Human-computer Interaction (HCI) Approach to Artificial Intelligence in Education (AIEd) in Architectural Design

Interacción Humano-computadora (HCI), Enfocada para uso en Inteligencia Artificial de Educación (AIEd) y Diseño Arquitectonico

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Abstract:

The field of artificial intelligence (AI) in architectural design (AIEd) has experienced significant growth, and there is great potential for the application of Generative AI (GAI) in architectural design education. However, addressing challenges associated with AI is important. These include overhyped speculation, hidden inherent drawbacks such as fairness and ethics, and a trend of lacking human interaction when AI is involved. To tackle these issues, this paper introduces a triangulated research framework encompassing three key perspectives: vision, technology, and user acceptance. This framework aligns with Human-computer Interaction (HCI) principles, AI technology development, and past experiences in AIEd. By adopting this multi-perspective analysis approach, the paper aims to comprehensively understand the phenomena surrounding AI in architectural design. Furthermore, the research presented in this paper goes beyond theoretical discussions and illustrates how the research findings are applied in practice. It showcases the design of an ongoing architectural design course that incorporates the insights gained from the research. Three key observations from the ongoing designed modules indicate the need to shift the focus towards integrating multi-modal AIs and existing parametric tools. Secondly, it is essential to emphasise AIs as design partners rather than making assumptions about AIs' specific uses at different stages. Lastly, providing user-friendly tools and theoretical foundations motivates students to explore beyond the design process, expanding their research and design boundaries.

Keywords: Human-computer interaction (HCI); AI in education (AIEd); architectural design process; architecture education.

Resumen:

El campo de la inteligencia artificial (AI) en el diseño arquitectónico (AIEd) ha experimentado un crecimiento significativo y existe un gran potencial para la aplicación de la AI generativa (GAI) en la educación del diseño arquitectónico. Sin embargo, es importante abordar los desafíos asociados con la AI. Estos incluyen especulaciones exageradas, inconvenientes inherentes ocultos como la equidad y la ética, y una tendencia a la falta de interacción humana cuando se involucra la AI. Para abordar estos problemas, este artículo presenta un marco de investigación triangulado que abarca tres perspectivas clave: visión, tecnología y aceptación del usuario. Este marco se alinea con los principios de interacción humano-computadora (HCI), el desarrollo de tecnología de AI y las experiencias pasadas en AIEd. Al adoptar este enfoque de análisis multi-perspectiva, el artículo tiene como objetivo comprender de manera integral los fenómenos que rodean a la AI en el diseño arquitectónico. Además, la investigación presentada en este artículo va más allá de las discusiones teóricas e ilustra cómo se aplican los hallazgos de la investigación en la práctica. Se muestra el diseño de un curso de diseño arquitectónico en curso que incorpora las ideas obtenidas de la investigación. Tres observaciones clave de los módulos diseñados en curso indican la necesidad de centrarse en la integración de AI multimodal y herramientas paramétricas existentes. En segundo lugar, es esencial enfatizar que las IAs son socios de diseño en lugar de hacer suposiciones sobre sus usos específicos en diferentes etapas. Por último, brindar herramientas amigables para el usuario y fundamentos teóricos motiva a los estudiantes a explorar más allá del proceso de diseño, ampliando sus límites de investigación y diseño.

Palabras clave: Interacción humano-computadora (HCI); AI en educación (AIEd); proceso de diseño arquitectónico; educación en arquitectura.

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1. INTRODUCTION

Artificial Intelligence (AI) provides pedagogical opportunities (Celik, 2023) and has been a discipline in the field of Artificial Intelligence in Education (AIEd) for over 30 years (Hwang *et al*. 2020; O'Shea & Self, 1986). In recent years, there has been increasing exploration of AI in the context of AIEd, as evidenced by several researchers (Celik, 2023; Holmes & Tuomi, 2022; Namatherdhala *et al*., 2022; Pham & Sampson, 2022).

AIEd can be categorised into three main areas. The first category focuses on management tasks, such as the automated marking of exams and the efficient arrangement of class schedules. The second category is teacher-focused and involves designing and preparing teaching materials using AI technologies. Finally, the third category is student-focused, emphasising the use of AI to enhance learning incentives, processes, and outcomes (L. Chen *et al*. 2020; X. Chen *et al*. 2022; Haderer & Ciolacu, 2022; Huang *et al*. 2021). These categories encompass various aspects of AIEd and highlight the broad range of applications and benefits that AI can bring to the field.

In this research, our primary focus is on the second and third categories of AIEd in the context of architecture education. It is worth noting that digital tools have played a significant role in architectural design studios (Hettithanthri & Hansen, 2022), particularly in the aftermath of the COVID-19 pandemic (Bakir & Alsaadani, 2022), which led to the widespread adoption of digital education worldwide. While AIEd has been primarily studied in the field of architecture in terms of management tasks, such as assessment (Smolansky *et al*. 2023; Tack & Piech, 2022), and teaching and learning, such as automatic generation of facades (Sun *et al*. 2022) and automatic floorplan generation (Weber *et al*. 2022), the potential of AIEd in the student-focused aspect remains largely unexplored within the architectural design process.

Therefore, to address this gap, this research focuses on how architectural design studio modules can be designed within the context of AIEd. This will be accomplished by considering past teaching experiences and the rapid development of AI technology. By exploring the integration of AI technologies in the architectural design studio, this research seeks to uncover new possibilities for enhancing the learning experience and outcomes for students in architecture education.

2. THREE OBSERVATIONS AND RESEARCH GAPS

2.1 Observation 1: Overhype of AI

The phenomenon of overhyping AI applications, much like any other technological breakthrough, has been acknowledged in the literature (Nemorin *et al*. 2022; Perez, 2002). As such, it is imperative to exercise caution and avoid becoming overly optimistic about the widespread application of AI tools in the architectural design process without a thorough understanding of their capabilities and limitations.

One area of AI that shows promise for integration into education is Natural Language Processing (NLP), which can enhance various aspects of education by enabling computers to understand and interact with human language (Villegas-Ch *et al*. 2020).

2.2 Observation 2: Inherent challenges of AI

The use of AI in various contexts presents challenges that need to be addressed, including concerns related to fairness and bias (Huang *et al*. 2021; Qiu, 2020). Additionally, there is a need to ensure that AI is used practically and meaningfully (Chatterjee & Bhattacharjee, 2020). These challenges are particularly relevant when considering Generative Artificial Intelligence (GAI) systems.

One of the major obstacles to utilising GAI is the limited understanding of its inner workings. GAI models, often based on deep neural networks, are inherently complex and difficult to comprehend in technical and conceptual ways. The "black-box" nature of GAI systems

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poses challenges in understanding their decision-making processes. However, it is important to recognise that continuous learning and practice can contribute to an increased understanding over time, echoing the significance of conversational properties in human-computer interactions (Cheung & Dall'Asta, 2023; Cheung *et al*. 2023b).

The learning curve for students from non-computational disciplines to apply advanced computational tools in the architectural design process is a well-known challenge (Qattan & AUSTIN, 2016). To address this, it is crucial to consider a realistic learning curve by balancing the selection of user-friendly user-interface tools and novel technologies. The combination of online tutorials and in-class exercises is well-received by students (Holzer, 2019).

Another important consideration is the presence of bias in data utilised by AI systems (Baidoo-Anu & Owusu Ansah, 2023). While it is technically possible to mitigate bias through continuous fine-tuning, this process often requires an unrealistic timeline for comprehensive bias elimination.

2.3 Observation 3: Lack of Human Collaborations

The current application of AI often lacks human interaction, which has raised concerns about the loss of human purpose in the face of the Pandemics of Today's AI, as coined by Pangaro (2020). This awareness has prompted a need to reevaluate the relationship between humans and AI (Markauskaite *et al*. 2022). Achieving a balance between human-centred education and AI applications has become crucial (Nabizadeh *et al*. 2023).

Despite recognising this phenomenon, the actual implementation of these ideas within the architectural discipline still needs to be explored. It is important to note that attributing AI technology as the sole cause would provide an incomplete picture, as this observation should also be examined from a human perspective.

This tendency of modern human consciousness to overlook its interconnected nature is a concern (Goodbun & Sweeting, 2021; Sweeting, 2022). It aligns with the worry from the architectural design discipline that the master-slave model (Glanville, 1992) is more akin to an "idiot-slave" model (Negroponte, 1976); tools are gradually taking over human designers.

The concept of conversation, which involves maintaining differences and achieving agreement among different parties, differs from mere communication, where identical information is passed and received (Goodbun & Sweeting, 2021; Pask, 1980). Human-Computer Interaction (HCI) has the potential to balance between overhyped AI applications and a human-centric approach.

A framework proposing Human-Computer Interaction as an approach has been previously suggested (Cheung & Dall'Asta, 2023; Cheung *et al*. 2023b). However, applying this framework in designing an AI-integrated course remains largely unexplored within the architectural field. Further research is needed to investigate and develop effective strategies for incorporating HCI principles into designing AI-integrated courses.

3. RESEARCH QUESTIONS

The research seeks to address the following three main research questions, which correspond to the theoretical foundation of Human-Computer Interaction (HCI), AI technology, and the practical implications of their connection:

1. What and how can HCI principles be effectively applied in designing an AI-integrated architectural design course?

2. What AI technologies should be employed in the architectural design studio context?

3. How can a balance between integrating novel AI technologies and user acceptance be achieved?

4. RESEARCH FRAMEWORK AND METHODS

The study will adopt three distinct perspectives to address these research

questions: vision, technology, and user acceptance.

