewee 1 suggested that:

“Embracing AI and adapting our teaching methods accordingly will be essential for staying relevant in this rapidly evolving landscape.”

Besides that, Interviewee 16 highlighted that she encourages experimentation and exploration within a clear scientific framework that ensures data accuracy and minimizes bias, leading to more reliable results. Also, she noted that:

“Ethical standards for AI usage must be developed to prevent the erasure of local identity due to data bias. Establishing such guidelines will help preserve cultural and architectural diversity in AI-driven applications.”

10. Provide Training for Educators and Students to Strengthen their AI Skills and Tool Familiarity:

Many interviewees emphasized the importance of the teaching staff developing and enhancing their skills and staying continuously updated, as AI advancements are evolving rapidly. In line with this, they should first understand how GenAI tools work so that they can evaluate student work with greater precision, as it is very challenging to be an effective educator without familiarity with the landscape of contemporary tools and developments. Building on this point, some interviewees suggested that colleges should make AI training mandatory for faculty to ensure they are well-equipped to guide students. Interviewee 15 indicated that:

“Educators need to recognize AI’s full potential rather than focusing only on its risks. Without a proper understanding of AI, they cannot accurately assess both its benefits and dangers. Every teacher should learn the fundamentals of AI through workshops, courses, or training to gain a well-rounded perspective.”

On the other hand, the interviewees also emphasized the importance of providing students with training on how to utilize AI effectively, ensuring that it serves as a genuine educational tool rather than merely a time-saving shortcut. Interviewee 10 mentioned that:

“We also need to provide training in tools like Grasshopper, MidJourney, and ML Generative Design. These tools must be introduced from the beginning as AI technologies evolve rapidly, with new advancements emerging every year.”

11. Develop a Structured and Inclusive AI Curriculum Across Architectural Disciplines:

Many interviewees emphasized that integrating AI into architectural education requires a structured, inclusive curriculum that extends beyond design studios to encompass a range of diverse subjects, fostering interdisciplinary understanding. Educators should also foster interdisciplinary connections that position AI within broader contexts such as ethics, cognitive science, and philosophy, topics which could be introduced through elective courses, to help students develop a deeper, more critical understanding of computational tools beyond their technical functions. Interviewee 11 pointed out that:

“There should be a well-defined course that teaches students how to use GenAI tools, ensuring equal opportunities for all students.”

Other interviewees highlighted that the integration of AI tools should not be limited to design courses alone, but should also extend to theoretical courses to reinforce practical applications.

12. *Enhance Students' Critical Thinking and Reflective Skills to Evaluate AI-Generated Design Outputs:*

Developing students' critical thinking and their ability to assess, explain, and reflect on their design processes is essential to ensure they engage thoughtfully with AI-generated outputs, question underlying biases, and clearly express their design decisions, as noted by many interviewees. They also emphasized the importance of teaching students to analyze and evaluate AI-generated results before incorporating them into their design work, and to avoid blind reliance on them. Interviewee 18 mentioned that:

“Starting first-year students directly with tools like Midjourney may not be ideal without first teaching them about AI biases and how training datasets work.”

Engaging students in analyzing AI-generated outputs helps them develop stronger critical thinking skills, a deeper understanding of design qualities such as balance and hierarchy, and the ability to clearly articulate their design decisions. Building on this, Interviewee 11 suggested that:

“Establish evaluation criteria prioritizing thoughtful AI utilization over mere technical proficiency or visual appeal. This includes assessing students' ability to critically engage with, rather than passively accept, machine-generated proposals.”

13. Monitor Student Engagement and Promote Transparency in AI Usage Within the Design Studio:

It is also essential to monitor students in the Design Studio and oversee the methods they use to ensure that they are utilizing AI tools correctly and effectively. Several interviewees pointed out that it is also crucial for the instructor to remain constantly aware of the students' work. Additionally, they indicated that it is important to monitor the methods students use to ensure they are utilizing AI tools correctly and effectively. Building on this, Interviewee 2 suggested that:

“I would also encourage instructors to use oral presentations (maybe exams), where students must critically explain their position on issues related to their work and describe in detail their processes.”

On the other hand, some interviewees emphasized that students should trust their intuition on this matter without fear of consequences. The Interviewee 14 said that:

“Transparency is a key; students should openly acknowledge their use of AI, just as they would cite sources in their academic work.”

Figure 4.9 Illustrates the percentage of responses for the recommendations of integrating AI into architectural education, as reported by the participants in the study. The recommendation that received the highest percentage of responses, with 72%, emphasizes the importance of establishing clear frameworks and guidelines for integrating AI into architectural education. This underscores the significance that educators and academic institutions should place on developing structured policies to effectively guide and govern the use of AI tools in educational settings. The second highest percentage among the

recommendations, with 50% of the participants mentioning it, stresses the need for providing comprehensive training to educators and students to enhance their AI skills and familiarity with relevant tools, reinforcing the importance of competence and confidence in AI utilization.

The next two highest recommendations, each mentioned by 33% of respondents, were developing a structured and inclusive AI curriculum across architectural disciplines and enhancing students' critical thinking and reflective skills to evaluate AI-generated design outputs. This highlights a balanced perspective among respondents toward curriculum design and critical evaluation as equally important elements for successful AI integration.

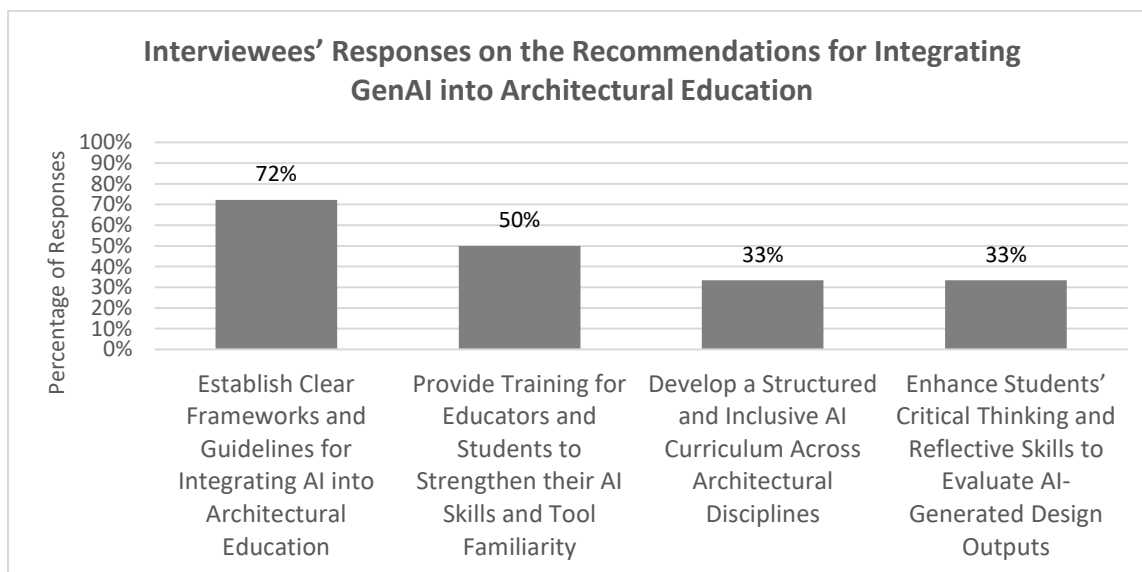


Figure 4.9: Interviewees' responses in percentages for the most cited recommendations of integrating AI into architectural education

4.3.7 Summary of Key Insights from the Interviews

This section summarizes the key findings from interviews with academic educators across four main axes: the current role and acceptance of AI in architectural education, the advantages and opportunities of AI integration in architectural design education, its risks,

challenges, and disadvantages, and the effectiveness of GenAI tools in different design phases.

A. The current role and acceptance of AI in architectural education

- AI is becoming increasingly accepted and viewed as inevitable in architectural education, despite initial resistance.
- Positive outcomes from global experiments encouraged educators to consider GenAI integration.
- Many participants emphasized that its utilization in architectural education is not yet fully explored and still lacks a standardized framework in academia.
- Students already use GenAI tools independently, often without educators' awareness. This independent exploration would be more effective and meaningful if carried out transparently, supported by clear institutional guidelines and appropriate training.

B. The advantages and opportunities

The findings revealed that, despite the positive and negative impacts of AI-based tools on students, all academic experts found the results of integrating generative AI tools into design studios to be promising and beneficial for students in enhancing their creativity, innovation, inspiration, and problem-solving skills. Key benefits are:

- All interviewees noted that utilizing GenAI tools reduces the time required for studio work and boosts students' productivity. They emphasized that with a solid foundation in architecture, students can assess, refine, and enhance AI-generated outputs.

- Most interviewees agreed that Generative AI tools help students to enhance creativity and inspiration in the short term by offering quick design iterations and enabling the exploration of multiple ideas and design variations.
- They also highlighted that Gen AI enhances aesthetic and visual representation, simplifying tasks that once required significant technical effort, allowing for greater experimentation and a broader design space.
- Several interviewees mentioned that AI aids in design optimization, sustainability, performance feedback, and data-driven decisions.
- All experts agreed that these tools should be used as assistive tools, not to replace human critical design thinking and creative decision-making processes.

C. The risks, challenges, and disadvantages

- The most frequently cited challenge by the interviewees is the lack of technical knowledge among educators and students, stressing the need for qualified faculty who can assist students and evaluate their work.
- The use of AI tools raises ethical concerns regarding originality, data storage, and intellectual property, as they are often reused without proper attribution.
- Many interviewees suggested that educators can address ethical concerns by setting clear guidelines and promoting transparency, such as requiring students to disclose their use of AI in their final design submissions.
- As mentioned by most participants, there is a need for guidelines and policies that are essential to ensure responsible use.

