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AI-assisted architectural design studio (AI-a-ADS): How artificial intelligence join the architectural design studio?

Güliz Özorhon[1] · Dilara Nitelik Gelirli[1] · Gülbin Lekesiz[1] · Can Müezzinoğlu[1]

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Abstract

Incorporating AI into design is a current and promising research topic. This article investigates and discusses the integration of AI tools into architectural design studios. A 4-stage research methodology (DCIE) is adopted in the article. Accordingly, in the first stage (discovery), the relationship between architectural design education and technology is examined. The second stage (creating) involves planning the architectural design studio (AI-a-ADS) and the workshop with an original setup by instrumentalising AI. In this workshop, AI (Midjourney) is used to relate different materials (text, perspective, and model) in the design process in a heterogeneous dialogue. The third phase (implementation) is the implementation of the workshop. In the final phase (evaluation), the workshop was evaluated by its participants within the framework of AI-a-ADS. The research findings indicate that AI integration supports students in developing their projects and forming the basis for some spatial solutions. Additionally, key issues emerged regarding AI applications in architectural design studios. It is crucial to produce materials that provide design context clues, define AI requirements in advance, and convey technical knowledge in such cases. At the same time, the research has demonstrated the significance of generating uncertain outputs for artificial intelligence to become co-designers. Thus, strategies can be prepared to trigger innovative ideas, and discussing vague outputs in a polyphonic studio environment can trigger the emergence of new potentials.

Keywords Architectural design studio · AI in design education · Midjourney · Diffusion models

Abbreviations

AI Artificial intelligence

✉ Dilara Nitelik Gelirli
dilara.nitelik@ozyegin.edu.tr

Güliz Özorhon
guliz.ozorhon@ozyegin.edu.tr

Gülbin Lekesiz
gulbin.lekesiz@ozyegin.edu.tr

Can Müezzinoğlu
can.muezzinoglu@ozyegin.edu.tr

[1] Architecture Department, Ozyegin University, Istanbul, Turkey

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AI-a-ADS	Artificial intelligence-assisted architectural design studio
CAD	Computer-aided design
DCIE	The method of the study. Discovery + creating + implementation + evaluation
MIT	Massachusetts Institute of Technology
MJ	Midjourney

Introduction

From past to present, social and cultural changes, global issues, and technological developments have transformed not only all disciplines but also architecture and architectural design education. From the fundamental methods of architecture to today's AI-assisted design practices, architectural pedagogy has continuously renewed itself to adapt to new requirements and capitalise on emerging opportunities. The architectural design studio is the centre of this evolution, a dynamic environment fostering problem-solving, creativity and collaboration.

The foundations of the architectural design studio were laid at the Beaux-Arts school, which is recognised as the beginning of formal architectural education. In this school, a project-based education system was based on the master-apprenticeship relationship. It aimed for students to conduct problem-oriented research with expert architects and peers and gain solution-oriented design experience (Taşçı, 2016). Industrialisation and modernisation with the Industrial Revolution led to the birth of the Bauhaus education model in 1922, and this model created radical changes in architectural education with its art-craft relationship and applied studies (Meyer & Norman, 2020). The development of the Bauhaus model, in parallel with technological advances and social changes, transformed the understanding of architectural education according to new needs (Arı, 2020). In new education models, where an interactive and holistic design approach comes to the fore, more emphasis has been placed on practices that support students' creativity and develop their personal expression opportunities (Şahin, 2013). This multidisciplinary approach has strengthened the dynamic and flexible structure of the studio in architectural education and facilitated its adaptation to changing conditions.

The development of the first architectural design software, Sketchpad, in the 1960s, the emergence of personal computers and the widespread use of CAD software in the 1970s revolutionised architectural design. The proliferation of the internet in the 1990s made information more accessible and faster dissemination and accelerated the development of computer-aided design (CAD) tools. In particular, the emergence of 3D software has enabled architectural design to move from the production of form to the search for form. It has enabled design complexity with new tools (Karabulut Gür, 2019). After CAD software, Building Information Modeling (BIM) software enabled multidimensional models, facilitating the solution of complex designs and improving the integration between different disciplines (Clayton et al., 2010). In addition, virtual reality (VR) technology has been integrated into architectural education with CAD and BIM software and has become an important tool in design processes (Gülel & Arabacıoğlu, 2019). As a result, architectural design has transformed throughout the historical process with cultural and technological changes. Architectural education also adapts this transformation within itself.

Artificial intelligence (AI), another example of technological development, has been integrated into architectural design in recent years. Realistic visualisations have been created with performance and product-oriented design algorithms, and processes have

become more effective with big data analysis, fast processing capacity and algorithmic design tools (Başarır, 2022). AI also contributes to the production and construction phases by integrating with CAD and BIM software (Ceylan, 2021). AI tools offer valuable research, learning and design development opportunities in architectural education. In leading institutions such as MIT, these technologies have been integrated into practical and theoretical courses (Díaz-Guerra et al., 2023).

The proliferation of deep learning and generative AI models mainly drives the widespread use of AI in design education. These models are Diffusion Models, which gain the ability to synthesise text, images or other types of media with written commands (Oppenlaender et al., 2023). Diffusion models are used in architectural design studios, especially in the early stages of the process when the design problem is more uncertain and requires more creative solutions (Dortheimer et al., 2023; Jaruga-Rozdolska, 2022; Paananen et al., 2023; Tong et al., 2023; Werker & Beneich, 2023).