The vision perspective will explore the application of HCI principles in the design of an AI-integrated architectural design course, considering the pedagogical aspects and learning objectives involved. The technology perspective will examine various AI technologies suitable for implementation within the architectural design studio, considering factors such as automation, generative design, and data analysis. The user acceptance perspective will focus on understanding students' and educators' attitudes, perceptions, and preferences towards integrating AI into the architectural design process.

The research will employ qualitative method primarily. It involves literature reviews and case studies to gain insights into the theoretical foundation of HCI, AI technology, and user acceptance, followed by case studies of experience to gather data on user acceptance and the effectiveness of the AI-integrated architectural design course. Examples of students' works from each experience were extracted and displayed for intuitive understanding and comparison.

To develop forward from the research above, an architectural design module is designed and implemented for the academic year 2023-2024, incorporating the findings and insights obtained from the previous research phases.

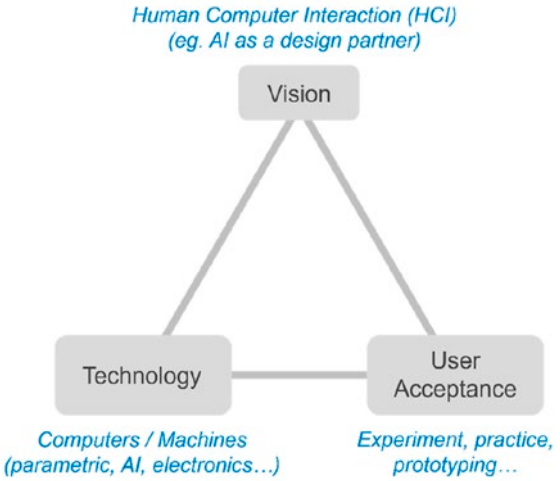

Figure 1. Vision-Technology-User Acceptance Research Framework
Source: created by the author.

5. RESEARCH - THREE PERSPECTIVES

5.1 Vision

Corresponding to the first research question:

The vision perspective of the research focuses on Human-Computer Interaction (HCI), which originates from the field of cybernetics (Cheung *et al*. 2023b). HCI establishes the foundation for understanding how humans interact with computers and machines. With the rapid development of various AI technologies, they can provide insights into answering Cedric Price's famous question, "Technology is the answer, but what was the question" (Price, 1979).

Considerations of HCI have been raised about AI (Hwang *et al*. 2020; Muller *et al*. 2022), and the collaborative relationship between humans and computers has been addressed from the outset (O'Shea & Self, 1986).

In terms of learning machines, there are two types. Teaching machines, such as SAKI (self-adaptive keyboard instructor) or Eucrates, designed by Pask, act as tutors or teaching assistants to students (Husbands *et al*. 2008; Pask, 1961) (Skinner, 1958). Conversely, URBAN5 (Negroponte, 1967) and Musicolour (Pask, 1971) illustrate computers as design partners or collaborators.

In recent theoretical research, conversational properties have been emphasised (Cheung *et al*. 2023b). Conversation, as the main type of interaction, focuses on how humans interact with computers. A unique feature of conversation is its learning process, where not only do humans learn about the tools iteratively during the design process, but the tools also have opportunities to understand the designers' intentions or preferences through AI techniques like fine-tuning (Cheung & Dall'Asta, 2023).

From the ecological perspective (Sweeting, 2022), the interconnectedness of technology, population, and hubris is highlighted. Hubris refers to the notion that

humans are separate from the environment. Bateson argued that technology and population are difficult to reverse, making hubris the easiest choice (Bateson, 1972/2000).

In summary, the vision perspective of the research explores the application of HCI principles in designing an AI-integrated architectural design course, considering the historical context, collaborative relationships, learning machines, precedent studies, recent projects, and the ecological aspects of technology and human interactions.

From the perspective of architectural education, it is important to emphasise reflection within the architectural design process. In this context, the outputs generated by AI art tools should be viewed as part of a thinking process rather than simply a tool for generating explicit design representations (Silva, 2019). Taking another perspective from the technology, programming can also be seen as an integral part of the design process rather than an "additional" component to an architectural design brief (Qattan & AUSTIN, 2016). Finally, applying HCI emphasises the importance of "collaboration" (Coleman, 2023) within the ecology between humans and GAI. Providing this full picture to the students potentially helps to address the hubris problems.

5.2 Technology

Corresponding to the second research question:

The technology perspective of the research focuses on Generative Artificial Intelligence (GAI), with a particular emphasis on computer vision (CV) applications and Natural Language Processing (NLP).

Regarding the CV GAI, its potential uses extend beyond image generation based on prompts. The aim is for the usual design process, including sketches and physical models, to be able to interact with AI tools. Consequently, image-to-image methods will be the main exploration approach. Previous research has demonstrated the importance of selecting tools students can understand rather than solely focusing on the fastest or highest-quality image production (Cheung & Dall'Asta, 2023).

Regarding NLP GAI, it acts as a discussion partner and bridge between other AI technologies. Pretrained Language Models (LLMs) like llama developed by Meta and GPT developed by OpenAI can be introduced for immediate application. Students can converse and discuss the studio design brief with the AI. Additionally, LLMs provide an ideal platform for students to discuss prompt engineering and generate images at different design stages using AI art generation tools based on diffusion models.

Ethical issues, such as authorship, have been discussed in the school policy, and ethical uses of AI should be emphasised within the context of different modules. Furthermore, other forms of GAI, such as text-to-music or image-to-animation, can be introduced. On the one hand, these technologies enhance architectural representation by providing audiovisuals and animations that complement static images, opening up new possibilities for design exploration and expression. On the other hand, students are encouraged to become accustomed to working with AI as a team, preparing them for the future implications of human-AI collaboration.

From the teaching team's perspective, tools for immediate application and less sophisticated but advanced tools are prepared. The latter serves as additional knowledge to provide students with a glimpse into AI's future implications and mentally prepare them for its integration into their architectural practice.

The potential use of Explainable AI (XAI) (Khosravi *et al*. 2022) can enhance user acceptance (Luckin *et al*. 2022). Although Large Language Models (LLMs) are not inherently designed as explainable AI, their interaction properties offer insights to human users regarding the thinking logic of models like GPT within the educational context (Kasneci *et al*. 2023; Villegas-Ch *et al*. 2020).

5.3 User Acceptance

The third point of focus in this research pertains to user acceptance, specifically addressing how students perceive and accept the use of AI in architectural design. The authors draw from their past teaching experiences to shed light on this aspect, supplemented by the perspectives of the teaching team. Since 2020, the authors have been actively involved in teaching and exploring the integration of artificial intelligence (AI) in the architectural design process. Feedback gathered from previous teachings provides valuable insights.

During the initial year, the teaching team introduced Google Colab, a free cloud-computing platform for students to run AI programs online. However, students' unfamiliarity with the Jupyter Notebook format posed a challenge initially. With the assistance of a computer engineering expert on the teaching team, students were successfully taught how to use the tool to generate images. Given the limited number of architectural precedents in this area, extensive discussions arose regarding the types of images that would be "useful" for the AI to produce meaningful results. As students became more proficient with the tools, discussions and reflections shifted towards their implications in the architectural design process. For instance, students explored how design strategies inspired by AI-generated images could be employed in their architecture design studio projects. During that semester, two tools, Deepdream and StyleTransfer, were introduced. Although Deepdream yielded less "promising" results, it provided insights into how computers perceive the world differently from human eyes.

In 2020 and 2021, the focus shifted to using StyleTransfer and introducing user-friendly applications, allowing students to explore various tools independently. With increased practical experience, over

```
[ ] import time
    start = time.time()

    epochs = 10
    steps_per_epoch = 100

    step = 0
    for n in range(epochs):
      for m in range(steps_per_epoch):
        step += 1
        train_step(image)
        print(".", end='')
      display.clear_output(wait=True)
      display.display(tensor_to_image(image))
      print("Train step: {}".format(step))
      print("Train epochs: {}".format(n))

    end = time.time()
    print("Total time: {:.1f}".format(end-start))
```

Figure 2.Google Colab interface
Source: created by the author.

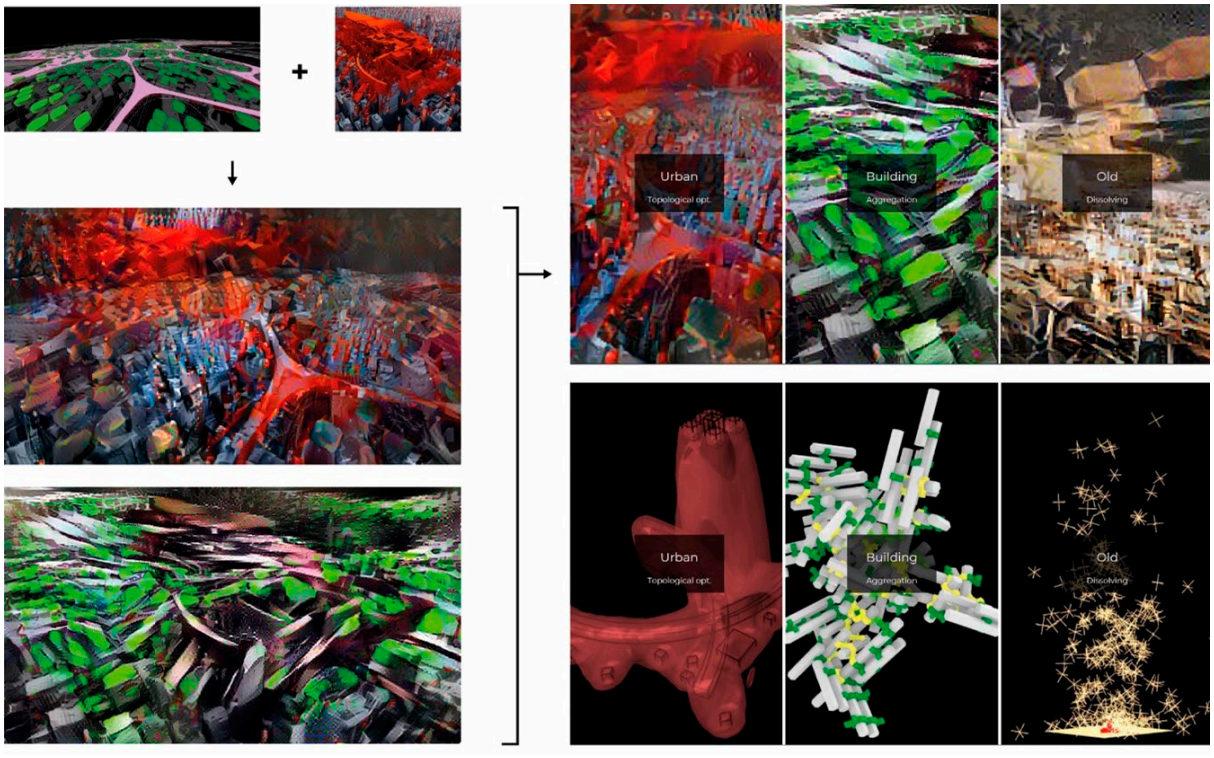

Figure 3. StyleTransfer experiments and inspired design strategies
Source: created by the author.