- A recurring concern raised by the interviewees was the need to maintain the right balance between the use of AI and the development of students' creative and critical thinking skills.
- Interviewees noted that many educators resist adopting AI due to a gap between their expertise and new technologies, a phenomenon that parallels past shifts (e.g., CAD adoption), which later became essential in the field.
- Another concern raised was data bias, observed by educators using GenAI in architectural design. They emphasized the importance of diverse, locally trained datasets and robust data validation to ensure balanced and accurate outputs.
- The least mentioned challenge is high tool cost and infrastructure, though some experts find them affordable

D. The effectiveness of GenAI tools in different design phases

- Most experts highlighted that the early stages are the most effective in utilizing GenAI tools, with 12 mentioned for the conceptual stage and 9 mentioned for the pre-design and analysis stages.
- In the conceptual stage, students can significantly impact students' ability to broaden their perspectives and enhance their imagination, thereby fostering creative development.
- Some other interviewees found GenAI tools most useful in the production and presentation stage, where quick idea testing and rendering are needed.
- The design development stage received the lowest effectiveness rating for GenAI Tools, primarily due to its technical complexity and spatial requirements.
- Some view AI as valuable in all design phases, depending on the user's proficiency.

- There are divided opinions on when to introduce AI in education: some prefer later years (after foundational skills are established), while others advocate for early exposure to digital tools.

4.4 Synthesizing the Implemented Interview and Questionnaire Methods

This section presents a comparative synthesis of findings from the two primary research methods: questionnaires completed by architects and in-depth interviews with academic experts. It highlights common key patterns, similarities, and differences to provide a clearer understanding of GenAI utilization in architectural education. Furthermore, recommendations from these methodologies are also included to support the responsible and effective integration of AI into architectural education.

Although the interview and questionnaire data differ in nature, the variables from both were ranked for comparison. The analysis focused on rankings rather than absolute values, enabling triangulation between quantitative trends and qualitative insights to enhance the reliability and validity of the study.

A. The current role and acceptance of AI in architectural education

Under this point, further discussion was conducted to gain deeper insight into the current role of AI in architecture education, considering the two study methodologies: the questionnaire with architects from the Saudi labor market and the interview with AI-focused architecture educators from international universities.

The questionnaire results yielded a weighted mean of 4.03 out of 5. This finding is further supported by the experts, all of whom unanimously confirmed that AI acceptance has

significantly increased among both educators and students across different institutions worldwide.

Moreover, most experts emphasized that since academic educators cannot prevent students from using AI-based tools in their architectural design, it is more effective for institutions to integrate these tools into the education system while providing proper training and clear guidelines. This approach would not only enhance the benefits of AI in architectural education but also help prevent misuse, which could lead to unintended consequences or a decline in essential design skills. Additionally, the experts pointed out that educators should closely monitor students' use of AI in design studios to ensure proper application and critical understanding. Transparency and oral presentations were also suggested to encourage accountability and reflective learning.

Finally, academic experts emphasized the importance of teaching students to view AI as an assistive tool rather than a replacement for their manual skills and critical thinking. They also stressed the need to equip students with a strong foundational understanding to effectively evaluate AI outputs, especially since most AI tools are not yet fully mature, and should be used carefully with clear guidance to ensure their responsible use.

B. The effectiveness of GenAI tools in different design phases

This subsection compiles and compares findings from the two study methods to provide improved clarity and insight into when and how GenAI tools are most effectively applied throughout the architectural design process.

Table 4.12 demonstrates the results from the two study methodologies, highlighting the perceived effectiveness of GenAI tools across different design stages and how these

perceptions align or diverge among participants. In the questionnaire analysis, rankings are based on the weighted mean, calculated from participants' level of agreement on a 5-point Likert scale. In the expert interviews, the rankings reflect the frequency with which academic experts mentioned each stage.

The results indicated that the conceptual design stage received the highest score from both methodologies, ranking first in both expert interviews and questionnaire analysis, suggesting that this phase is widely perceived as the most suitable and impactful for integrating GenAI tools. The next highest rank was observed in the pre-design and analysis stage, which ranked second in the expert interviews and third in the questionnaire analysis, indicating that GenAI tools are particularly effective during these early stages in academic contexts. In contrast, participants from the labor market, reflected in the questionnaire results, ranked the design production and rendering stage second, while this stage ranked third in the expert interviews, highlighting a difference in perception between academic and professional settings regarding AI's optimal application in the design process.

The least stage considered by the two methodologies is the design development stage, ranked fourth by both experts and architects, which suggests that participants view this phase as less compatible with GenAI tools, as they mentioned due to its requirement for detailed technical and spatial decisions and manual refinement. Additionally, these findings indicate that the use of GenAI in the design production stage is highly effective in the job market. Therefore, academia should place more emphasis on this stage, while reserving traditional methods for the design development phase, which requires more manual detailing and time.

Table 4.12: Comparative results from expert interviews and questionnaire analysis on the effectiveness of utilizing AI across different architectural design phases

The effectiveness of utilizing GenAI tools across design stages	Questionnaire Analysis		Experts Interviews		
	Rank	Mean	Rank	Freq.	%
Pre-Design & Analysis	3	4.10	2	9	50%
Conceptual Design	1	4.22	1	12	67%
Design Development	4	3.60	4	2	11%
Design Production & Rendering	2	4.18	3	4	22%

C. The advantages and opportunities of AI integration in architectural design education

This section presents the findings on the advantages and opportunities of utilizing AI in architectural design, based on the two study methodologies. Table 4.13 Provides a comparative overview of the ranked advantages identified, which were common in both methods, highlighting shared priorities in perception between professional and academic participants.

The compiled results confirmed that the highest advantage, according to both methodologies, is saving time and increasing productivity, ranked first by architects and experts. This highlights that the GenAI tools' ability to benefit students by helping collect and analyze data, generate multiple design concepts, and explore different ideas within a short time. This aspect is particularly valuable in architectural design studios within educational institutions, which can significantly support the design process and learning outcomes while saving time.

The next advantage that was found common by both methodologies is fostering creativity and inspiration, which ranked second according to academic experts and third according to questionnaire participants. This clearly suggests that Generative AI tools support creativity and help inspire designers by providing quick iterations and drawing their attention to new possibilities and ideas they might not have considered independently.

Moving forward with the next advantage, which is assisting in exploring more innovative variations and aesthetics, this was ranked third by the experts and second by the questionnaire participants. This indicates that it is a valuable benefit for both students in design studios and professionals in the labor market.

The lowest common advantage for integrating AI into architectural design, as mentioned by the interviewees and architects, is the GenAI tools' ability to optimize students' design functionality. This advantage targets different fields, emphasizing the importance of this function, which supports the utilization of these tools in design education.

Lastly, enhancing teamwork and collaboration, which according to the interview results, is considered a disadvantage rather than an advantage, with one mention by Interviewee 1, who said that: *“Unfortunately, AI-based tools negatively impact students’ communication and collaboration abilities.”*

Table 4.13: Comparative results from the expert interviews and the questionnaire on the common opportunities of AI utilization in architectural design

The opportunities of utilizing the GenAI tools in the architectural design process	Questionnaire Analysis		Experts Interviews		
	Rank	Mean	Rank	Freq.	%
Save time & improve productivity	1	4.31	1	18	100%
Foster creativity and inspiration	3	4.06	2	16	89%
Explore more innovative variations & aesthetics	2	4.10	3	13	72%
Optimize design functionality	4	3.63	4	7	39%

D. The risks, challenges, and disadvantages of AI integration in architectural design education

In addition to these benefits, several concerns and disadvantages were also raised and discussed. Table 4.14 Presents the results from the two study methodologies: expert interviews and the questionnaire conducted with architects from the labor market. In the expert interviews, the rankings reflect the frequency of mentions by academic experts. In the questionnaire analysis, the rankings reflect the level of agreement among participants on a 5-point Likert scale.

The results revealed that the lack of technical knowledge and training is the most pressing common challenge identified across both methodologies, ranked first by experts and by architects. This highlights the urgent need for targeted training programs to support both educators and students in maximizing the benefits of AI on learning and design outcomes. Next, the absence of clear guidelines and policies, reinforcing the demand for institutional frameworks to govern AI use in architectural education. Resistance to change followed, suggesting that hesitation in adopting new technologies remains a challenge across academia and practice.

The last common challenge is the high cost, pointing to practical financial barriers that some institutions and firms may face in adopting advanced tools.

Table 4.14: Comparative results from the expert interviews and the questionnaire on the common opportunities of AI utilization in architectural design

The challenges of utilizing the GenAI tools in the architectural design process	Questionnaire Analysis		Experts Interviews		
	Rank	Mean	Rank	Freq.	%
Lack of Technical Knowledge and Training	1	4.09	1	16	89%
Absence of Guidelines	2	3.94	2	12	67%
Resistance to Change	3	3.61	3	10	56%
High Cost	4	2.79	4	6	33%

4.5 Field Experiment

The field experiment aimed to evaluate the impact of integrating GenAI tools into the architectural design studio, particularly regarding design quality, creativity, and efficiency, and compared AI-assisted design methods with traditional approaches. As mentioned, the 10 participants were divided into two groups: one utilizing specific GenAI tools (6 students) and the other relying solely on conventional design techniques (4 students). Over a two-week period, students worked on designing a small pavilion for a public space, and their progress, problem-solving abilities, and creative outcomes were observed. Additionally, their feedback was collected at the end of the experiment to gain insights and capture their experiences.

4.5.1 Experiment Application and Students' Results

Throughout the experiment, instructors and the author closely monitored each group's progress. Students were required to submit an A3-sized architectural presentation board containing the design concept, design development, drawings, and final 3D renderings, illustrating the pavilion within its urban context. *Figure 4.10 and Figure 4.11* presents two samples of the students' works from the AI-assisted group, while *Figure 4.12 and Figure 4.13* presents two samples from the traditional control group works, providing a visual representation of the differences in design outcomes.

After the task was completed, all design submissions from both groups were collected and evaluated by the supervising instructors using a defined evaluation rubric. The rubric included analysis of context, conceptual and innovative design thinking, responsive functional solution, form and aesthetic, and graphic presentation.

The evaluation of students' designs based on the defined criteria reveals a notable difference. The AI-assisted group achieved an average overall performance of 91.25%, while the traditional control group scored 83.88%, as indicated in Table 4.15. This indicates that integrating AI tools into the architectural design process positively contributed to improvements across multiple evaluation aspects, as described below:

- **Creativity & Innovation:** The AI group performed better, as they were able to explore a broader range of design alternatives generated by AI, leading to new ideas and enhanced conceptual exploration.
- **Functionality:** AI tools improved design optimization, leading to better functional solutions.
- **Aesthetics and Presentation:** AI-assisted students demonstrated superior, refined aesthetics and more visually appealing presentations using digital media, surpassing those of the traditional group.