This research aims to develop a methodology for integrating AI in architectural design studios. It examines how these tools can be integrated into architectural education by conducting a case study on Midjourney, one of the diffusion models. Exploring the applications, limitations and potentials of AI Tools to foster creativity contributes to the ongoing debate on the evolving role of technology in shaping the future of architectural education pedagogy.

Aim of the study

As both architectural educators and researchers, it is our responsibility to contribute to the development of architectural design education and to work for its adaptation to innovations. Today, the most important actor that makes this development necessary is technology, and the address of technological innovations is artificial intelligence applications. This article focuses on integrating AI applications into architectural design education and how the architectural design studio's traditional educational methodology can evolve with AI's participation. Within the scope of the study, diffusion models are specifically studied. The main questions of this research are: (1) How can a methodology for integrating diffusion models into architectural design education be developed? (2) How can this involvement enrich the production environment and design development? (3) How can this integration be structured to support student creativity?

Methodology of the study

This study adopted a methodology based on design-based research (DBR). DBR is a systematic and flexible research method in which the analysis, design, development and implementation processes are carried out in collaboration with researchers and participants in an actual practice environment; it is a systematic and flexible research method for the development of context-sensitive design principles and theories and for improving educational practices (Wang & Hannafin, 2005). The goals of DBR can be summarised as producing and/or improving innovative environments and understanding how these environments achieve their goals. Therefore, the DBR method is compatible with this research. For this study, DBR is designed as a discovery, creation, implementation, and evaluation step (DCIE for short) (Fig. 1).

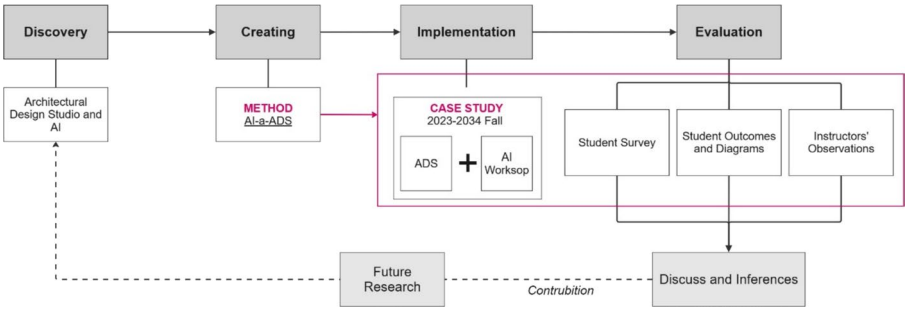


Fig. 1 Research method

- Discovery: The first stage of the research focuses on examining the interaction between architectural design and architectural design education, technology and AI. In this examination, current practices and research are discussed. Thus, alternative ways and methods of incorporating AI in architectural design education are discussed.
- Creating: In the second stage of the research, a method for integrating AI into the architectural design studio was developed. The method called AI-Assisted Architectural Design Studio (AI-a-ADS for short) is based on the short-term inclusion of AI as a creative agent in the architectural design studio curriculum through a workshop. In architectural education, workshops offer short-term learning experiences that encourage active, experiential learning and meet the needs of a variety of learners using a variety of learning activities (Brooks-Harris, 1999). Such workshops enrich the architectural design studio and allow students to produce creative solutions by separating the studio from the routine.
- Implementation: The third stage of the research involves the application of the developed method as a case study. Although they have limitations, case studies provide rich insights and detailed accounts of specific inferences (Walsham, 1995). They are also a particularly appropriate method for investigating processes (Langley, 1999). The Architectural Design Studio (ADS) and the AI-a-ADS workshop structured the case. The case study was realised with a total of 14 participants (10 students and 4 instructors). The case study details are described in Chapter 4.
- Evaluation: The fourth (final) stage of the research is the evaluation stage. In this stage, AI-a-ADS was evaluated by its participants (students and instructors) through various methods (questionnaire, diagram, observation). A questionnaire was conducted to get feedback from the students about their experiences. The details of the questionnaire are explained in Chapter 5. Students were also asked to interpret the interaction between their semester projects and workshop productions with diagrams. The instructors' evaluations were based on their observations during the workshop process and the studio jury at the end of the semester.

Participants

The participants of the study were the lecturers and students of the architecture department of XXX University. Four lecturers (3W, 1 M) from different fields of specialisation (architectural design (1), architectural design computing (2), and building technology (1)) participated in the study. This diversity is necessary and valuable for the development

and application of the method. 1st and 2nd-year students (X students in the age range of YY-YT, 7W, 3 M) in the Architectural Design Studio MIM 102A-MIM 201 A group of the Department of Architecture students participated in the study. Ethics committee approval was obtained before the research, and the participants were informed about the purpose and subjects of this research.

Architectural design studio (ADS) and artificial intelligence (AI)

Today's architectural education aims to raise future architects as intellectual professionals with an education that aims to increase their level of awareness and thus their social and environmental sensitivity to become successful designers and to gain critical thinking skills (Kararmaz & Ciravoğlu, 2017; Yücel & Aydınlı, 2015). The architectural design studio is at the centre of this education. The architectural design studio can be defined as a process in which the learning activity is emphasised, and students practice learning through the design object. The primary purpose of the studio as an environment and method is to provide different design experiences, to develop the ability to take an active role in different areas of design and to take risks, and to provide a strong communication and motivational environment for students with different cognitive styles and intellectual skills by facilitating knowledge acquisition, exchange and processes (Paker Kahvecioğlu, 2007).