90 % of students expressed a positive attitude towards applying AI in their design approaches, and nearly 90 % envisioned its relevance in their future practices (Dall'Asta, 2023). Some students who participated in these courses or workshops have even been employed due to their unique proficiency in employing AI tools in practice and research environments.

Our teaching team successfully conducted a four-day online workshop titled "Hacking Machine Learning Style-Transfer" on the DigitalFutures platform. This workshop attracted the participation of twenty students from around the world who had little to no coding knowledge. Our primary objective for this workshop was to enhance user acceptance by providing students with a clear and familiar workflow.

To achieve this, we structured the four-dayday workshop to allow immediate use of a web application for StyleTransfer inspiration. The students could create 2D collages by manually editing selected AI-generated images and 3D modelling their designed collages. The final step involved presenting their work (as shown in Fig. 4 and 5). By providing a well-defined objective and a clear path to achieve their desired AI-generated results, the students exhibited a notable increase in confidence throughout the design process.

However, it is worth noting that although the workshop successfully increased user acceptance, we observed a limited utilisation of AI capabilities. In this particular case, AI served merely as an inspiration generation tool due to the dominant involvement of manual image editing and 3D modelling. Nevertheless, user acceptance has dramatically increased.

Two main findings emerged from the previous study. Firstly, the importance of conversations between students and AI in the architectural design process was emphasised. Secondly, the probabilistic nature of AI allows for unlimited design suggestions, indirectly encouraging students to reflect on their choices rather than relying on absolute design decisions.

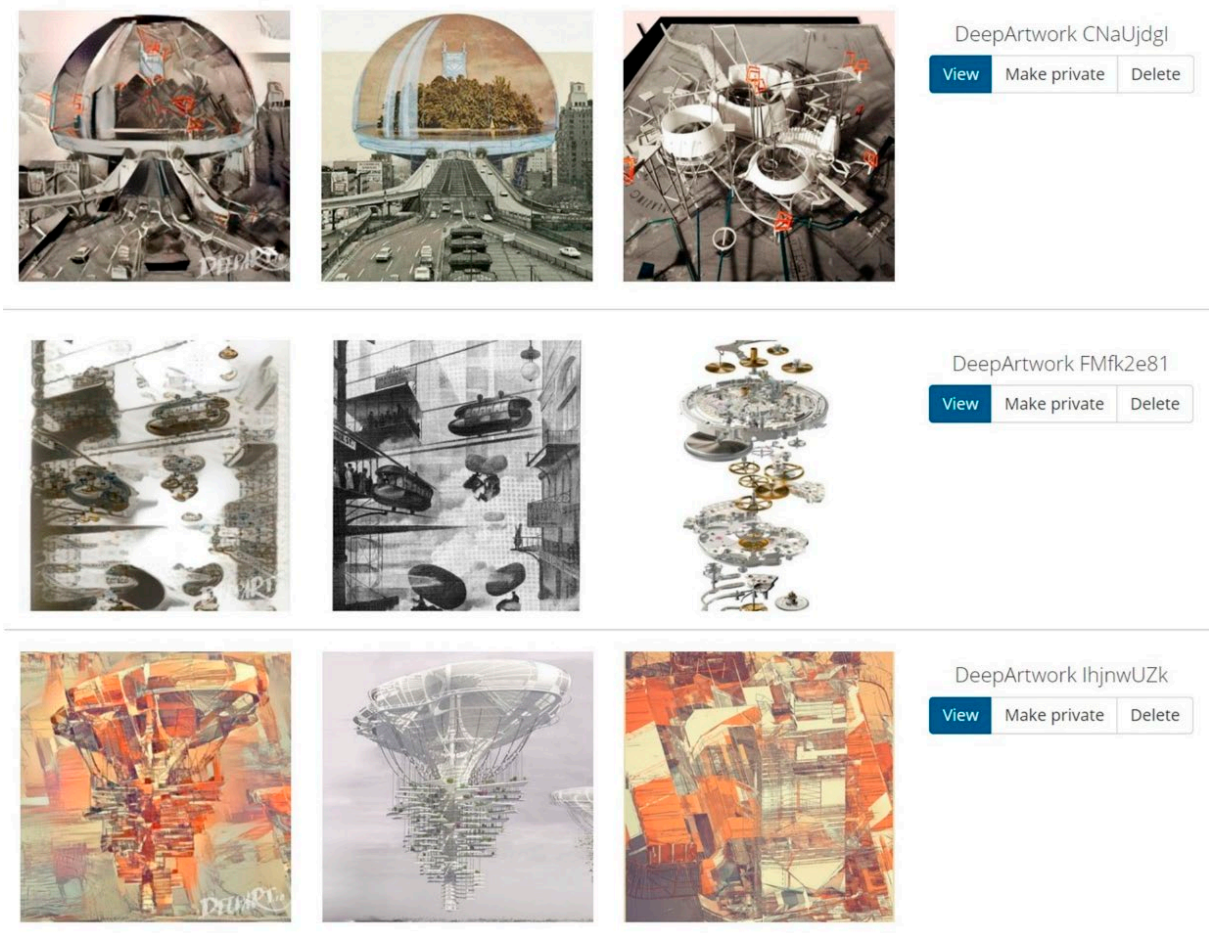

Figure 4. User interface of StyleTransfer on a web application, experiment by Lakita
Source: Ralph Spencer Steenbilk,2021.

Figure 5. Edited collages of AI images inspired 3D modelling, by Xinyi Zhang
Source: (Spencer, 2021).

Since 2022, new tools have emerged due to advancements in AI, particularly in Diffusion Models, including large pre-trained language models like GPT. Consequently, the teaching team reassessed existing tools and reflected on how the latest AI developments could be taught and applied in architectural design. This involved testing different AI art generation tools and exploring applications of large language models while delving into technical and theoretical aspects. As a result, a collaborative and intuitive framework for the combined application of AI art generation tools in the architectural design process was being researched in 2022, and proposed in early 2023 (Cheung & Dall'Asta, 2023). Through reflection, three potential areas for improvement and further exploration were identified.

Firstly, instead of using plain images, students could attempt to apply filters such as depth detection to their physical model photos. Secondly, a streamlined application for students, including a 3D intuitive workflow like 3D modelling in AI applications, could enhance usability. Thirdly, when feasible, real-world scenarios, particularly within the academic environment of architectural design studios, should be incorporated.

During the summer of 2023, the first author participated in a Summer Undergraduate Research Fellowship (SURF) project, designing a streamlined workflow using Google Colab as a platform to provide students with a free tool. The project spanned eight weeks and aimed to package three AI models (BLIP for Visual-Question-Answering, GPT as a large language model, and SD as an AI art generation tool) into a single Colab notebook. However, it became apparent in the second week that students preferred to find separate web applications for BLIP and GPT and a local application for Stable Diffusion. Some even explored alternative tools like Midjourney and additional applications of StableDiffusion, including customised AI models. This reflection indicated that streamlined applications with script-based user interfaces, such as Google Colab, had lower preference among students.