It is important to note that the AI-assisted group achieved these higher results despite the experiment being conducted over a short period and without sufficient prior training on AI tools. This suggests that with proper training, students' performance would likely improve even further.

Inspiration: Inspired by desert dunes and wind-sculpted landscapes, the pavilion blends organically with its arid environment.

Research:

Used ChatGPT to explore pavilion principles.

Concept:

Generated ideas with MidJourney prompts.

Analysis:

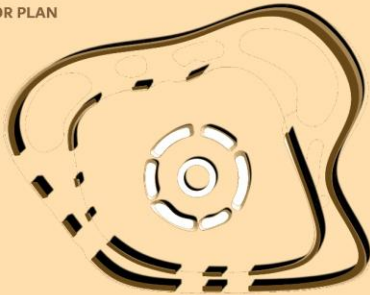
Identified key elements from AI outputs.

Modeling: Designed in Rhino.

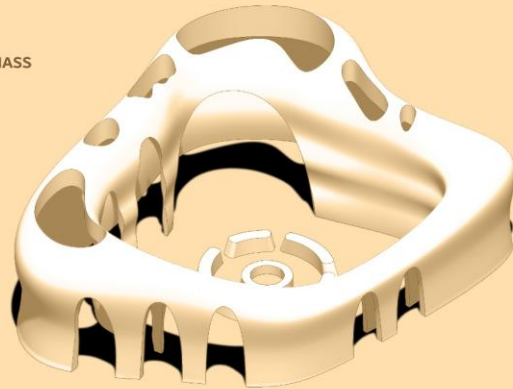
Rendering: Visualized using: mnml.ai



FLOOR PLAN



3D MASS



ELEVATIONS



SECTIONS



Figure 4.10: Samples of students' designs – AI group – Sample 1



Figure 4.11: Samples of students' designs – AI group – Sample 2

FUTURE MAKERS PAVILION: A CAPSTONE EXPO

DESIGN COCEPT

THE KFUPM SENIOR PROJECTS PAVILION IS NOT JUST A STRUCTURE BUT A SYMBOL OF THE UNIVERSITY'S DEDICATION TO FOSTERING TALENT AND INNOVATION. IT SERVES AS A BRIDGE BETWEEN ACADEMIA AND THE FUTURE, PROVIDING A PLATFORM AREA FOR STUDENTS TO SHOWCASE THEIR ACHIEVEMENTS AND INSPIRE THE NEXT GENERATION OF PIONEERS.



THE MAIDAN AREA



AXIS LINE



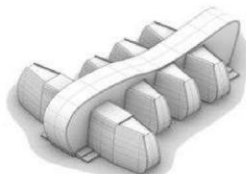
NODAL POINT



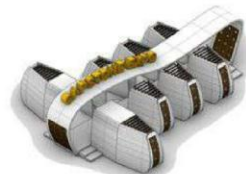
6 COLLEGES & GIFT AREA



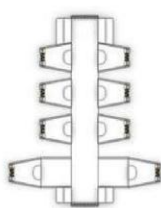
MASS 1



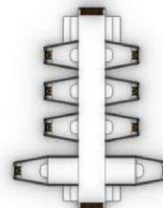
MASS 2



MASS 3



PLAN AT 0.45M



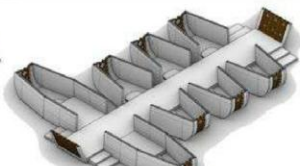
PLAN AT 1.6M



PLAN AT 4.5M



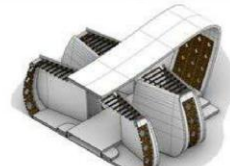
SECTION AT 0.45M



SECTION AT 1.60M



LONGITUDINAL SECTION



CROSS SECTION

Figure 4.12: Samples of students' designs – control group – Sample 1

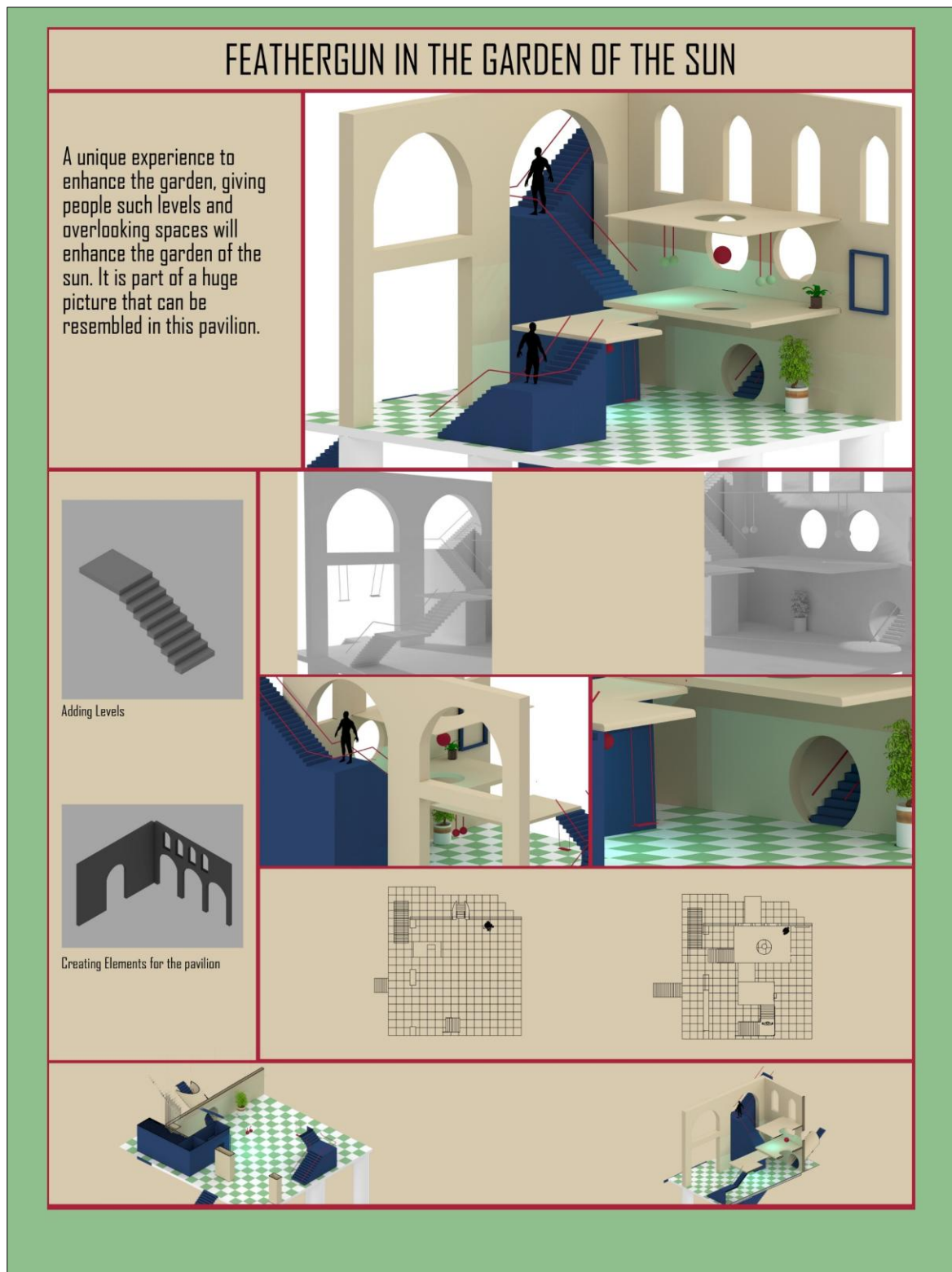


Figure 4.13: Samples of students' designs – control group – Sample 2

4.5.2 Instructors' Evaluation

This section discusses the instructors' evaluation of the students' work submitted for the field experiment, considering both the AI group and the control group. The results show an overall improvement in every criterion, as indicated in Table 4.15. The enhancement ranged from the highest criteria with 15.85% for formal solution and aesthetics, to the lowest criteria with 2.56% for the analysis of site/context. Furthermore, the table illustrates that the overall evaluation was enhanced by around 9%, highlighting the positive impact of integrating GenAI tools on students' design performance.

Table 4.15: Instructors' evaluation of students' performance in the field experiment for AI and control groups

Overall Instructors' Evaluation							
Grade		10	30	20	20	20	100
Graded Item		Analysis of Site/Context	Conceptual and Innovative Design Thinking	Responsive Functional Solution	Formal Solution and Aesthetics	Graphic Presentation Using Digital Media	Total Points
AI Group							
1	Student 1	8.5	30	17.5	19	20	95
2	Student 2	8	30	18.5	18	18	92.5
3	Student 3	8	27	17	15.5	18	85.5
4	Student 4	8	29	15.5	18.5	19.5	90.5
5	Student 5	10	29	19	18	20	96
6	Student 6	7.5	28	16.5	17	19	88
Mean		8.33	28.83	17.33	17.67	19.08	91.25
				Total Score Mean			
Control Group							
7	Student 7	7	27	14.5	13	17.5	79
8	Student 8	9	29	17	17.5	19	91.5
9	Student 9	7	25.5	14	12.5	17.5	76.5
10	Student 10	9.5	26	15	18	20	88.5
Mean		8.13	26.88	15.13	15.25	18.50	83.875
				Total Score Mean			

Relative Performance Improvement	0.21	1.96	2.21	2.42	0.58	7.38
	2.56%	7.29%	14.60%	15.85%	3.15%	8.79%

4.5.3 Assessing GenAI Support in the Architectural Design Process and Tasks

Within the Experimental Design Studio

To better understand the practical implications of integrating generative AI tools into architectural education, this section presents a detailed analysis of the design process as applied in the experimental studio. The design process was divided into four main phases, each consisting of specific tasks typically undertaken by students during a studio project. Drawing from student outcomes, observations, and feedback during the experiment, each task was assessed for its compatibility with GenAI tools—whether AI could fully support the task, partially assist it, or offer no meaningful contribution.