Architectural design studios are dynamic, open to innovations and developments, and collaborative and experience-based learning environments. The pluralistic structure of the studios creates a multicultural environment that offers a strong possibility for interaction (Ozorhon & Lekesiz, 2021). This structure involves students and lecturers working together, sharing ideas, testing solutions and showcasing results. It also creates an interactive culture of knowledge sharing and a learning-by-doing approach where students learn through reflection. This culture differs and changes according to the actors and methodology.

Although studios mostly stick to traditional methods, changing conditions requires adding new tools and methods. To adapt to the innovations of architectural education, it is important to plan the architectural design studio as a dynamic and flexible, multi-layered experience space organised from different perspectives, allowing alternative opportunities and being open to innovations (Özorhon & Sarman, 2023). For this planning, it is necessary to follow, recognise, collaborate with and create opportunities for collaboration with new technologies and tools. Today, this expansion can be associated with artificial intelligence technologies. The proliferation and accessibility of artificial intelligence technologies necessitate a reconsideration of architectural design studio pedagogy.

Artificial intelligence (AI) tools have become important in architectural design studios (Paananen et al., 2023). The use of AI technologies, including machine learning and deep learning, in architectural education and practice has the potential to accelerate, diversify and deepen design processes. The AI considered in this research are diffusion models that generate images using deep learning, and these models utilise Natural Language Processing (NLP) to generate images from user-supplied text (Çiçek et al., 2023; Leach, 2022). These algorithms are trained on various image data and parameters and generate visual representations based on text descriptions (Vilgia Putri Beyan et al., 2023).

Although the impact of AI goes beyond image generation in the field of architecture, the quality of images produced by diffusion models can provide clues to the future potential of AI (Walsh, 2023). On the other hand, there is a need to increase the number of experiments on

how innovative design tools can be used in education, especially how they can be integrated into studio education.

Text-to-image AI tools can be considered a promising technology in architectural design studios. Integrating these tools into the architectural design process has created the need for educators to question and renew the existing curriculum. AI in the studio, one of the fundamental elements of architectural education, has become a tool used in different design stages, such as research, analysis, performance-based decision-making, representation and façade design. Integrating AI into the architectural design studio has diversified design education in parallel with the developments in AI. On the other hand, AI tools emerging in 2022, which generate images from text with natural language support, have a high potential to be used in the early stages of design and concept generation. While the contribution of generative algorithms and computer-aided design tools to architectural design processes has been explored, text-to-image AI tools must be integrated into the process, and their potential uses must be expanded.

In the early stages of design, how AI will be incorporated into the studio, what data will be used, and how this data will be defined is crucial. The design process is a complex process with multiple factors. The view that the involvement of AI tools in the early stages of design will feed the design process has been emphasised many times in the related literature (Cicek et al., 2023; Dortheimer et al., 2023; Jaruga-Rozdolska, 2022; Paananen et al., 2023; Tong et al., 2023; Werker & Beneich, 2023). For example, providing students with various solution alternatives for problems that are ill-defined (Cicek et al., 2023), helping students think in 3D by strengthening part-whole relationships (Tong et al., 2023), helping students develop ideas (Dortheimer et al., 2023; Jaruga-Rozdolska, 2022) can be counted as positive effects.

On the other hand, it is critical to consider AI tools as a participant in the design process and to construct their interaction with the designer without stealing the designer's role (Figoli et al., 2022; Kavakoglu et al., 2022). Different approaches can be mentioned in the construction of this interaction. The fact that the design process has a structure fed by various media has created the potential for AI to be fed by the outputs produced in these media. For example, some studies (Dortheimer et al., 2023; Doumpioti & Huang, 2023; Jaruga-Rozdolska, 2022; Paananen et al., 2023; Werker & Beneich, 2023) try to ensure the transformation of the imagined space in architectural education from instant writing to visualisation with generative artificial intelligence tools. Various studies involve different media in the design process. Sketches (Kavakoglu et al., 2022; Tong et al., 2023), various literary activities (Dortheimer et al., 2023; Yıldırım, 2022) and model photographs (Çelik et al., 2023) collaborate and feed on the data obtained from these media, and the artificial intelligence tool becomes a partner in the process thanks to the prompt created.

As a result, the following conclusions can be drawn from the research that presents different ways of integrating text-to-image AI tools into the architectural design studio process: (1) The integration of AI in the early stages of design, when design is more uncertain and requires creative solutions, supports the process. (2) Designing AI and student interaction increases the quality of productions. (3) While students' production processes with AI are fed through various media, it is important to maintain the student's effectiveness in the process.

A method-proposal for develop creativity with AI in architectural design studio: AI-assisted architectural design studio (AI-a-ADS)

The design process is a rational and creative activity that requires both technical knowledge and design education that encompasses the development of creative thinking in the field of design (Paker Kahvecioğlu, 2007; Öztürk & Türkkan, 2006). On the other hand, creativity in architecture is not only about producing a new and valuable end product but also about applying one's creative skills throughout the creative design process (Paananen et al., 2023). This paper focuses on the potential of AI to support the creative potential of the design process.

The AI-Assisted Architectural Design Studio (AI-a-ADS) is a workshop model that involves the participation of AI as a creative agent in the architectural design process through a workshop. On the other hand, the participation of any tool (in this case, AI) in the architectural design process requires the architectural design process to be shaped accordingly. For this reason, the architectural design studio process in AI-a-ADS is based on organising the process in a way that includes AI.