Considering the importance of AI ethics, especially fairness, it is crucial to address potential issues. Students from economically challenged backgrounds may need more access to AI application opportunities, highlighting that user acceptance is not solely a cognitive matter but also influenced by financial considerations. Therefore, prioritising

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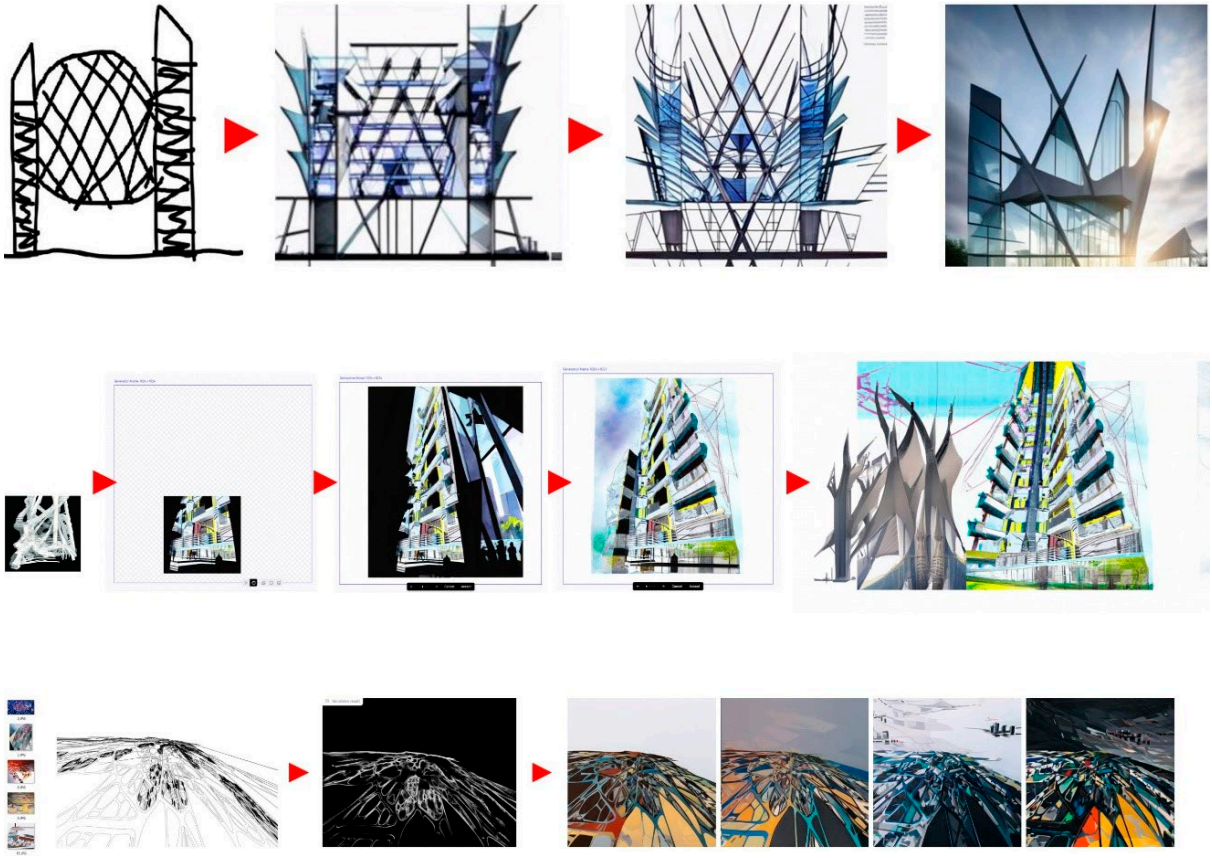

Figure 6. Three simulated scenarios in the architectural design process, by Lok Hang Cheung
Source: created by the author.

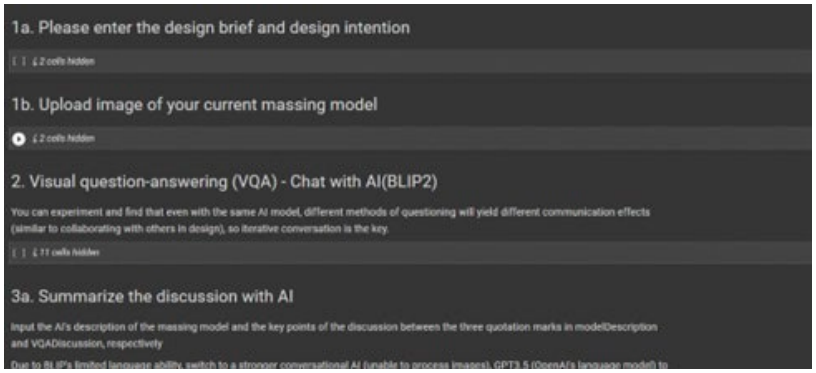

Figure 7. A streamlined AI toolkit designed for the SURF project using Google Colab
Source: created by the author.

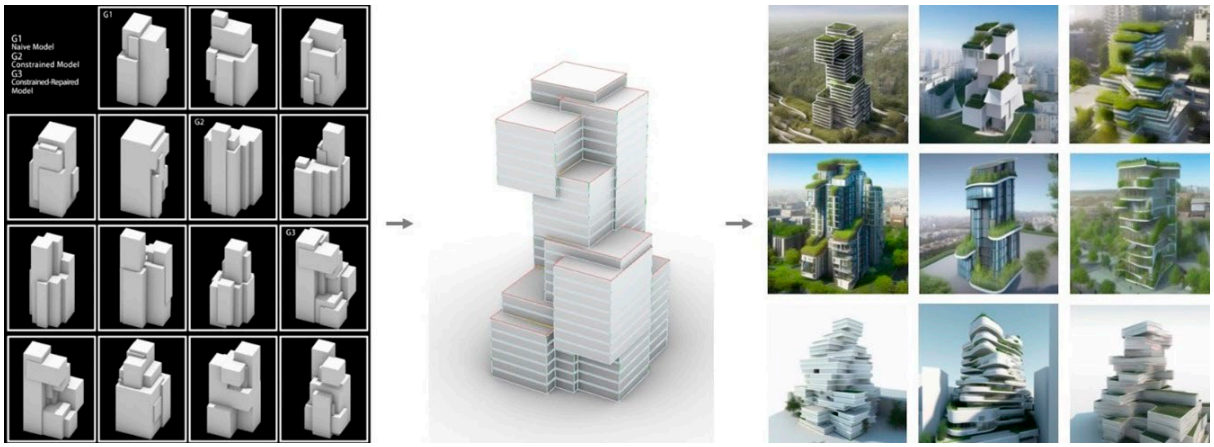

Figure 8. Parametric optimisation tool and AI tools in the same workflow, by Chuwen Zhong and Yian Shi, supervised by Likai Wang, Leyuan Jiang and Lok Hang Cheung
Source: reproduced from author, with permission

open-source or free applications over pursuing the most advanced or newest tools, which often require costly computational power, is essential.

Several strategies can be employed to increase user acceptance. Firstly, providing user-friendly interfaces for immediate application during in-class exercises is important. Secondly, incorporating precedent studies, in-class discussions, and post-exercise reflections can enhance students' knowledge and theoretical understanding of AI development and tools. Lastly, setting clear student goals, establishing explicit expected outcomes, and providing short-term, immediate feedback are crucial for ensuring students can effectively utilise the tools. Additionally, encouraging reflections from students after each in-class exercise fosters long-term application in the design studio and future design projects.

6. RESEARCH – SYNTHESIS IN PRACTICE

After reflecting on the framework from the perspectives of vision, technology, and user acceptance, we designed modules for the architectural design course in the academic year 2023-24.

6.1 Introduction

The architectural design module titled ARC 411, known as Practice Based Enquiry and Architectural Representation, is designed for second-year Master of Architectural Design students in their final year of the RIBA Part 2 course at Xi'an Jiaotong-Liverpool University. The module consists of one weekly class and adopts a highly practice-based approach, incorporating in-class exercises, tutorials, and discussions. For 14 weeks, students must submit and present their work every four to five weeks, each being an independent coursework assignment.

The teaching team responsible for the module comprises two individuals. The first author serves as the teaching assistant. In contrast, the second author fulfils the role of the module leader for ARC 411 and the programme director for the Master of Architectural Design course.

With a focus on advanced practice-based methodologies, this module introduces students to the latest artificial intelligence (AI) technologies and their application in critical, creative problem-solving and communication within architecture. The course encourages students to explore Western and Eastern art practices, enabling them to engage with and perceive such engagement as a form of critical inquiry into prevailing architectural presentation and representation methods.

Through the re-presentation of architectural projects and the utilisation of various media, such as drawings, models, video, sculpture, interactive digital media, and installation art, students are exposed to novel approaches for identifying questions, addressing them, and effectively communicating their ideas to audiences that may not possess specialised knowledge in reading architectural plans and models. This approach acknowledges and accommodates differing interpretations of architecture, broadening students' horizons and fostering an expanded understanding of the discipline.

6.2 Coursework 1 – AI as a Design Partner

The first coursework is titled "AI as a Design Partner, Generative Artificial Intelligences as a Design Team." Within the field of architecture, Generative Artificial Intelligence (AI) has garnered significant attention, particularly with the emergence of techniques like Deepdream and Style Transfer, which have been explored since 2015. This exploration has paved the way for advancing more sophisticated AI techniques in computer vision (CV), such as diffusion models. These advancements have led to the rapid development of various AI art generation tools capable of producing high-quality images, including notable examples like Midjourney and StableDiffusion. However, it is crucial to acknowledge that many current applications tend to view these AI art generation tools merely as random "inspiration generators" or, in the words of Nicholas Negroponte, "a fast draftsman who doesn't eat." (Negroponte, 1976).

To fully harness the potential of AI in the architectural design process, it

is crucial to view AI as a design partner rather than a mere tool. This coursework aims to explore practical applications of different AI technologies at various design stages, from conceptual exploration to architectural representation. Generative AI techniques, particularly in Natural Language Processing (NLP), have made significant advancements. Large Language Models (LLMs) like ChatGPT will be utilised in this assignment to facilitate discussions, explorations, and interpretations of the design process.