Figure 4.14 illustrates the sequence of design tasks across the four main phases of the architectural design process, using clear symbols to indicate the extent of GenAI involvement in each task, ranging from full support to partial or no support. Also, Table 4.16 provides an analytical breakdown of how GenAI tools can support each stage of the design process. Overall, GenAI demonstrated strong potential in tasks related to ideation, visual inspiration, design rendering, and presentation enhancement. However, its support was limited or absent in tasks that require contextual judgment, functional programming, or in-depth problem analysis. This highlights GenAI’s current role as a complementary assistant that enhances creative and representational aspects of design, while more technical and strategic decisions still rely on human input.

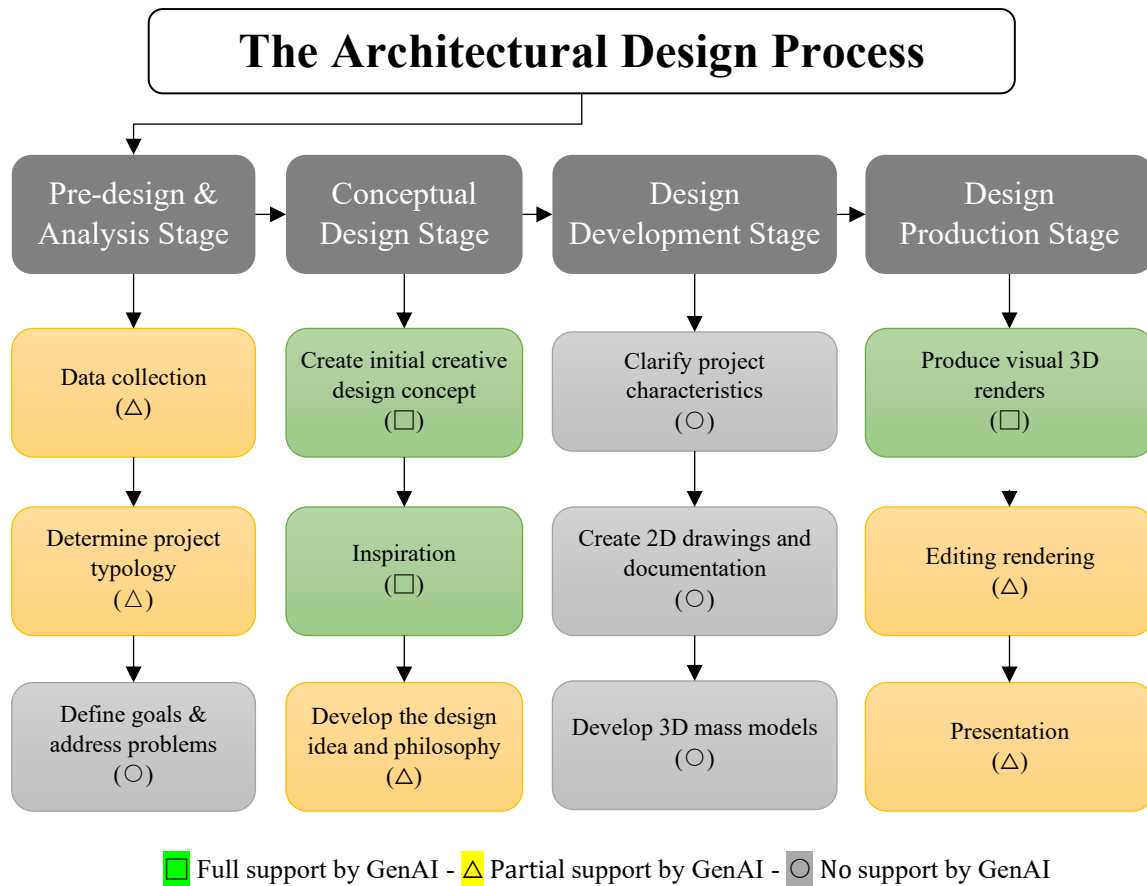


Figure 4.14: Flowchart representing GenAI support across architectural design phases and tasks

Table 4.16: Analytical evaluation of GenAI support across the architectural design process

Design Phase	Task	GenAI Role			GenAI Support Type
		No AI support	Partial support	Full support	
Pre-Design & Analysis Stage	Data collection		✓		Speeds up info gathering using text/image prompts
	Determine project typology		✓		Suggests typologies based on similar cases
	Define goals & address problems	✓			No support
Conceptual Design Stage	Create an initial design concept.			✓	Generates creative concepts based on user input
	Inspiration			✓	Provides a variety of visual inspiration

	Developing design ideas and philosophy		✓		Suggest ideas to refine the design direction.
Design Development Stage	Clarify Project's Characteristics	✓			No support
	Create 2D drawings and documentation	✓			No support
	Develop 3D mass models	✓			No support
Design Production Stage	Produce visual 3D renders.			✓	Generates photorealistic or conceptual renders
	Editing renderings		✓		Enhances images or renders using AI tools
	Presentation		✓		Helps in layout design, formatting, and visuals

4.5.4 Students' Feedback Analysis

Throughout the experiment, students from both groups provided valuable insights into their experiences, highlighting the advantages and challenges of their respective design approaches. To systematically capture their perspectives, all students completed a brief survey at the end of the experiment, sharing feedback on how the process influenced their learning. Their responses highlighted the impact of AI tools on creativity, efficiency, and the overall design experience for the AI group, while the control group, relying solely on traditional methods, offered perspectives on working without AI assistance.

Part 1: Prior Experience and Background

Both groups were asked about their familiarity with digital design tools. The results indicated a strong foundation in digital design tools among students within both groups, with familiarity almost equally split between intermediate and advanced levels. In the AI

group, roughly half of the students were at an intermediate level, while the rest had advanced proficiency. Similarly, in the control group, a comparable distribution was observed.

However, students were also asked about their familiarity with GenAI design tools. The results show that in the AI group, half of the students had only beginner or no experience, some were at an intermediate level, and one student had advanced familiarity. Meanwhile, half of the control group students were beginners or had no experience, while the other half were at an intermediate level, as illustrated in *Figure 4.15*.

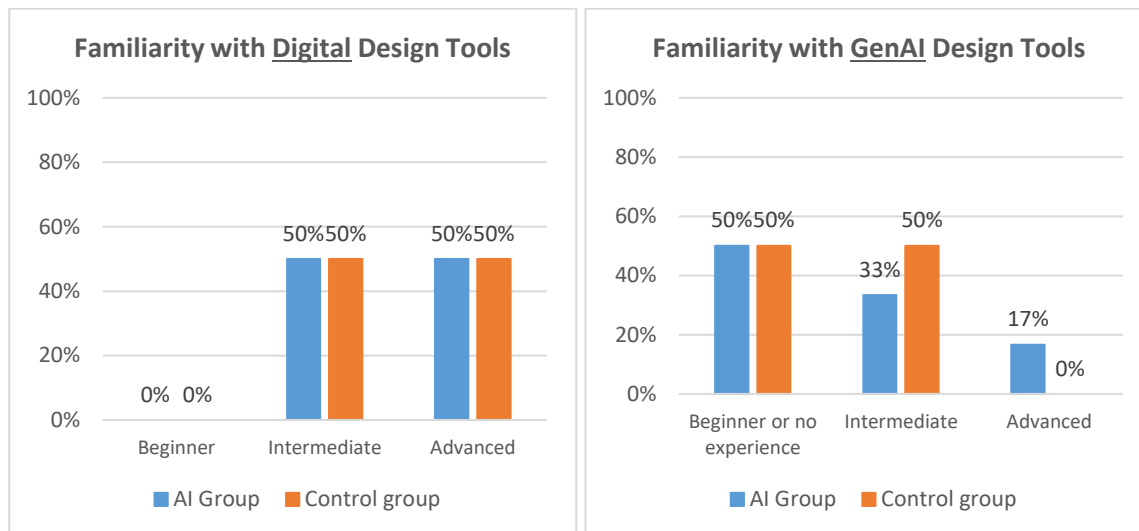


Figure 4.15: Students' familiarity with digital design tools, as well as GenAI tools for both groups

Part 2: Opportunity and Benefits of Integrating Gen AI Tools

The AI group students were asked about the opportunities and advantages that AI tools provided them during their design process. Based on their feedback, half of the students agreed that GenAI tools enhanced their creativity, while the majority agreed that AI helped them explore innovative design solutions, save time, and improve productivity. These

results indicate that GenAI tools generally had a positive impact on students' experience. However, the remaining students gave neutral responses, indicating they faced challenges in seamlessly integrating AI into their workflow.

In addition to the above, students highlighted in their responses to the open-ended question that GenAI tools enhanced their ability to accelerate ideation, automate repetitive tasks, and support research, particularly in material selection, site analysis, and design visualization. Also, some appreciated how AI tools expanded their exploration of diverse design styles, providing new inspiration and alternative approaches, and helped them reduce stress and improve workflow by automating routine tasks, allowing students to focus more on creative refinement rather than manual processes.

On the other hand, the control group showed dissatisfaction with traditional design methods, with most students expressing dissatisfaction and only a few reporting satisfactions. This suggests that most students found these methods limiting their creativity and efficiency, as the majority believed that GenAI tools would have enhanced their creativity, and reduced their time spent on tasks. Some students also expressed a sense of missing out, as they were not permitted to use AI tools during the experiment. Additionally, control group students responded to the open-ended question, stating that the limited duration was challenging for them to generate creative ideas and complete the task, while the AI group did not report this issue.

Part 3: Utilizing Gen AI Tools in the Different Design Stages

This includes an additional question for the AI group on utilizing the AI tools in the different design stages. All students agreed that the AI was most effective in the conceptual

design stage, as these tools helped them generate, explore, and visualize creative ideas, while the majority found GenAI tools useful in the Pre-Design and Analysis Stage, particularly for research and site analysis. Furthermore, in the Design Production Stage, some students agreed on its effectiveness, while half were neutral and a few disagreed, indicating challenges related to accuracy and integration in detailed execution. Moreover, as previously noted, AI tools were not applied in the Design Development Stage due to their limitations in precision, flexibility, and technical accuracy at this phase, as advised previously by some experts during the interview.