In AI-a-ADS, the AI workshop is addressed to the early stages of the architectural design process. As emphasised above, integrating AI in the early design stages, where the design is more uncertain, can support the process with creative solutions. The early stage of the design process includes the identification of the design problem, design thinking, verbal communication, data collection and literature review, and sketching. Visual representation in design is seen here as a transformation/transition of conceptual visual information, which allows the designer to immediately check, introduce or evaluate certain aspects of the design in progress. The visual aspects of the design are explored and reflected through sketches. Furthermore, visual representations such as sketches are seen as a graphical problem-solving method where the conceptual ideas of the design are embodied in visual form (Babangida Idi & Khaidzir, 2015).

Design is transforming the image in the mind into a final product (Yıldırım & Kavut, 2024). In parallel, AI-a-ADS aims to produce abstract images with the AI workshop. Because architecture is a field that communicates through images (Paananen et al., 2023). Image-making is particularly important in the early stages of architectural design. Moreover, design is a continuous process of interpretation (Goldschmidt, 1988). Abstract images, due to their nature that allows for multiple interpretations, can notably support designers in developing ideas during the early stages (Fig. 2).

AI-a-ADS is constructed in 3 consecutive phases:

- In preparation (AI is a pre-active agent): Early-stage activities developed specifically for the design studio are carried out in this phase. Students express their initial ideas about the site and the subject through different modes of representation.
- In production (AI is an active agent): AI is involved in the studio through a workshop in this phase. In the AI workshop, the early products of ADS (sketches, models, writings, etc.) are used to create a new and creative image. The AI workshop is realised in three interconnected steps.
- Data Preparing: In the first stage of the workshop, various studio products (sketches, models, scripts, etc.), which are determined depending on the AI-a-ADS implementation, are rethought by the students through text and various concepts and keywords are obtained. The student evaluates and eliminates these words, and the keywords that best fit the design ideas are determined. At this stage, students are encouraged by the studio

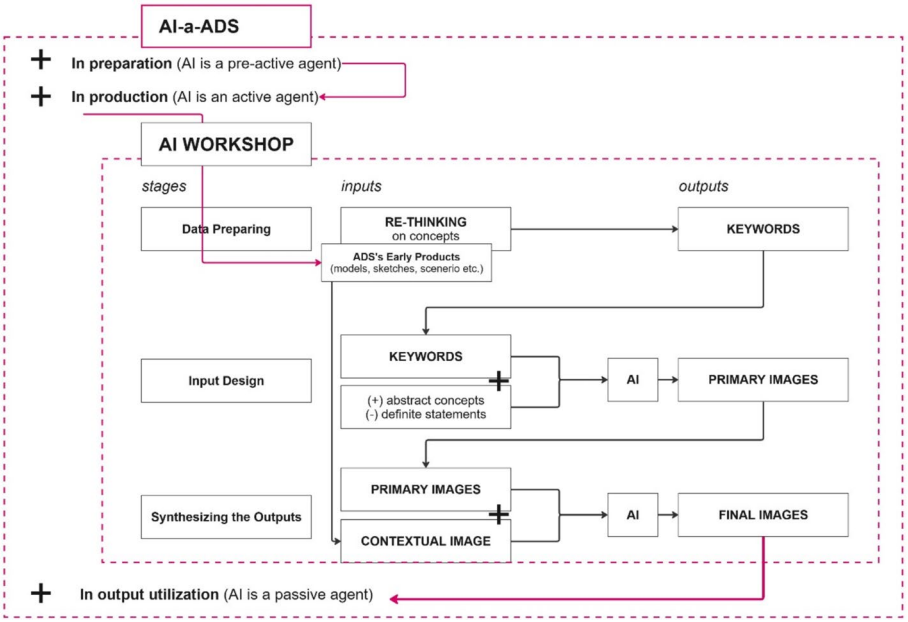


Fig. 2 AI-a-ADS method

instructors to think through concepts and express their thoughts with concepts. Thinking through concepts offers substantial potential in the idea development phase of architectural design. Moreover, since AI-a-ADS is developed using AI tools that generate images from text, it is important to determine the concepts/words correctly.

- Input Design: In the second phase, the keywords determined in the previous phase are combined with common expressions determined following the studio purpose, prompt alternatives are constructed, and visuals are produced using the text-to-image generator AI tool with these prompts. In determining the common prompt, using definite statements like building materials, architectural functions, or some words that may lead to generic conclusions and contain high bias, such as specific architect names, architectural styles, etc., are avoided. Statements supporting the production of abstract images (such as abstract concepts, vague expressions, etc.) are selected.
- Synthesising the Outputs: In the final phase, these images are processed by associating them with a contextual product obtained during the design process. In this process, image-to-image generator AI generates the final images. The contextual product is an abstract output produced by the student in the ADS and associated with the site.
- In output utilisation (AI is a passive agent): In this stage, the outputs obtained in the previous stage are incorporated into the process as an additional component to stimulate students' creativity.

Case study

In this part of the article, an application of AI-a-ADS is presented. In this context, the architectural design studio in which the workshop is engaged, and the AI-a-ADS application are explained in detail.

The architectural design studio (ADS) in this case study

This case was carried out in the studio course attended by the 2nd semester (MIM 102A) and 3rd semester (MIM 201A) students of the Department of Architecture, XXX University, in the fall semester of 2023–2024. The topics were determined as "student living centre" for 201 and "lodging and guest house" for 102, which was in line with the course plan and objectives of the architecture department. A design process consisting of 5 modules (Fig. 3) was also designed.