The exercise has three primary objectives:

Firstly, it provides an overview of AI applications, emphasising the concept of "AI as a design partner." This ensures that students clearly understand different AI categories and encourages them to envision the untapped potential of AI in architecture. Secondly, the exercise introduces the latest generative AI techniques, such as StableDiffusion, PlaygroundAI, and GPT, among others, and explores their practical applications in real-world design scenarios. Emerging techniques like BLIP, a Visual-Question-Answering (VQA) AI, will also be introduced and tested. Lastly, the exercise prompts students to reflect on how designers can collaborate with AI as a design team in different stages and scenarios of the design process, prevent-

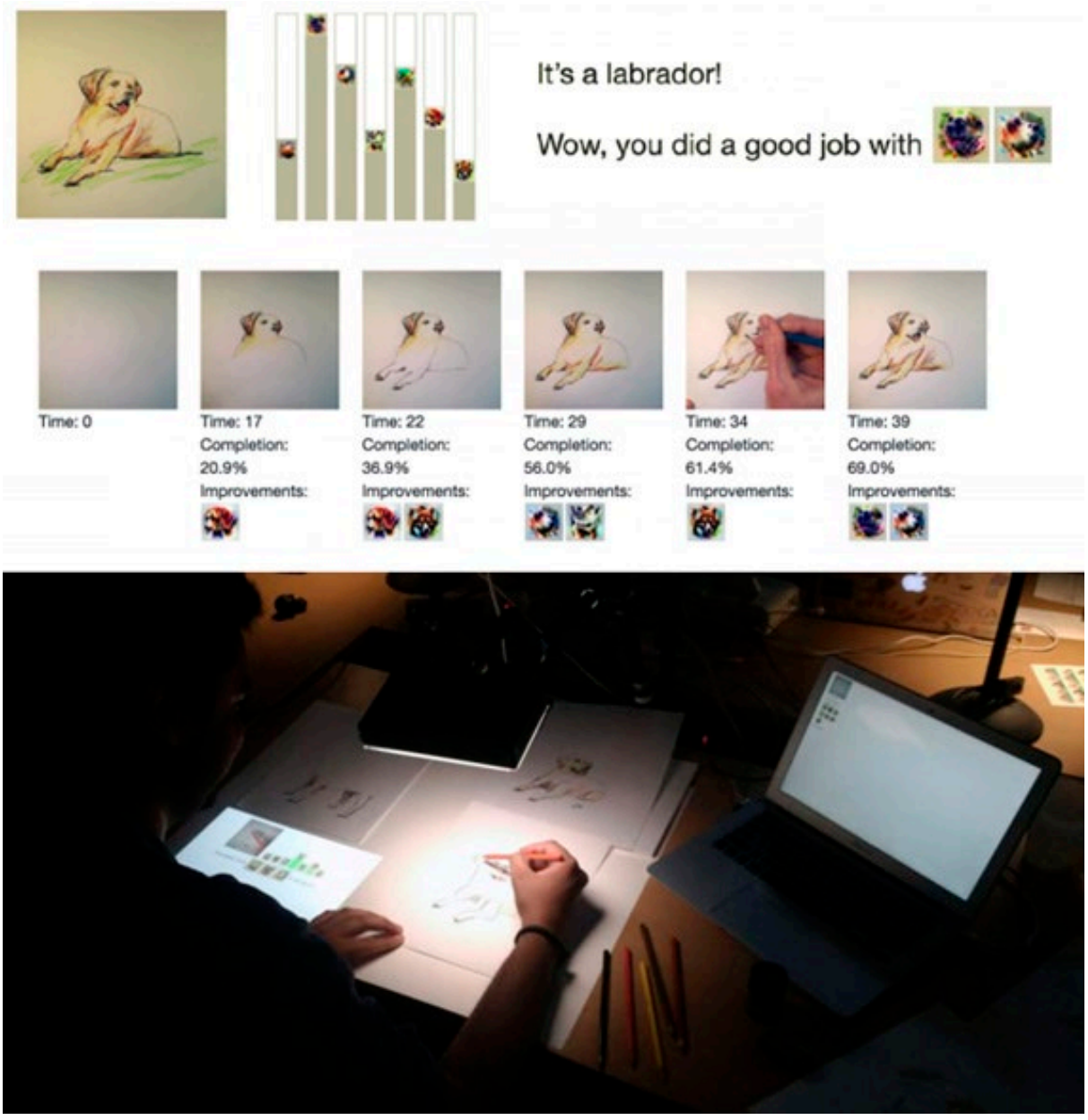

Figure 9. A Conversation with a Machine by Erik Ulberg
Source: Erik Ulberg, https://www.erikulberg.com/#/conversationwithamachine

ing them from solely relying on supervisor comments (Sweeting, 2014). Particular emphasis will be placed on reflecting on the experiences of working with different AI technologies, enabling students to develop their approaches to collaborating with various AIs in their current and future architectural projects.

Although the module has only been underway for one week, it has already been observed that students feel comfortable using StableDiffusion through PlaygroundAI, a user-friendly and free web application. They have engaged in image-generation experiments by modifying prompts and employing text-to-image and image-to-image techniques. The intuitive interface of StableDiffusion has encouraged students to ask design-related and theoretical questions regarding AI creativity and its implications in design studios and thesis work. Furthermore, students with prior experience using other AI art applications, such as Midjourney, have taken the initiative to compare the outcomes produced by StableDiffusion. A few students have also independently explored StableDiffusion on their computers before starting the module.

In the initial week of the course, the focus was on introducing the background of AI, emphasising understanding its application in the architectural design context rather than approaching it solely from a computational or technical perspective. Subsequently, case studies will be presented weekly to broaden students' knowledge and enhance their acceptance of AI by providing multiple perspectives. For instance, the case study of URBAN5 by the Architecture Machine Group has been introduced. Relevant projects incorporating recent advancements in AI technology, such as "A Conversation with a Machine" by Erik Ulberg (2019), have also been included to enable students to observe the continuous development in this field.

Throughout the course, each lesson will include two to three in-class exercises to engage students in practical applications of AI techniques. Exercise 1 introduces the Large Language Model (GPT), available on poe.com. Students are tasked with exploring how they can brainstorm ideas or engage in discussions with GPT, including generating prompts for AI art generation tools. Following this activity, students are encouraged to reflect on their challenges and potential opportunities for applying these techniques in the design process. In the exercises, students must prepare four sets of images, with at least one example for each set. These images serve as a means for students to explore their creative applications. Each set focuses on a specific topic,

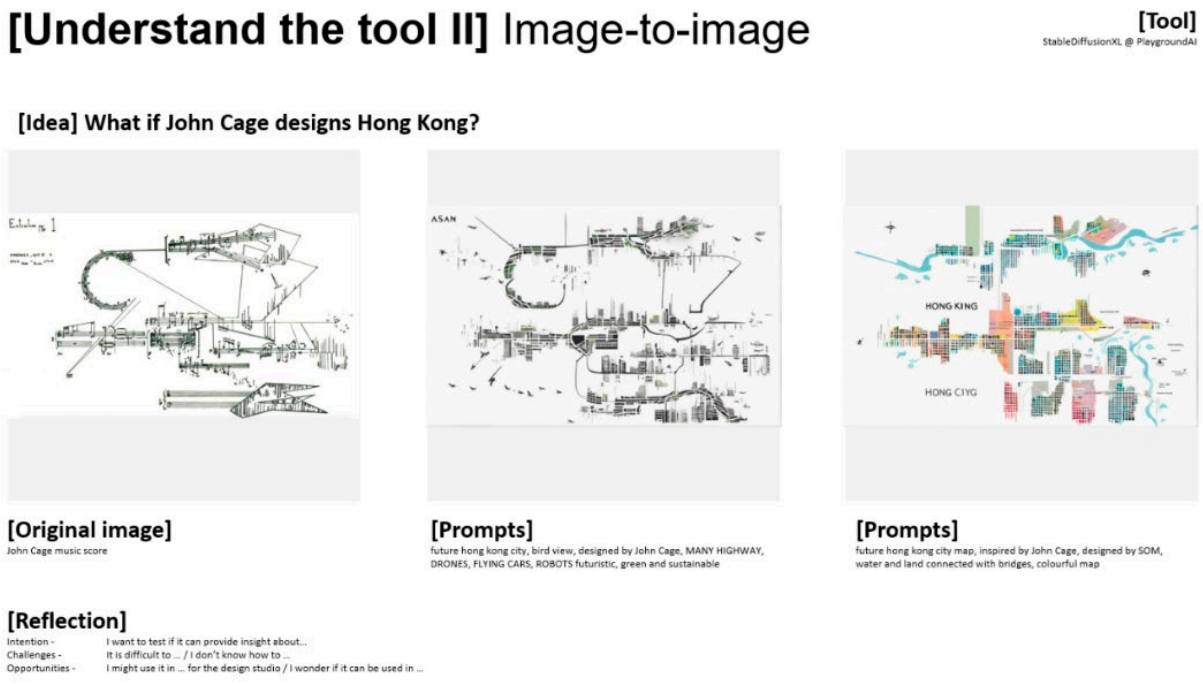

Figure 10. An example template slide for the students
Source: created by author

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such as site exploration or a design idea. In the reflection section, students present their original intentions behind generating the images, discuss the challenges they faced, and highlight any opportunities they discovered. Students are guided to practice various techniques, including text-to-image and image-to-image skills, and gain an understanding of parameters such as prompt strength, image selection, and style manipulation.

Exercise 2 introduces the AI art generation tool, StableDiffusion, to students with little to no prior experience with AI. PlaygroundAI, a user-friendly application platform, is utilised to facilitate their engagement. After registering, students can immediately generate free images using StableDiffusion. While some AI techniques and tools may be introduced as extensions of knowledge without immediate practical use, they contribute to the student's understanding of the broader AI landscape. For instance, the Visual-Question-Answering AI model, BLIP2, is introduced in the first week, showcasing the potential merging of Computer Vision (CV) and Natural Language Processing (NLP) in seamless applications. Although BLIP2 demonstrates the feasibility of combining CV and NLP through image-captioning and question-answering, its limitations in handling complex inquiries highlight the need for further development in real-world scenarios.