Part 4: Total Time Needed to Complete the Task

The results highlighted a notable difference in time efficiency between students who used AI tools and those who relied on traditional design methods. *Figure 4.16* demonstrates that in the AI-assisted group, most students completed their tasks in under 10 hours, while the rest took between 10 and 20 hours. No students exceeded 20 hours in total, suggesting that AI tools contributed to streamlining the design process and reducing the time needed for ideation and development.

On the other hand, in the control group, half of the students required 10 to less than 20 hours, while the others took more than 20 up to over 30 hours to complete the task. Notably, no students from this group completed the task in under 10 hours, indicating that traditional design methods required more time for concept development and execution compared to the GenAI tools methods.

These findings suggest that AI tools have significantly improved efficiency by automating repetitive tasks, facilitating faster decision-making, and reducing the overall time required

for design stages. In contrast, traditional methods have demanded more manual effort and iteration, leading to extended completion times.

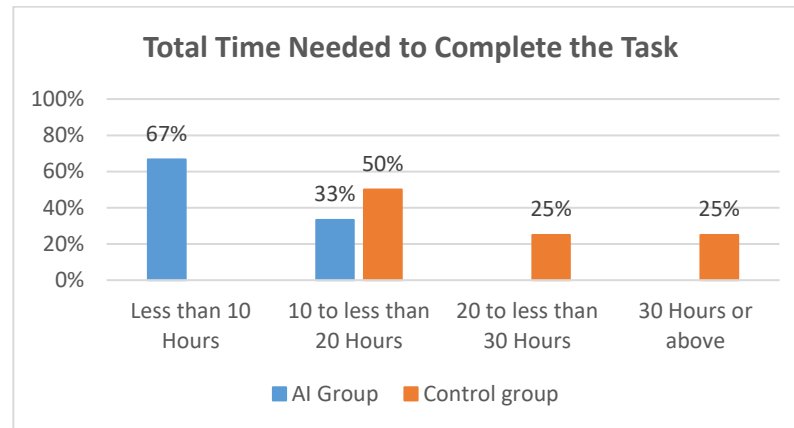


Figure 4.16: Total time needed for each group to complete the experiment task

Part 5: Challenges of Integrating Gen AI Tools

Students from the AI group faced distinct challenges in their design processes, reflecting the limitations of each approach. Most of them encountered difficulties due to a lack of training and knowledge, making it challenging to fully utilize AI's potential. Moreover, half of the students struggled with interpreting AI-generated outputs and ensuring compatibility with traditional design methods, often requiring additional adjustments to integrate AI-generated elements effectively. Additionally, half of the students found AI to be limited in flexibility when handling complex architectural tasks and expressed hesitation toward adopting AI-driven approaches over traditional workflows. Additionally, concerns about AI's factual accuracy were also raised, particularly when verifying AI-generated content for design presentations.

Part 6: Perceived Integration of Gen AI Tools into Architectural Design Education

All students (100%) unanimously agreed that Generative AI tools have the potential to be integrated into architectural education, recognizing their role in enhancing creativity, efficiency, and design exploration. This consensus indicates a general openness and growing acceptance among students of AI's application in design processes, even among those primarily using traditional methods. The results indicate that students acknowledge AI as a tool with possible benefits in architectural learning, though its effectiveness in various design stages may require further evaluation and structured implementation.

Furthermore, the students provided some suggestions for improving the integration of AI in architectural design education. A key recommendation was adopting iterative design methods, such as Agile or Design Thinking, which allow for early user involvement, flexibility in change, and frequent prototype testing to enhance efficiency. Many students, particularly those in the control group, expressed a desire for more time to explore AI tools, emphasizing the need for structured training programs to familiarize students with AI's capabilities and limitations. While AI was recognized for accelerating idea generation and conceptual exploration, students acknowledged that finalizing a design still requires significant human input, refinement, and iteration due to the complexity of architectural projects.

Additionally, students highlighted the importance of mastering AI-related skills, such as understanding prompts and keywords, to maximize AI's effectiveness in the design process. Some noted that while AI tools offer valuable assistance, they do not always align perfectly with a designer's vision, reinforcing the need for human oversight in decision-making.

4.5.5 Summary of the Field Experiment

The outcome of the field experiment is discussed and summarized in this section, including: the results of the design task and its evaluation, the advantages and opportunities, the risks and challenges, as well as the effectiveness of GenAI tools in different design phases.

Design Task and Studio Performance Evaluation:

- Students were assigned a two-week design task to create a small pavilion within an urban public space. The AI-supported group demonstrated stronger performance, as evaluated by instructors, with a 9% improvement across all criteria compared to the control group.
- The AI group produced more creative and visually diverse outcomes and completed their work ahead of the deadline. In contrast, the control group focused more on manual detailing and basic structure, with some students unable to complete the task.
- The analysis of design phases and tasks within the experimental studio revealed that GenAI tools were most effective in supporting creative, visual, and representational tasks, such as ideation, rendering, and presentation, while offering limited or no support in tasks that require contextual analysis and strategic decision-making.
- These findings highlight the positive influence of GenAI on creativity, efficiency, and the overall design process within studio learning.

A. The advantages and opportunities

- The results under this point were collected exclusively from the AI group of students who participated in the field experiment and engaged with AI-based tools.

- Their feedback indicated that the majority of AI group students found the tools: time-saving and improved productivity, exploring innovative ideas.
- Some highlighted that these tools expanded their exploration of design styles and helped reduce stress by streamlining routine tasks, allowing more focus on creative refinement.

B. The risks, challenges, and disadvantages

- The analysis of the students' feedback highlighted that the major obstacle they encountered was the lack of knowledge and training, despite a three-day preparation before the experiment.
- Some students struggled to interpret AI outputs and align them with traditional design methods and found AI to be limited in flexibility when handling complex architectural tasks.

C. The effectiveness of GenAI tools in different design phases

- All AI group students confirmed that GenAI tools were most effective in the conceptual design stage for idea generation and visualization.
- Most students also found them helpful in the pre-design and analysis stages.
- Lower effectiveness was reported in the design production stage due to integration challenges and the limited experience of Gen AI tools at this stage.
- The design development stage was not tested, due to the tools' technical limitations.

Additionally, the results of post-experiment student feedback indicated that all students from both groups agreed on the potential of integrating Generative AI into architectural education, recognizing its value in enhancing creativity, efficiency, and design exploration.

4.6 Overall Comparative Analysis:

This section presents the findings from the three methodologies employed in the study: interviews with academic experts, a questionnaire administered to professional architects in the Saudi labor market, and a field experiment. It highlights recurring patterns, major similarities, and notable differences, providing a comprehensive understanding of the role, effectiveness, opportunities, and challenges associated with GenAI integration in architectural education. Furthermore, the discussion integrates insights from the literature review presented earlier, offering a more comprehensive perspective on the study's findings.

4.6.1 Synthesizing the Implemented Interview, the Questionnaire, and the Field Experiment Methods

A. The current role and acceptance of AI in architectural education

Further to the agreement among academic experts and professional architects on the widespread acceptance of AI, the feedback from all students who participated in the field experiment also confirmed that Generative AI tools can be effectively integrated into architectural education. These consistent findings across all methodologies, and further supported by the reviewed literature, highlight the growing importance of integrating AI into architectural education to better equip future architects for the evolving demands of the profession.

B. The effectiveness of GenAI tools in different design phases

This subsection compares the findings from the three study methodologies to provide deeper insight into the effectiveness of GenAI tools on the architectural design process. The results from the survey conducted with senior students who participated in the field experiment, supported by the findings from the two methodologies, indicate that the most

effective stage for integrating Generative AI tools is the conceptual design stage. These findings, which have been agreed upon across all three methodologies, draw attention to the effectiveness of AI in this stage for both academic practice and the professional field, as also emphasized in the literature. Additionally, the second-highest agreement among students in the field experiment was for the pre-design and analysis stage, aligning with the academic experts' perspectives. This suggests that early design phases offer more beneficial and more impactful results for academic contexts compared to later stages.

C. The advantages and opportunities of AI integration in architectural design education

The findings from the field experiment survey revealed that improving productivity and saving time received the highest level of agreement among participating students, which aligns with the perspectives of the expert interviews and the professional architect's questionnaire. This benefit has also been repeatedly highlighted in previous related studies, reinforcing its relevance and consistency across the literature. The compiled results highlighted GenAI tools' ability to help students collect and analyze data, generate multiple design concepts, and explore different ideas within a short time.

Additionally, exploring more innovative variations and enhancing design aesthetics received the highest level of agreement among students, ranking second among professional architects and third among academic experts. This emphasizes the importance of this advantage in enhancing students' overall design outcomes and fostering a richer design experience.

Moving forward, optimizing design functionality ranked fourth according to the questionnaire method and last according to the interview method. However, results from the field experiment emphasized the significance of this advantage in architectural design

studios, demonstrated by educators' evaluations showing an enhancement of this feature by approximately 9% between the two groups, as shown in Table 4.15.

In addition to the above, enhancing learning outcomes and students' performance ranked fifth according to interviews with the academic experts. However, the results from the field experiment method, which was based on educators' overall evaluations, showed an overall enhancement by 9%, as indicated in the instructors' evaluation shown in Table 4.15. Aligning with Interviewee 11's feedback that the results of her experiments received 75–85% positive feedback, and students indicated that using AI helped them become more innovative in their design process. This synthesized set of findings, supported by the literature review, stresses the importance of integrating AI into architecture education. Next, improving acceleration and automation ranked fourth according to the frequency of mention by the academic interviews. According to the field experiment method, there is a noticeable enhancement in the total average time needed by the AI group students to finish the experiment tasks, as illustrated in *Figure 4.16*.

Lastly, fostering students' creativity and inspiration, even though it is ranked second according to the interview method and third according to the questionnaire method, it is ranked lowest in the field experiment feedback, likely due to students needing more time and training to use the tools effectively. With improved skills, their neutral responses could shift toward agreement, especially as no participants disagreed with this advantage.

D. The risks, challenges, and disadvantages of AI integration in architectural design education

This subsection discusses the findings from the field experiment and compares them with the results from the two previously addressed methods: interviews with academic experts and architects' questionnaires. The students' feedback from the field experiment identified the lack of technical knowledge and training as the most significant barrier to integrating AI into architectural design, aligning with findings from the other two methodologies and supported by the literature review. This emphasizes the urgent need for training for both students and educators to maximize the benefits of AI and enhance its effective use.