- *Research:* The first module of AI-a-ADS, the research module, involves students getting acquainted with the subject and the place, understanding it, and finally transforming this knowledge into a production. In this module, students researched and read about the topic and site from the literature, participated in a field trip, and tried to understand the site. The physical, historical, social, and cultural data and personal experiences were combined in a 'superposed analysis.' This process introduced an understanding of the site and the subject matter and formed the basis for the subsequent design modules (Fig. 4).
- *Programming:* This module includes elaborating the architectural program by putting the user at the centre and understanding the spaces in the program, the areas, and the actions in these spaces. In this module, the students are expected to customise their architectural programs by considering the knowledge of the site and user behaviours. In this phase, which is a continuation of the research phase, which is the beginning of the design process, the students started to think about the permanent and temporary users of the space, their actions, and needs, together with the data they obtained about the site and the subject and put forward their project concepts. Each student created their original *scenario text* and simultaneously narrated their scenarios with *sketch perspectives* (consisting of 9 sequences) (Fig. 5). In addition, during the scenario development process, students analysed the project area and its surroundings with sectional models, discussing and making spatial potentials visible, solid-void relationships, spatial organisation, connections, and movement. The outputs of this phase have a multifaceted and comprehensive structure consisting of text, perspective sketches, and physical models. These products enabled the students to express their ideas spatially and were also evaluated as data for artificial intelligence integration.
- *Image:* This intermediate module, in which AI participated in the process, is planned to be a connector between the first two modules of the design process and the later modules where the project becomes concrete. In this module, students tried visualising the spaces they imagined based on their research and studies in the first two modules by constructing a heterogeneous dialogue with an artificial intelligence workshop. The early design products (text, sketch, and section model) produced by the students in the previous module were used as the inputs of this workshop, and the visuals they obtained

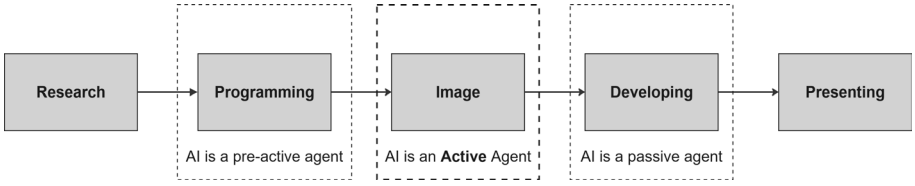


Fig. 3 Modules of the studio

Fig. 4 Conceptual collage work (on the left) and land readings (on the right)

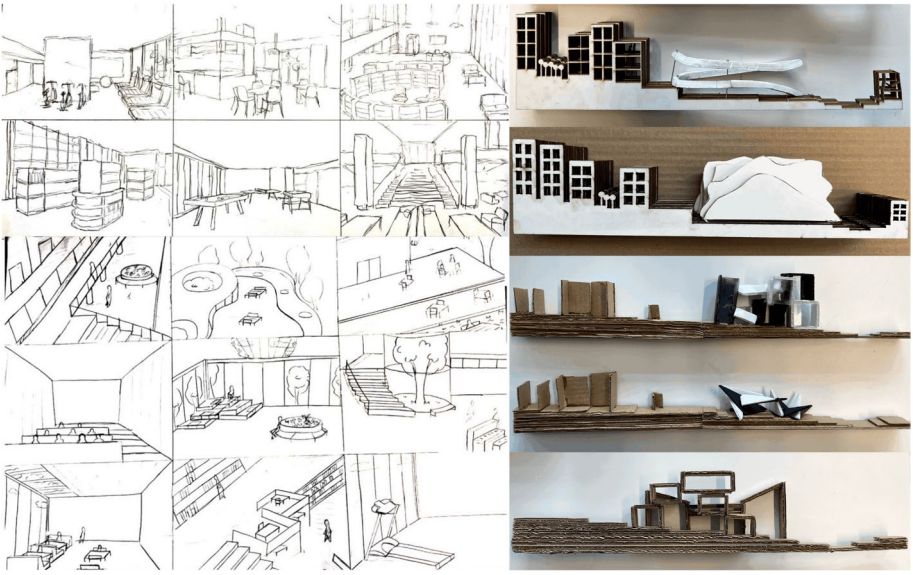


Fig. 5 9-Frame sketches (on the left) and section models (on the right)

as a result of the workshop were intended to form the basis for the developing module where their architectural projects were concretised. It is intended that the abstract productions obtained in this module will support students' creative processes and allow them to develop their ideas more freely without restricting them. The workshop details are presented in more detail in the rest of the study.

- *Developing:* The developing module involves students developing their designs through the visuals they produced in the previous module and maturing them using architectural representation tools. Different alternative usage possibilities were developed in this module, and these designs were matured with multiple representations. In this phase,

students developed preliminary layout proposals and on-site models and sketched site plans aligned with the architectural programs, concepts, and scenarios they developed in the second module. The process started with hand-made models and drawings and continued with two and three-dimensional computer-aided tools as the designs matured. It was planned to produce sections, plans, and three-dimensional models simultaneously, and it was requested to bring all these productions together in the studio environment. This stage is the most intensive module of the studio, where the architectural projects mature, and the space organisation is solved.