During the second and third weeks, the coursework will explore StableDiffusion, which is considered the assignment's core tool. StableDiffusion is chosen due to its open-source nature, availability, and extensive range of applications. While one student uses a Mac system, the remaining students utilise Windows, and all have successfully installed and run StableDiffusion. The widespread exploration of StableDiffusion in the global AI community has led to the development of installation packages for both Windows and Mac users. During this period, the in-class exercises will revolve around architectural design-based techniques. Students will learn to create design inspiration within a site context using existing site plans or photos. They will also explore ways to achieve similar effects to StyleTransfer using StableDiffusion and generate design ideas based on their sketches or model images.

Parts of two presented projects closely related to the design studio project are displayed below. In the first case, the student expressed a keen interest in painting art styles but needed more certainty regarding their application within the design studio project. He first generated inspirational images by

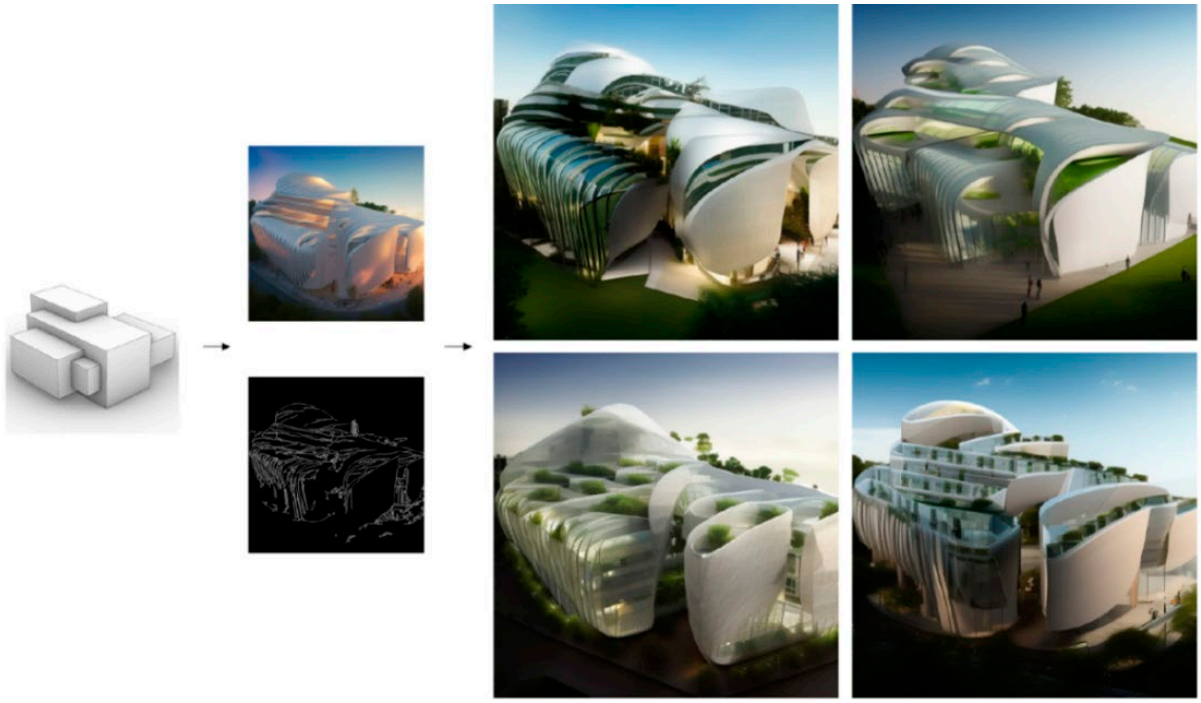

Figure 11. An example of applying StableDiffusion in generating controlled variations as a design exploration method.
Source: created by author.

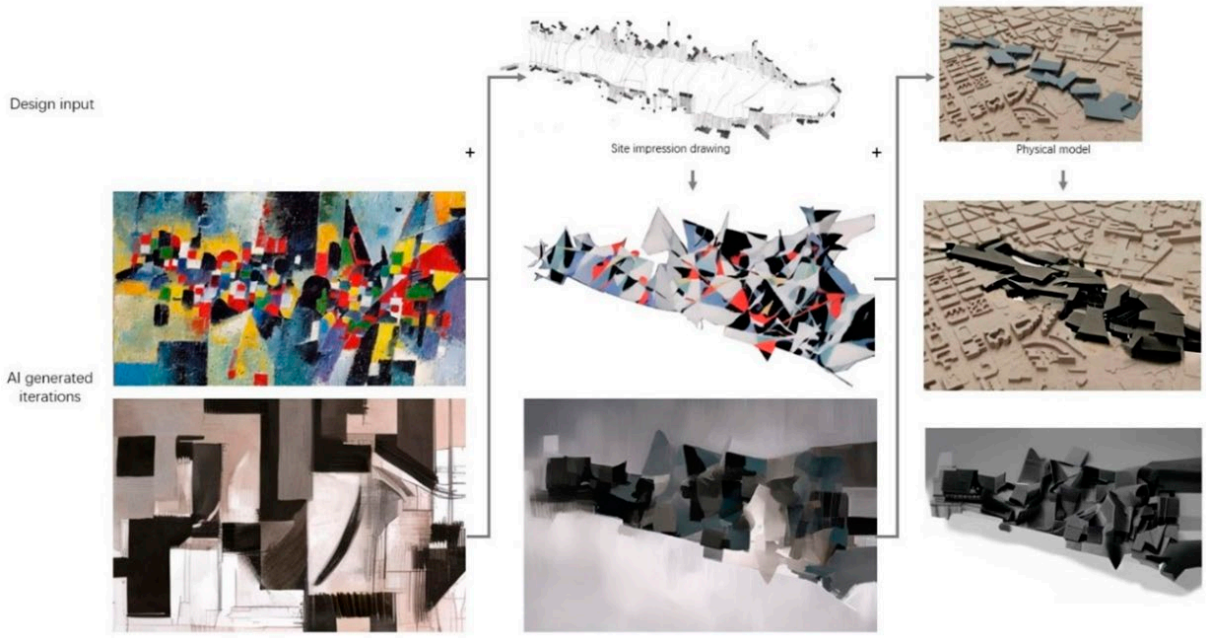

Figure 12. Student iterative AI exploration in the design project, by Huanyue Gao
Source: reproduced from author, with permission

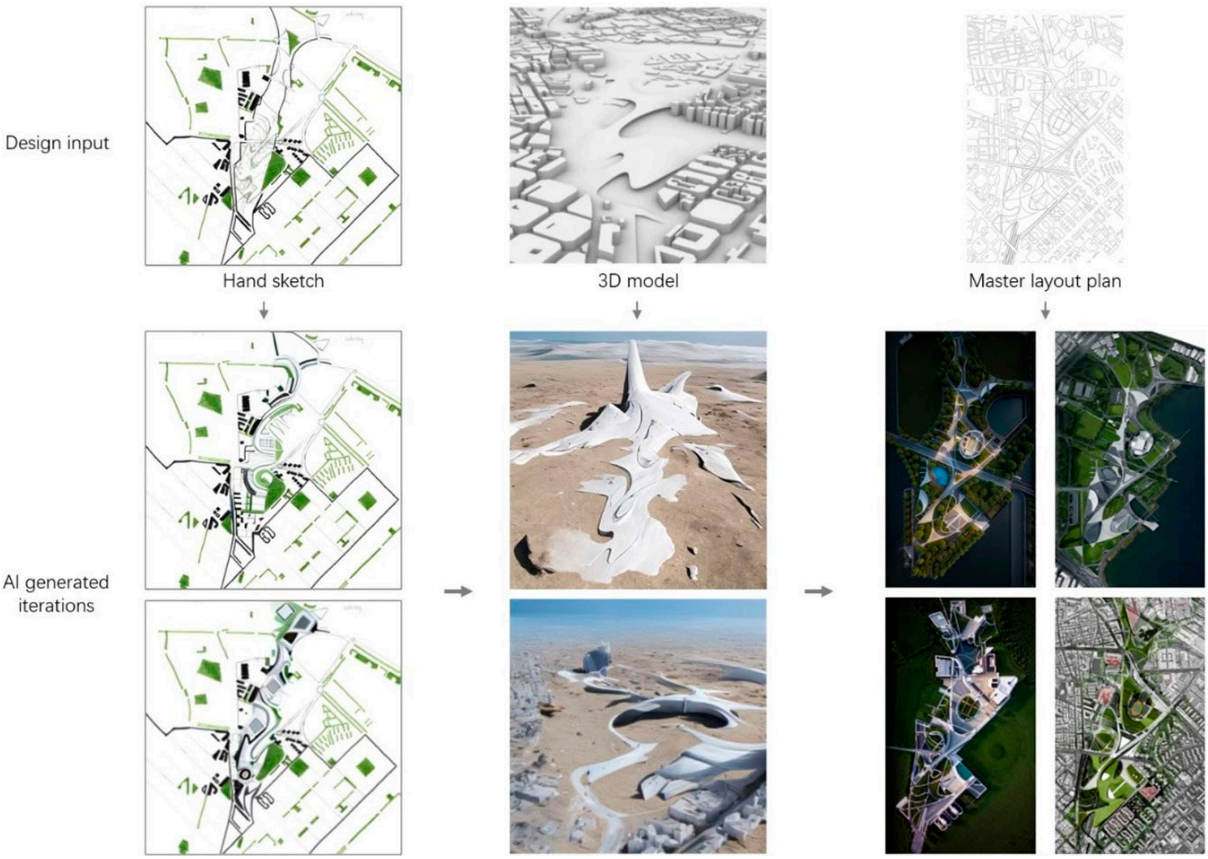

Figure 13. Student AI exploration in different design stages, by Yibo Zhao
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inputting different art style names and Barcelona, the project site. He then selected two desired results and integrated them with his site impression drawing. This iterative approach continued as he incorporated the generated images into his physical conceptual model, as shown in Fig.12. The second student showed his passion for applying computational skills, including AI, in the very early stage. Upon discovering StableDiffusion and grasping the fundamentals of ControlNet, the student embarked on extensive self-experimentation throughout various stages of the design studio project. Fig.13 showcased some extracted attempts at different stages.