Following this is the incompatibility with traditional methods, ranked second based on students' feedback and last according to the experts' interviews. This indicates varying perspectives on how traditional architectural practices align with AI-based approaches, stressing the need for clear guidelines and trained educators to improve the integration of AI and enhance educational outcomes.

Also, limited functionality was ranked lowest in the field experiment and was not raised by academic experts. Although it received little attention, this highlights the importance of selecting appropriate tools that truly enhance the value of utilizing AI-based solutions.

4.6.2 SWOT Analysis Overview and Classification

SWOT analysis is a strategic planning tool used to evaluate an organization's internal strengths and weaknesses, as well as its external opportunities and threats (GÜREL, 2017). This study conducted a SWOT analysis to evaluate the potential impact of integrating GenAI tools into architectural design education by identifying the key strengths, weaknesses, opportunities, and threats associated with their integration. This analysis

draws upon findings derived from perceptions gathered through expert interviews, questionnaires, and field experiments.

In order to provide a more structured and strategic understanding of the findings, the SWOT analysis in this study is classified into internal factors (strengths and weaknesses) and external factors (opportunities and threats), as illustrated in *Figure 4.17*. This distinction allows for a clearer identification of elements directly influenced by educational institutions, educators, and students (internal), versus those driven by broader technological, market, and societal trends (external). This classification supports the development of more targeted and actionable recommendations.

SWOT Analysis for GenAI Integration in Architectural Design Education

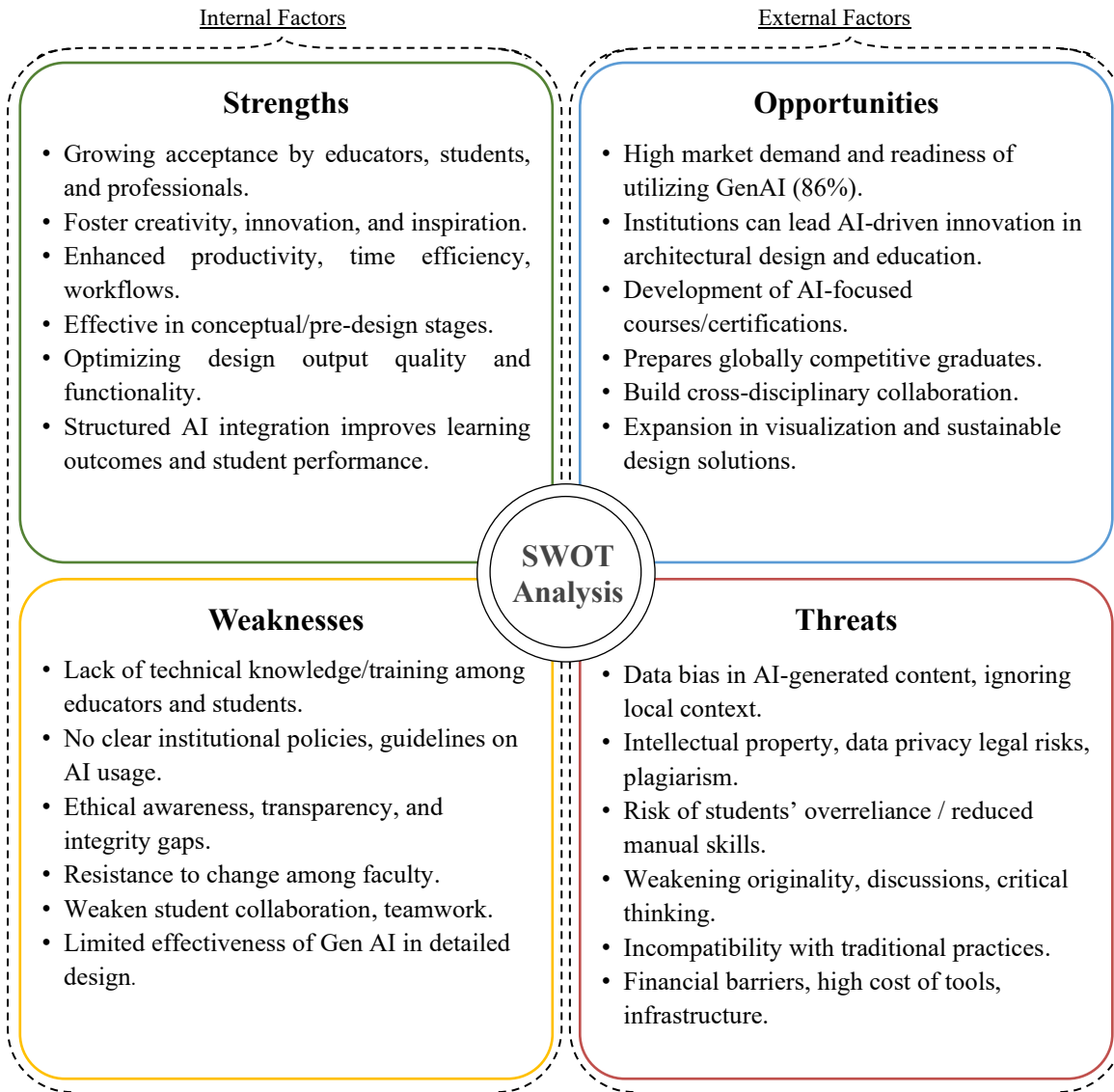


Figure 4.17: SWOT analysis of strengths, weaknesses, opportunities, and threats for integrating GenAI in architectural design education.

Chapter 5 : Conclusion and Recommendations

This chapter concludes the study by synthesizing the main findings developed through the research methods and highlighting their implications for integrating generative AI into architectural pedagogy. Based on these insights, practical recommendations are proposed to guide educators, institutions, and policymakers. The chapter also presents a strategic framework for the responsible integration of AI and outlines potential directions for future research to further explore the evolving role of AI in architectural design education.

This study comprehensively investigates the potential impact of Generative AI on architectural design education, focusing on its influence across design stages, student creativity, and technical development, and identifying both opportunities and risks. It began with a comprehensive review of the literature on the evolution of architectural education, highlighting the shift from traditional studio-based methods to technology-integrated approaches. Prior research explored pedagogical challenges and suggested strategies to enhance creativity and engagement. Recent studies also examined AI applications in architectural practice and specific educational stages like ideation and visualization.

However, a clear gap remains in understanding the broader positive and negative impacts of GenAI on the architectural design process, and how these tools can be applied in the design studios at various design stages, and comprehensive studies for effective integration are still lacking. These gaps, along with ongoing challenges, widen the divide between academia and practice, raising concerns about graduates' readiness for a tech-driven industry. To address these gaps, this study proposed a conceptual framework linking AI

tools to design stages, covering the gap theoretically. Practically, it conducted expert interviews with educators, questionnaires with architects, and a field experiment with students, aiming to bridge the gap by exploring the real-world integration of GenAI in architectural education.

Findings from the interviews, questionnaires, and experiments collectively indicate a growing acceptance and recognition of GenAI tools among educators, students, and architects. This was confirmed by most academic experts, supported by a mean score of 4.03 out of 5 reported by professional architects in the questionnaire, and 100% agreement from students in their field experiment feedback. To provide a clear synthesis of these insights, Table 5.1 below summarizes the main aspects identified in the study, including the benefits, risks, challenges, and perceived optimal phases for integrating GenAI into architectural design education.

The highest impact of GenAI effective utilization in the design studio was seen by experts, architects, and students in the conceptual design phase, with 12 mentioned out of 18 by academic experts, a mean weight of 4.22 by professional architects, and 100% of the experiment students. The second most optimal phase for integrating GenAI tools varied: educators and students favored the early design stages (pre-design) with 9 mentioned out of 18 by academics and the majority of the experiment students, while architects preferred the later stages (design production), with a mean weight of 4.18, reflecting real-world project demands. However, GenAI tools were seen as least effective in the design development stage by both academics and professional architects, due to the detailed technical refinement and spatial accuracy required. This indicates that academic programs should prioritize GenAI use in early design stages, while relying on conventional

techniques for the technically demanding design development phase, where GenAI tools are immature and still evolving.

Moreover, there is a consensus on AI's opportunities in several areas, particularly in saving time and improving productivity, which ranked highest, as mentioned by all academic experts and most students from the field experiment, supported by professional architects with a mean weight of 4.31 out of 5. Following this is enhancing creativity and inspiration, with 16 mentioned by the academic experts out of 18, and ranked third by the architects from the labor market, with a mean value of 4.06. As well as exploring more innovative and aesthetic variations, which was cited 13 times by the educators, had a mean value of 4.10 among the architects, and was emphasized by the field experiment outcomes.

However, despite these advantages, participants raised concerns about pedagogical risks, particularly in academic settings, such as data bias, overreliance on AI, and diminished manual skills of students, weakening their collaboration. Furthermore, operational barriers were also noted that affect GenAI adoption. The most critical factor identified was the lack of technical knowledge and training, highlighted by 16 AI academic experts and supported by a 4.09 out of 5 mean rating from the questionnaire. They also highlighted the absence of structured and clear guidelines for AI use (by 12 experts; mean 3.94 of 5 by architects). Ethical issues, including intellectual property rights and transparency, also emerged consistently, highlighting the need for training and governance frameworks.

Based on the overall insights gathered from the combined methods, this study concludes that integrating Gen AI into architectural design education is feasible, beneficial, and promising. It shows strong potential for enhancing the design process when implemented with appropriate pedagogical and ethical oversight, supported by clear guidelines and

instructions. AI should be regarded as a complementary tool that supports, enhances, and expands the architectural learning experience, rather than as a replacement for human creativity and critical thinking.

In response to these insights, the study proposes strategic recommendations for effectively integrating GenAI into architectural pedagogy, including targeted training, clear institutional policies, ethical guidelines, and curriculum alignment. This balanced approach upholds core values and ensures that future architects can leverage AI while maintaining fundamental architectural principles and manual skills, aiming to prepare Intelligent Architects (IA) who harness technology to advance their expertise rather than become AI-dependent drafters.