- *Presenting:* The main aim of the module is to mature the projects in the expected representational quality and to develop a quality presentation in a designed manner. Within the scope of this module, which is the last phase of the design process, a seminar on representation was given to the students, and the importance and power of representation in explaining the project/idea was emphasised through examples. Students were asked to research how to express their projects and design process well in two- and three-dimensional expressions and prepare their final presentations using various tools. They were also asked to think about different methods and materials for the physical and section models and make productions specific to their projects. This module is also designed to combine the students' productions throughout the studio design process, visually express the research and project development process, and think and work on presenting their projects with a stronger expression.

AI workshop

The AI-a-ADS methodology proposes a framework adaptable to different times and uses. Therefore, the method must be developed and elaborated in a specific way to the case. This way, it can evolve and become practical according to the architectural design studio's content, purpose, and structure. In this case, AI-a-ADS has been shaped by integrating the AI workshop into the imaging phase of the architectural design process. The workshop aims to assist students in visualising the spaces they imagine and to generate alternative images that would stimulate creative ideas (Table 1).

The workshop was planned in two phases. The first phase consisted of a seminar introducing students to AI tools, and the second phase consisted of an application. Although many different AI tools can generate images from text, Midjourney[1] Was chosen for this study. A seminar was held in the first stage within the workshop's scope. Within the seminar's scope, the historical background of AI, its working principles, its integration into the architecture discipline, and the programs used in this field were mentioned, and the

[1] Midjourney was developed by a team led by David Holz using Python. Midjourney generates various images using text parameters, which is similar to other tools that generate images based on text or web links, such as DALL-E, NightCafe, Wombo Dream, and Latent Majesty Diffusion (Jaruga-Rozdolska, 2022). Midjourney was created in February 2022 and was only available in beta form until the end of March (Jaruga-Rozdolska, 2022); however, like any deep learning, it evolved rapidly with user feedback and became increasingly popular. In addition, Midjourney allows the user to be more involved than other popular tools such as Adobe Firefly, Stable Diffusion, and Dall-E (Jaruga-Rozdolska, 2022). It has features such as creating alternatives for the generated image, changing image sizes, and having a user-friendly interface (Sadek & Gelil Mohamed, 2023). Moreover, as mentioned earlier in the study, Midjourney produces more abstract images for students who are working on more abstract visual outputs than other tools (Dortheimer et al., 2023).

Table 1 Previous productions generate data for AI, and final images are produced with AI

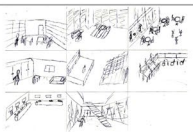
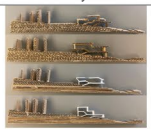
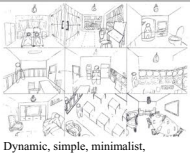
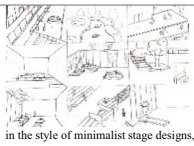
	Keywords selected from the scenario	9-frame sketches and keywords from prompts created with the "describe" command	Section models and keywords from prompts created with the "describe" command	Prompt consisting of the scenario and the texts obtained with the "describe" command and visuals resulting from the "imagine" command with the prompt (MJ1)	Final images generated using the "blend" command (MJ2)
S1	continuity, organic, flexible, character, different, permeable	 showing an entrance, simple designs, transparent/translucent medium	 paper city skyline stands, in the style of wavy resin sheets, cad (computer-aided design), poured resin, edward hopper, detailed engraving, design architecture study	 3d abstract and conceptual section model, organic, continuity, flexible, permeable	
S2	fragmentary, transparency, fluid, sharp form, dissimilarity, brutalism	 monolithic structures, post-minimalist structures, minimalist conceptualism	 depth of layers	 3d abstract and conceptual section model, dissimilarity, transparency, open concept, connectedness, sharpness, communication, fragmentation, brutalism, minimalism	
S3	complexity, dynamic, action, soft lines	 dynamic action sequences, dynamic angles, outdoor scenes, simple designs	 Courtyard, contrasting balance, style of reef wave	 3d abstract and conceptual section model, Courtyard, continuity, complexity, dynamic action sequences, translucent overlapping, soft lines	
S4	crossroads, transparency, permeability, art, creativity, outdoor, sharing, interaction, interbedded	 minimalism, setting atmosphere, movement, art, focus, multiple perspectives	 futurism, assembled, light, abstraction, forms, deep distance	 3d abstract and conceptual section model, includes crossroads, transparency, permeability, art, creativity, sharing, interaction, interbedded	
S5	flexible, transparent, social, common	 Dynamic, simple, minimalist, atmospheric	 detailed, multilayered, soft, kinetic, airy	 3d abstract and conceptual section model, flexible, transparent, social, common	
S6	continuity, permeability, connections	 in the style of minimalist stage designs, focus on joints/connections, gathering	 passage, connections, immersive environments	 3d abstract and conceptual section model, permeability, continuity, centrality, gathering, passage, connections, immersive environments	

Table 1 (continued)

	Keywords selected from the scenario	9-frame sketches and keywords from prompts created with the "describe" command	Section models and keywords from prompts created with the "describe" command	Prompt consisting of the scenario and the texts obtained with the "describe" command and visuals resulting from the "imagine" command with the prompt (MJ1)	Final images generated using the "blend" command (MJ2)
S7	opposition, flexibility, movement, spontaneity, difference, circulation, crowd, communication, interaction	 movement, spontaneity, decisive, moment, soft lines	 explosive, lively action poses, dynamic	 3d abstract and conceptual section model, movement, lively action poses, dynamic, opposition, flexibility, difference, interaction	
S8	interaction, open space, connection, green space, nested, transparency, privacy, communication, links	 flexibility, convenient	 modernity, dynamic	 3d abstract and conceptual section model, interaction, open space, green space, connection, dynamic, links	

MJ interface was introduced to the students. They were encouraged to experiment, and the application to be made in the next stage was explained.