In the first case, it appears that the student utilised AI to generate inspiration, similar to previous cases. However, what sets this case apart is the student's ability to exert control over the selected tools, such as GPT and StableDiffusion. This control enabled the student to transition from inspiration-only to a collaborative design approach. The second student, who was more proactive in using AI tools and trying to apply them in every design step, illustrates the possibility of smooth workflow integration once tools become familiar.

6.2 Coursework 2 – Translations, Synthesizing Reality

Visual language is only one of the mediums expressing architectural design. Therefore, in the second coursework, students will explore different audiovisual mediums or interactive techniques to design a spatial performance.

The first week of teaching will focus on expanding students' understanding of various AI tools, similar to the beginning of Coursework 1. Using web applications that can be implemented immediately is crucial to kick off the coursework and increase user acceptance among the students. Three tools will be introduced: image-to-video generation through the web application developed by RunwayML, text-to-music using the web application Mubert, and text-to-speech narration using the free platform Topmediai. These tools offer a range of AI methods for video generation, music creation, and speech synthesis, providing students with a comprehensive overview of available techniques.

Introducing these tools aims to assist students in exploring audio-visual and 3D mapping applications. The possibility of deriving ideas or prompts from discussions with the GPT model will be explored, integrating it with the concepts covered in the first coursework.

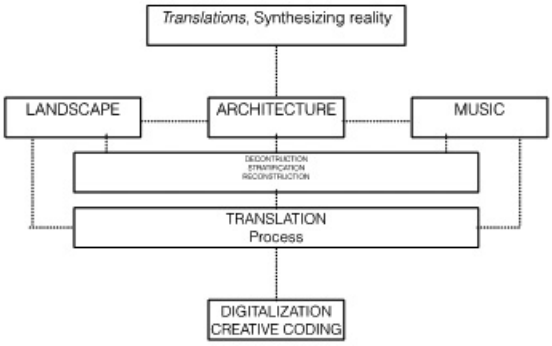

Figure 14. Framework of coursework two
Source: created by author.

In the second part of the course, the focus is on establishing connections with existing architectural design tools, such as Grasshopper. This is particularly important as students would have made progress in their design studios after approximately one month of the course. Instead of relying solely on site context or design intentions expressed in text, students now have additional information and data from their design projects, such as building parameters. Building on previous teaching and learning experiences, plugins and electronic tools that directly translate architectural model parameters into audio-visual representations will be introduced. This allows for a more interconnected conversation between AI and the students, as they can input design ideas verbally through prompts and utilise familiar parametric tools.

Similar to the first part of the course, projects, case studies, and theoretical discussions related to multimodal architectural representations and interactive architecture will be explored. Additionally, a brief introduction to ongoing research on exploring AI-integrated architecture (Cheung *et al.* 2023a) will be provided. It was not focused on AI as part of the computational tool but integrated into the built environment, such as a design studio. The course will introduce audio-visual techniques within standard architectural software such as Rhinoceros and

Grasshopper and explore AI tools such as text-to-music and image-to-animation. By integrating AI and parametric tools within the design framework, the course extends the concept of “AI as a design partner” from the first coursework, offering a holistic approach to architectural design.

Two ongoing projects were progressing in noteworthy and surprising ways. In the first case, the student observed from Coursework One that AI-generated images in pixel format couldn’t be directly used in the design process, lacking the necessary vectorised information such as points and lines. Consequently, she integrated a large language model into the 3D modelling software Rhino and Grasshopper. Through experimentation, she developed codes with the AI capable of generating geometries that could be effectively utilised in the design process, as depicted in Fig 16. The current video production adopts a video-blogging style, capturing the conversation between her and the AI partner within the Grasshopper environment.

The second student expressed reservations about employing AI as a design partner due to its unpredictable nature, approaching the matter from a philosophical standpoint. In Coursework Two, she took the opportunity to compare how different

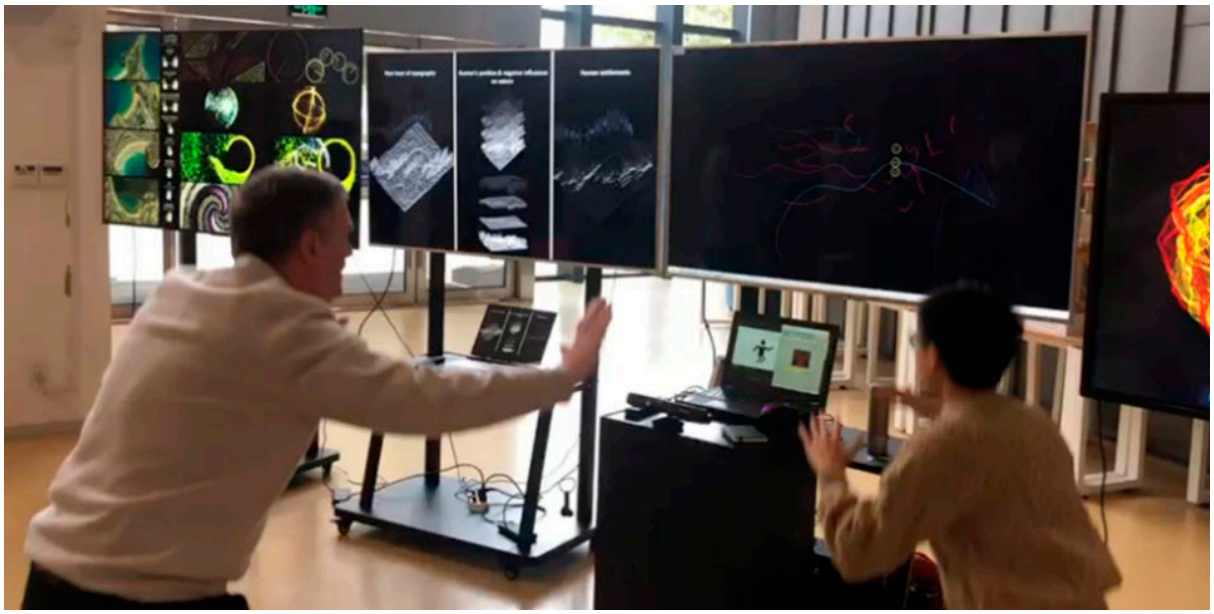

Figure 15. Interactive performance for coursework two from the same module in the previous year
Source: created by author.

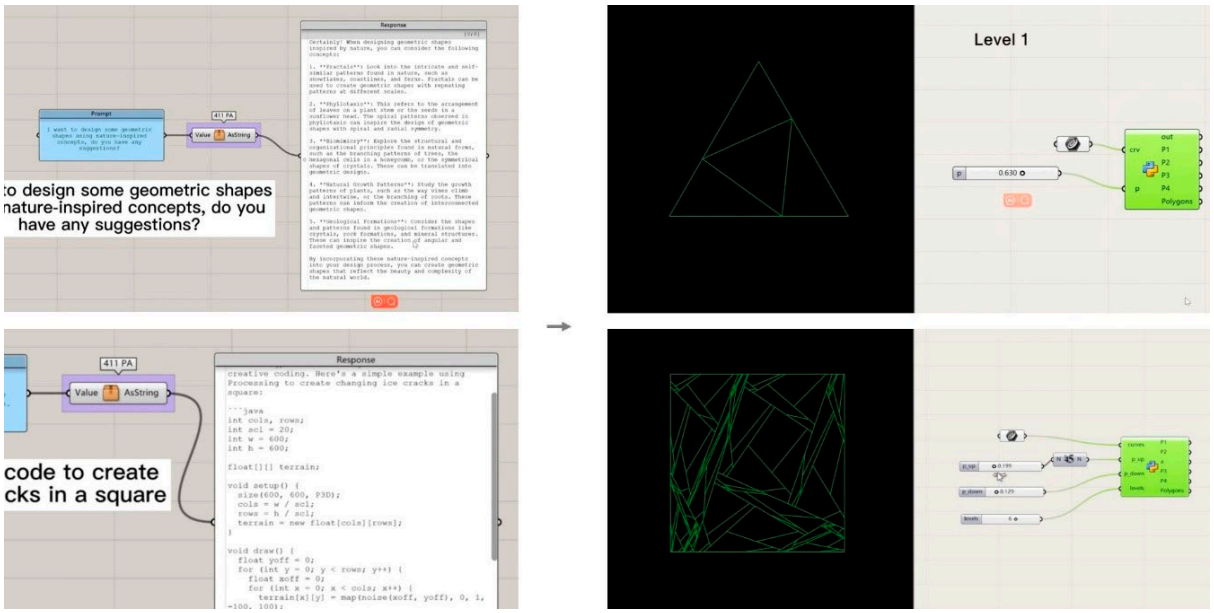

Figure 16. GPT integrated into Grasshopper to generate vectorised geometries instead of pixels, by Zhiyan Peng
Source: reproduced from author, with permission

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entities (human, machine, and AI) perceive the world in distinct ways. Starting with the observation of a moss-covered wooden branch, she proceeded to perform a 3D scan. Then, she provided the resulting 3D model image to the AI, allowing it to reimagine the object, as illustrated in Fig. 17.