Table 5.1: Summary of key insights related to GenAI Integration in architectural education

Main Aspects	Key Insight	Supporting Data
Acceptance of GenAI		
Growing Acceptance of GenAI	Strong agreement among academics, professionals, and students on the value of GenAI in architectural education.	All educators and students, with a mean rating of 4.03/5 by architects.
Effectiveness of GenAI on the Design Stage		
Most Effective Stage	The Conceptual Stage, due to the strong impact of GenAI on visualization and conceptualization.	12/18 experts, 4.22/5 architects, 100% students
Least Effective Stage	The Design Development Stage, which required detailed technical and spatial refinement.	Mentioned the least by all participants.
Top Benefits of GenAI		
Top Benefits of GenAI	Improved productivity and time efficiency.	Top-ranked across all groups.
	Enhanced creativity and aesthetics	Commonly agreed across architects and academics.
	Exploring more variations	
Risks and Practical Challenges		
Risks and Drawbacks	Overreliance on AI tools, Data bias Limited tool maturity in detailed design phases	Frequently mentioned in interviews and literature

Practical Challenges	Lack of knowledge and training	16 experts, 4.09/5 mean by architects, most students.
	Absence of clear guidelines.	12 experts, 3.94/5 mean
	Ethical concerns: transparency, intellectual property.	Consistently raised in interviews.
Proposed Path		
Proposed Path Forward	AI should complement, not replace, traditional methods.	Aligned with experts', architects', and students' perceptions.
	Balanced approach with core values while leveraging AI.	

5.1 Implications of the Study

The findings of this study carry several significant insights into understanding how GenAI can be effectively and responsibly integrated into architectural pedagogy. Building on these findings, it is important to reflect on their broader meaning and implications for architectural education:

- This collective shift in perception and strong consensus among academic experts and professional architects underscores the need for institutions to embed GenAI literacy into the learning process, positioning familiarity with AI tools as essential to professional competence rather than an optional specialization
- The consistently high valuation of AI's effectiveness in the conceptual design stage implies a clear opportunity to reconsider early design stages. However, architecture pedagogy needs to prioritize ideation workflows enhanced by AI, encouraging students to experiment creatively while critically engaging with AI-generated alternatives.

- GenAI's ability to streamline workflows, accelerate design iterations, and enhance time management and productivity should not be viewed as merely a time-saving tool, but rather as a boost toward enhanced strategic thinking and more efficient outcomes, ultimately preparing students for complex and informed decision-making.
- The identified skills challenges of integrating AI into architecture education call for systemic investment in faculty development and training, curriculum reform, interdisciplinary collaboration, and overall institutional readiness. Without addressing this gap, there is a risk that AI adoption will remain superficial or uncritical.
- The ethical challenges, ranging from data bias to overreliance, highlight the need for design pedagogy and institutional guidance. Ethics should be embedded throughout design studios and assessment practices, adopting a balanced and critical approach that preserves the creative and cultural values central to the field.

5.2 Recommendations and Strategies

This section presents a set of synthesized recommendations and strategic actions to guide the effective integration of generative AI in architectural design education. These recommendations are derived from findings across the study's methodology, including expert interviews, questionnaires with professional architects, and field experiments. To support clarity and implementation, the recommendations have been structured into seven strategic pillars and visually organized in a mind map (*Figure 5.1*). This strategic framework aims to help academic institutions integrate GenAI tools in a clear, balanced, responsible, and effective way that supports architectural pedagogy, highlighting the following key areas:

- Train educators and students through continuous, hands-on programs that strengthen technical proficiency and promote responsible use of technology.
- Integrate AI across the curriculum, extending beyond design studios into theoretical, ethical, and technical courses for a more comprehensive understanding.
- Establish clear guidelines that define how AI should be used, specify which tools are permitted, and outline how students must acknowledge their use to ensure academic integrity.
- Strengthening departmental capacity through dedicated research and development efforts that support ongoing AI experimentation and innovation in architectural education.
- Encourage transparency and monitor engagement by requiring students to reflect on and present how AI contributed to their design process.
- Connect academia with practice through collaboration with professionals and alignment of coursework with real-world design tools and industry standards.
- Encourage student engagement through AI-focused competitions, workshops, and awareness initiatives to foster innovation and collaboration.

Foster critical thinking about AI through activities that encourage students to question outputs, identify biases, and articulate informed design decisions.

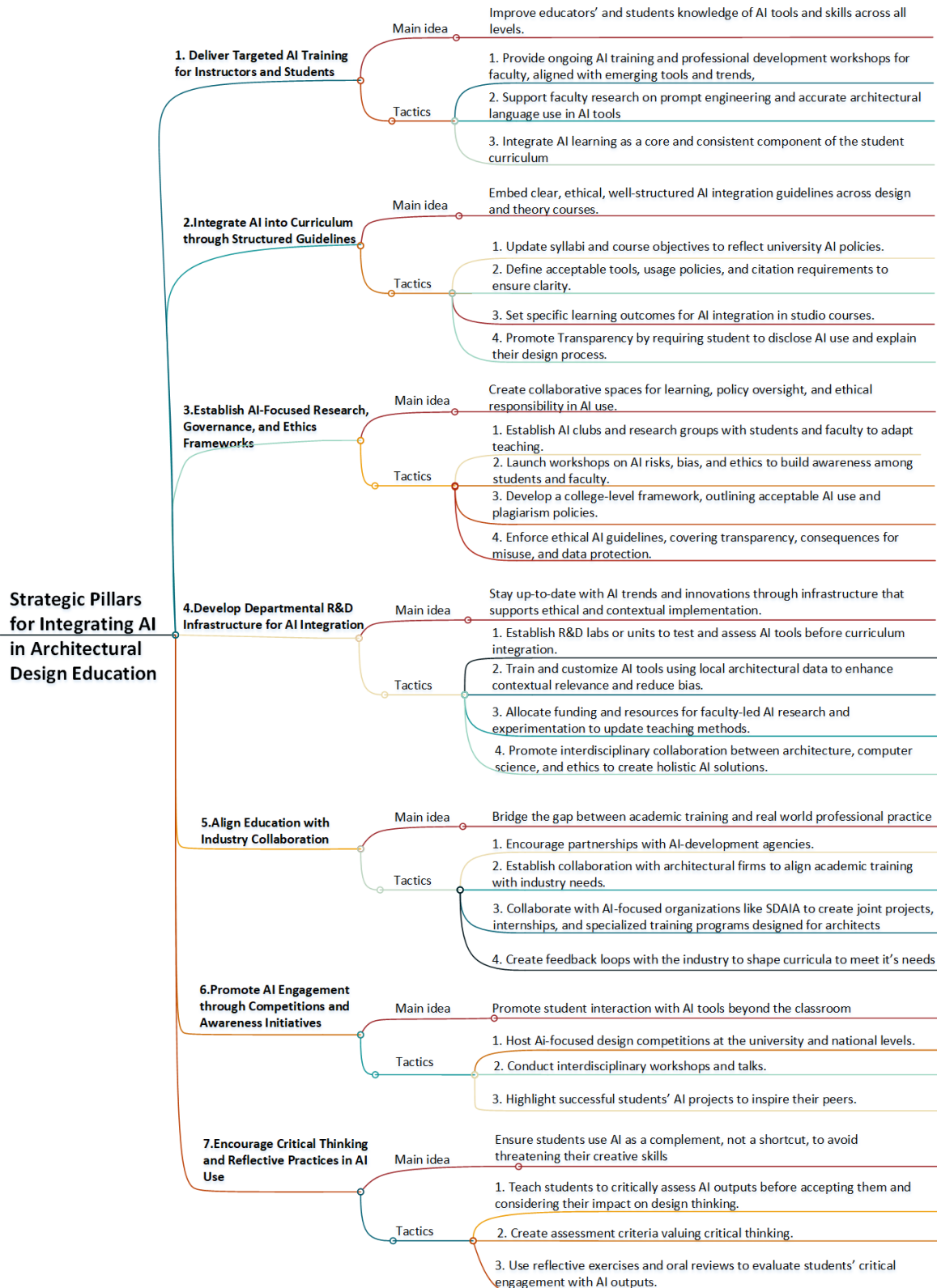


Figure 5.1: Strategic framework for integrating AI into architectural education. (produced by the author)

5.3 Future Research

To build upon the findings of this study, future research can explore the following areas:

1. Examine the long-term impact of GenAI across multiple semesters and different design studio levels.
2. Explore how GenAI tools can be applied in courses beyond the design studio courses (e.g., history, theory, sustainable architecture, and urban design).
3. Study the effect of GenAI on students' decision-making and collaboration in group projects

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Appendix

Appendix A: Questionnaire Questions

Section 1: Sample Characteristics

1.1 Gender

- ☐ Male
- ☐ Female

1.2 Education level

- ☐ High School
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Ph.D. Degree

1.3 How many years of experience do you have in the architecture profession?

- ☐ Less than 3 years
- ☐ 3 to less than 6 years
- ☐ 6 to less than 9 years
- ☐ 9 years and more

1.4 Do you utilize digital design tools, such as (Revit, Rhino, etc.) in your architectural design projects?

- ☐ Always
- ☐ Often
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

1.5 I am currently using, or willing to use, AI-based tools in my future architectural design projects.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

1.6 To what extent do you rate your familiarity with AI tools in architecture projects?

- ☐ Very Good
- ☐ Good
- ☐ Average
- ☐ Low
- ☐ Not Familiar → (This response leads to the end of the questionnaire)

Section 2: Opportunities in Utilizing AI in the Architectural Design Process:

To what extent do you agree with the following statements:

2.1 I believe that Generative AI could be used effectively in architectural design projects to **foster creativity and inspiration**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

2.2 I believe that Generative AI could be used effectively in architectural design projects to **optimize design functionality**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

2.3 I believe that Generative AI could be used effectively in architectural design projects to **explore more innovative variations and aesthetics**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

2.4 I believe that Generative AI could be used effectively in architectural design projects to **enhance teamwork and collaboration**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

2.5 I believe that Generative AI could be used effectively in architectural design projects to **save time and, therefore, improve productivity**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

2.6 I believe that Generative AI could be used effectively in architectural design projects to **reduce design costs**

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

Please write down any other opportunities not listed above.