The AI workshop was organised in 3 stages (Fig. 6) depending on AI-a-ADS as follows:

- *Data Preparation* involves students transforming their productions into prompts[2] they can use in Midjourney. In this stage, students used three types of materials (9-frame sketches, section models, and scenarios) that they had produced in the first two modules of the architectural design studio. This use involved rethinking the previous productions and utilising the "describe" command in Midjourney (Fig. 7). Among the three materials, it was possible to use some of the concepts in the scenario production developed through the text directly in the prompts. On the other hand, to use visual productions such as 9-frame and section model for prompts, the "describe" command in Midjourney was used to describe what the visuals were, and a prompt pool was created by selecting some texts that were thought to be efficient (concepts that could support spatial production and did not directly refer to the space) to be used in the next stage.
- *Input Design* is the stage where students produce the second of the two images required for the "blend" command they will use in the next stage (the first image is a photograph of the section models they have already produced.) The expression "3d abstract and conceptual section model" was used in common to have a certain commonality in the students' productions and to support the spatial production with the section model. The rest of the prompt to be created using the "imagine" command is composed of words chosen by the students and the workshop and studio coordinators from the prompt pool created in the first phase. As a result, four alternative images (versions) were produced in this phase.

[2] The descriptive text format inputs of AI tools that generate text from images are called prompts.

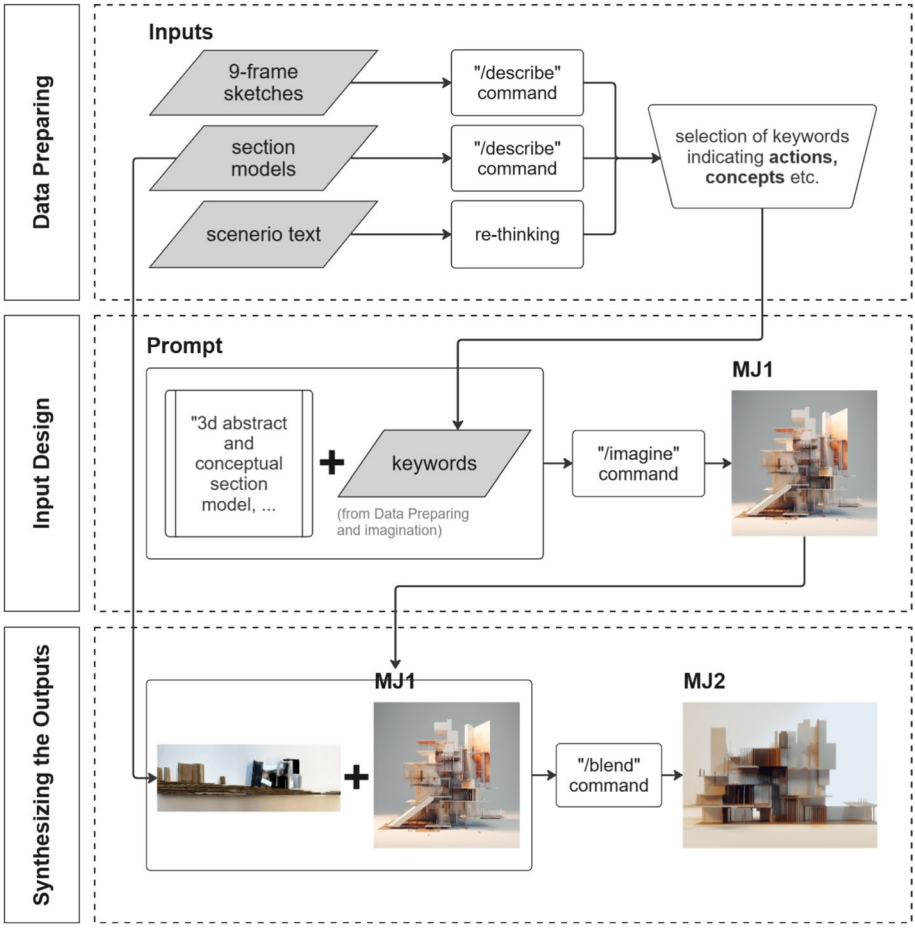


Fig. 6 AI workshop method

- In *Synthesizing the Outputs*, the students chose one of these images (*the one they found closest to their design ideas and the atmosphere they imagined*) (MJ1) and combined MJ1 and the photo of the section models, this time with the "blend" command. Midjourney again created four alternative images in this final stage, and students chose one as the final image (MJ2).