Both students demonstrated original and unexpected approaches to their coursework. The first student adopted a pragmatic parametric design workflow and successfully integrated AI. On the other hand, the second student explored the philosophical aspects by investigating how humans, traditional machines (such as cameras and 3D scanners), and AI perceive the world differently. They delved into the iterative conversation among these entities, presenting a novel approach to design.

These "out-of-box" experiences deviate from previous research and teaching experience, highlighting the value of introducing user-friendly AI tools. Students can immediately engage in experimentation by eliminating the need for coding knowledge, providing greater freedom for imagination and exploration.

6.4 Coursework 3 – Final Exhibition, Video performance /video reportage and joint exhibition with Design Studio

The final exhibition in ARC411 will showcase all the coursework developed throughout the semester. In addition to the coursework, students will apply AI and parametric tools to assist in designing and developing an exhibition centred around the project from ARC413. This exhibition will include a 3D video mapping performance that tells the story of the ARC413 project's process. By utilising computational tools, students can work alongside them as a design team, from the conceptual stage to the final presentation.

The 3D video mapping performance is a pedagogical project that builds upon previous experiences with 3D mapping. This approach to architectural design connects content to representation directly and effectively, incorporating elements such as image, video, and sound editing. Final presentations of this nature encourage student participation and engagement with the subject matter while also fostering critical thinking and creativity.

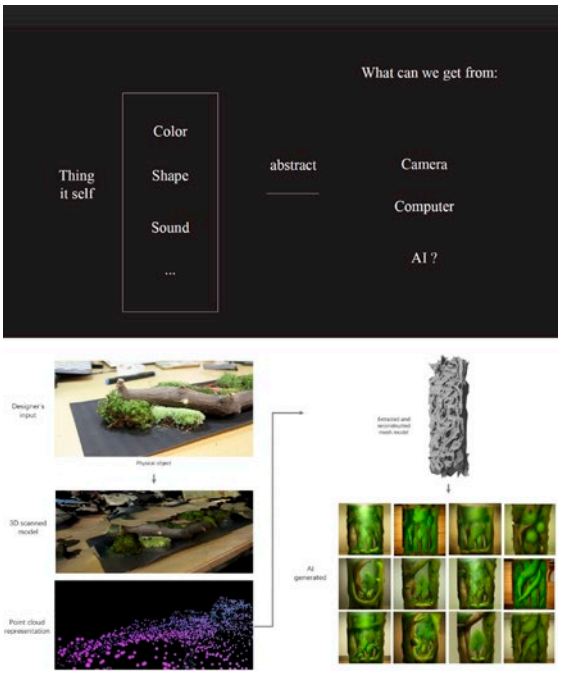

Figure 17. Experimentation of how we, camera, computer and AI see differently, by Yuheng Liu.
Source: reproduced from author, with permission

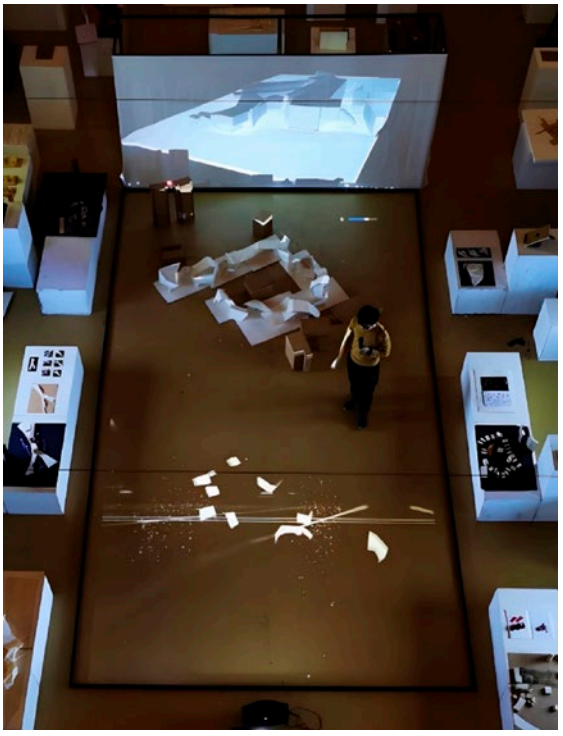

Figure 18. A 3D mapping performative presentation for coursework three from the same module in the previous year
Source: created by author.

In previous attempts, students shared the same site model, allowing each student to prepare their model to be placed on the site. Some students explored creative approaches, such as presenting the design process or simulating

a conversation between the users of the buildings. However, there needed to be more connections between the models and the students, with the students functioning more as MCs.

Other attempts involved using larger models, which allowed students to interact and perform, creating a more immersive experience. However, the sophistication level of the models could have been improved. Conversely, a more controlled environment was created using a smaller 60x60cm model, enabling greater detail and more controlled mapping. However, the immersive perception of the performance was diminished. Finding a balance between delicate models and immersive interactivity in the form of an interactive performative presentation requires further planning that aligns with the students' design direction.

7. CONCLUSION

7.1 Contributions

Table 1 summarises the aforementioned teaching and research experience based on the triangulated framework of technology, vision and user acceptance. In addition, each experience's findings are concluded so each iteration's influence can be observed.

This paper presents a human-computer interaction (HCI) framework to bridge the gap between AI technology and the conventional human-centric approach in architectural design studios. The framework contributes in several ways. First, it highlights the importance of controlled variations throughout the design process. Second, it seeks to extend the potential collaboration with AI beyond inspiration, encompassing the design process and presentation stages. The framework goes beyond mere attempts and actively strives to integrate AI into the architectural design workflow.

Several key findings can be highlighted based on the observations presented in Table 1.

1. Regarding technology, it is advisable to shift the focus away from AI art generation tools and instead promote the integration of multi-modal AIs and existing parametric tools. This approach would result in a more comprehensive toolkit for architectural design.

2. Regarding vision, it is important to prioritise the role of AIs as design partners rather than making assumptions about their specific usage at different stages of the architectural design process.

3. About user acceptance, it is crucial to provide user-friendly tools and theoretical foundations. By offering tools that can be immediately utilised and supporting them with relevant theoretical knowledge, students are encouraged to explore beyond the design process and expand their research and design boundaries.

7.2 Challenges

There are inherent challenges in the AI and architecture domains that must be addressed. AI is a rapidly developing discipline, and even with a conversational framework in place, there is an inevitable learning curve. Furthermore, architectural design processes are highly subjective and iterative, often characterised as "wicked" problems (Rittel & Webber, 1973). These problems do not have one-size-fits-all solutions, necessitating frequent reflections and adaptations.

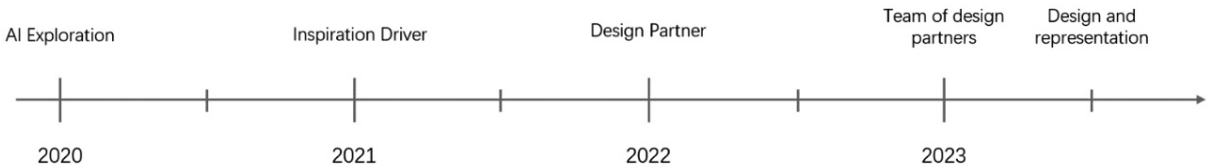

Figure 19. Timeline of AIEd in architectural design discipline, by the authors
Source: created by author.

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Table 1. Summary of AIEd in architectural design by the authors

Date	Design activities	Number of students	Technology		Vision	User Acceptance	Findings
			AI tools	Platforms			
2020	XJTLU Master Year 2 Module ARC411	12	Deepdream, Style-Transfer	Google Colab	Explore what AI art generation tools can do in the architecture discipline	Involve a tutor with a computing background to teach AI techniques	Depends heavily on the designer's imagination
2021	"Hacking Machine Learning Style Transfer", Digital FUTURES online workshop	20	Style-Transfer	Web application (Web application (DeepArt.io))	Involve AI art generation tools in the design process	Integrate AI into a common design workflow	Still depends heavily on imagination and manual inputs Underused AI
2022	Self-research	N/A	Stable-Diffision, DALLE-2	Web application (PlaygroundAI) Google Colab Web application	Framework for applying AI art generation tools in the design process	Simulated scenarios for designers with different levels of computational knowledge	Proposed an intuitive, collaborative, combined application of AI art generation tools
2023	XJTLU SURF (Summer Undergraduate Research Fellowship)	6	BLIP2, GPT, Stable-Diffusion	Google Colab	Explore a workflow applying AI art generation tools with a parametric optimisation tool	Compiled different AI tools into one single streamlined web application	Students prefer user-friendly UI over a streamlined application that requires coding knowledge
2023 (on-going)	XJTLU Master Year 2 Module ARC411	12	GPT, Stable-Diffusion	Web application Local computers (WebUI)	HCI-based AIEd framework for multi-modal AI tools as design partners and representation	Introduced tools that required minimum computational knowledge	More seamless integration into the process. Multimodal AI and integration into parametric tools allowed a variety of applications (Still ongoing)

7.3 Future Opportunities

First, there is an opportunity to extend the framework to other aspects of AI in Education (AIEd), including system-focused and teacher-focused approaches. The framework can encompass a broader range of educational contexts by exploring these areas.

Second, it is important to incorporate feedback from the ARC411 and ARC413 modules to reflect on and improve the framework continuously. This iterative process will contribute to its refinement and effectiveness.

Third, the potential of AI extends beyond being a design partner in the form of digital applications or IoT devices. Integrating AI directly into the design studio is possible, creating an AI-integrated built environment. This opens up new avenues for exploration, where human-computer

interaction focuses on the human-machine conversation (HMC) (Cheung *et al.* 2023b), emphasising the physicality of architecture and the design environment. The learning process for AI during its employment within the design studio is also a valuable area to be explored, extending the notion of reflection not only for students or designers but also for AI systems.

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