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Section 3: Challenges in Utilizing AI in the Architectural Design Process:

To what extent do you agree with the following statements:

3.1 I believe that one challenge that faces the effective use of Generative AI in architectural design projects is **the lack of knowledge and training**

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

3.2 I believe that one challenge that faces the effective use of Generative AI in architectural design projects is **the high costs of AI tools**

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

3.3 I believe that one challenge that faces the effective use of Generative AI in architectural design projects is **the resistance to change among stakeholders**

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

3.4 I believe that one challenge that faces the effective use of Generative AI in architectural design projects is **the fear among designers of job loss**

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

3.5 I believe that one challenge that faces the effective use of Generative AI in architectural design projects is **the absence of clear regulations and guidelines of AI use**

- Strongly Agree
- Agree

- Neutral
- Disagree
- Strongly Disagree

Please write down any other Challenges not listed above.

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Section 4: Utilizing AI in the Architectural Design Education:

To what extent do you agree with the following statements:

4.1 In principle, Generative AI should be incorporated into architectural design education

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.2 The integration of Generative AI into education should fully replace the traditional design methods

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.3 The integration of Generative AI into education should observe a balance between the traditional design methods and the emerging AI capabilities

- Strongly Agree
- Agree
- Neutral

- Disagree
- Strongly Disagree

4.4 Integration of Generative AI into architectural design education requires a substantial update of the traditional design process followed in the design studio courses as many design tasks could be automated

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.5 I believe that Generative AI could be effectively used in the **Pre-Design and Analysis** stage for data collection and project requirements analysis

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.6 I believe that Generative AI could be effectively used in the **Conceptual Design** stage to generate creative design concepts

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.7 I believe that Generative AI could be effectively used in the **Design Development** stage for schematic planning and preliminary 3D massing

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.8 I believe that Generative AI could be effectively used in the **Design Production** stage for rendering, design refining, and presentation

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4.9 Integration of Generative AI into architectural design education requires continuous training of faculty members on AI tools and technologies

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

If you agree with AI adoption in architectural design education at universities, please provide your recommendations and suggestions.

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Appendix B: Interview Questions

Section 1. Relevance of AI in Architectural Education:

Q1: How do you perceive the current role of AI in architectural education?

Q2: Have you noticed any shifts in how AI tools are utilized in education? If so, how do you think it will evolve in the future?

Section 2. Influence of Generative AI on the Design Process and Learning Outcomes:

Q3: In your opinion, do generative AI tools positively or negatively impact the architectural design process and learning outcomes in studio projects?

Q4: Do you think these tools enhance or limit students' creativity, innovation, problem-solving abilities, and the quality of their work? How do you see these effects in both the short and long term?

Q5: To what extent do you believe these tools can help reduce working time in design studios and increase students' productivity?

Section 3. Exploration of Risks and Challenges:

Q6: In your opinion, what are the main challenges or barriers to integrating AI tools into architectural education (e.g., lack of technical knowledge, training, cost, etc.)

Q7: How can we address potential ethical concerns associated with AI adoption in architectural education, such as students' over-reliance on these tools or data bias?

Section 4. Sharing Personal Experiences:

Q8: From your perspective, at which stage of the design process (pre-design, conceptual design, design development, or design production) do AI tools have the most significant impact, and why?

Q9: Can you share any practical examples from your teaching experience (if available) where the integration of generative AI tools had a noticeable effect on students' learning?

Q10: What recommendations would you provide educators on how generative AI can be successfully integrated into architectural design education?

Appendix C: Student Survey for the Experiment

(AI Group)

Part 1: Background:

1.1 What is your name:

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1.2 Which group were you part of during the experiment?

- AI Group (used AI tools)
- Control Group (did not use AI tools)

1.3 How do you rate your familiarity with digital design tools used in architectural design, such as (Revit, Rhino, etc.)?

- Beginner
- Intermediate
- Advanced

1.4 How do you rate your familiarity with Generative AI (Gen AI) tools used in architecture design before this experiment?

- Beginner or no experience
- Intermediate
- Advanced

Part 2: Questions for the AI Group:

2.1 To what extent do you agree with the following statements:

2.1.1 I believe Gen AI tools enhanced my creativity during the experiment task.

- Agree
- Neutral
- Disagree

2.1.2 I believe Gen AI tools helped me explore more innovative design solutions during the experiment task.

- Agree
- Neutral
- Disagree

2.1.3 I believe that Gen AI helped me **save time** and **improve my productivity**:

- Agree
- Neutral
- Disagree

2.1.4 Please write down any other benefits and opportunities not listed above.

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2.2 During your work on the experiment task, rate your agreement with the following:

2.2.1 Gen AI tools were helpful in the **Pre-Design and Analysis** stage:

- Agree
- Neutral
- Disagree

2.2.2 Gen AI tools were helpful in the **Conceptual Design** stage:

- Agree

- Neutral
- Disagree

2.2.3 Gen AI tools were helpful in the **Design Development** stage:

- Agree
- Neutral
- Disagree

2.2.4 Gen AI tools were helpful in the **Design Production** stage:

- Agree
- Neutral
- Disagree

2.3 What challenges did you face when using the AI tools? (Select all that apply)

- Lack of knowledge and training
- Limited functionality of the AI tools
- Difficulty interpreting AI output and its incompatibility with traditional design methods
- Resistance to change.
- Other (please specify): _____

2.4 Did you use any AI tools other than those mentioned in the experiment?

- No
- Yes. (please specify):

Part 3: General Questions for Borth Groups:

2.1 How much total time did it take you to complete the tasks:

- Less than 10 Hours
- 10 to less than 20 Hours
- 20 to less than 30 Hours
- 30 Hours or above

2.2 Do you believe that generative AI tools can be effectively integrated into architectural education?

- Agree
- Neutral
- Disagree

2.3 Based on your experience during the experiment, please write down any recommendations or suggestions you have:

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(Control Group)

Part 1: Background:

1.1 What is your name:

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1.2 Which group were you part of during the experiment?

- AI Group (used AI tools)
- Control Group (did not use AI tools)

1.3 How do you rate your familiarity with digital design tools used in architectural design, such as (Revit, Rhino, etc.)?

- Beginner
- Intermediate
- Advanced

1.4 How do you rate your familiarity with Generative AI (Gen AI) tools used in architecture design before this experiment?

- Beginner or no experience
- Intermediate
- Advanced

Part 2: Questions for the Control Group (Non-AI Tool Users:

2.1 During your work on the experiment task, rate your agreement with the following:

2.1.1 I am satisfied with the traditional design methods I used for the assigned tasks

- Agree
- Neutral
- Disagree

2.1.2 I believe that accessing AI tools would have made my design process more creative:

- Agree
- Neutral
- Disagree

2.1.3 I believe that accessing AI tools would have made my design process more productive and effective:

- Agree
- Neutral
- Disagree

2.2 At what stage of the design process do you expect AI to be more efficient?

- Pre-Design and Analysis stage
- Conceptual Design stage
- Design Development stage
- Design Production stage
- Post-Production stage

2.3 What challenges or problems did you face during the design process with the traditional design method?

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Part 3: General Questions for Borth Groups:

3.1 How much total time did it take you to complete the tasks:

- Less than 10 Hours
- 10 to less than 20 Hours
- 20 to less than 30 Hours
- 30 Hours or above

3.2 Do you believe that generative AI tools can be effectively integrated into architectural education?

- Agree
- Neutral
- Disagree

3.3 Based on your experience during the experiment, please write down any recommendations or suggestions you have:

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Appendix D: List of Interview Participants and Academic Affiliations

Code of the Interviewee	Title	Academic Institution	Country
Interviewee# 1	Professor /Chair, Department of Architectural Engineering	University of Sharjah	United Arab Emirates
Interviewee# 2	Professor /School of Architecture/ Director David T. Fortin Architect	University of Waterloo	Canada
Interviewee# 3	Professor of Architecture /Vice-Chair of Saudi Planners Association	Effat University	Saudi Arabia
Interviewee# 4	Associate Professor of Architecture / Design Technologist /Design Contributor at Microsoft AI	University of Nevada-Las Vegas	United States
Interviewee# 5	Associate Professor of Architecture, Deputy Dean (Research, Innovation)	University Putra Malaysia	Malaysia
Interviewee# 6	Associate Professor of Architecture / Expert in Technology & VR in Design	Istanbul Kultur University	Turkey
Interviewee# 7	Associate Professor of Architectural Engineering, Design Manager	Tanta University	Egypt
Interviewee# 8	Associate Professor of Architecture Technology	University of Science and Technology	Jordan
Interviewee# 9	Assistant Professor, Head of the Laboratory of Digital Technologies	Gdańsk University of Technology	Poland
Interviewee# 10	Assistant Professor /Chair, Department of Architectural Eng	AlFaisal University	Saudi Arabia
Interviewee# 11	Assistant Professor /Consultant in Architecture	King Saud University	Saudi Arabia
Interviewee# 12	Assistant Professor/ Museum Consultant/ Digital Heritage Specialist	University of Sharjah	United Arab Emirates
Interviewee# 13	Assistant Professor of Architecture, Researcher	Texas A&M University	United States
Interviewee# 14	PhD, Lecturer / Education Designer / Specialist of Curriculum Development & Pedagogical Innovation	University of Sydney	Australia
Interviewee# 15	PhD, Faculty of Architecture Studies, BIM Consultant	Ara Institute of Canterbury	New Zealand
Interviewee# 16	PhD, Faculty Member/ AI & Architecture Researcher	Nahrain University	Iraq
Interviewee# 17	AI Innovator and Researcher/ CEO & Co-Founder of DEOND/ Creative Director & Design Strategist	Independent Researcher	Dubai, UAE London, UK
Interviewee# 18	AI in Architecture Educator/ Parametric Designer/ Generative Art Researcher	Unitedworld Institute of Design	India

Vitae

Name : Rawan Emadulden Alamas

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Zami, M. S., Alamas, R. E., Hassanain, M. A., & Almahdy, O. E. (2025). Assessing Design Criteria of University Campus Walkway Systems in the Middle Eastern Arid Environment. *Architecture*, 5(1), 14.
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