After the workshop, the studio's architectural design process continued with the design idea's development and transformation into an architectural product. In this process, students were frequently reminded of their workshop productions, and they were encouraged to integrate the visuals obtained in the workshop into the design during the project development process, both in workshop critiques and juries, but this was not

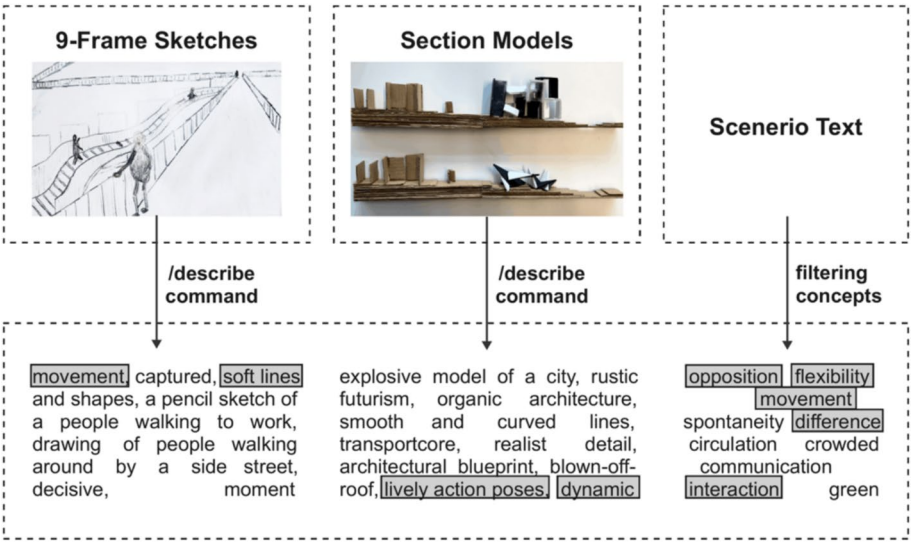


Fig. 7 Converting workshop productions into textual data for prompt writing and selecting concepts for the prompt pool

described as an obligation, and students were expected to use individual initiative at this point.

Evaluation

Evaluating the workshop process and discussing the results of this evaluation is important to test the methodology applied in the workshop and to see its potential. Accordingly, an evaluation was conducted that included the views of both the students and the facilitators. A questionnaire was conducted to get the students' comments, and they were expected to produce diagrams, and the opinions of the facilitators were added to these. This chapter systematically presents the data and findings collected and the evaluations of the students and the facilitators.

Survey

The questionnaire (Fig. 8) was designed with five sections and 23 questions. Part 1 of the questionnaire consisted of 3 questions (Q 1–3) general questions; Part 2 consisted of 4 questions (Q 4–7) about the inputs (9-frame, section model and scenario) that participated in the practice realised in the workshop and the contribution of these inputs to the workshop production; Part 3 consisted of 2 questions (Q 8–9) about the evaluation of the seminar; Part 4 consisted of 3 questions (Q 10–12) about the use of the Midjourney tool. Part 5 (Q 13–22) questions integrating workshop production into the architectural design studio process. Among the 22 questions asked in the questionnaire, five were open-ended,

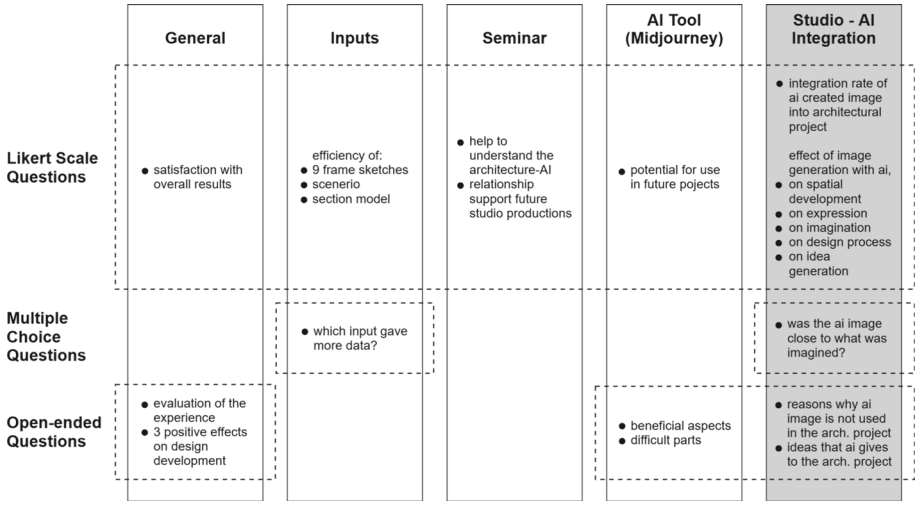


Fig. 8 Structure of the student survey

four were multiple-choice, and 13 were rating questions (a Likert scale[3] Ranging from 1 to 5 was used). The rating questions and response averages can be seen in Table 2.

- *General Evaluation.* The open-ended questions asked the participants to evaluate their overall experience with the workshop and the Midjourney tool and its contribution to their projects. According to the results, while the participants found the participation of innovative design tools in the process positive, they stated that these tools contributed to the process in areas such as giving new ideas for the design process, externalisation their ideas, and exploring the possibilities of spatialisation of abstract concepts. For example, one participant shared his views on the potential of the tool by saying, "*We used it (Midjourney) as an assistive tool to prepare certain section design proposals in artificial intelligence and outline the project…*" about the roles of artificial intelligence and designers, and *"…I think it was useful in terms of some idea development*" about the use of MJ.
- *Evaluation of inputs.* The participants found the effect of scenario writing on the following stages of the project (3.6/5) to be the highest among the design mediums they produced before MJ production. This was followed by 9-frame sketches (3.1/5) and section-model (3/5). When the participants were asked to compare how these mediums provide data for creating prompts in the Midjourney, scenario ranked first (50%), section-model ranked second (40%), and 9-frame sketches ranked last (10%).
- *Evaluation of the seminar.* The participants found it positive that they were informed about the relationship between AI and architecture (4/5), while they were undecided about its contribution to the ongoing production of the workshop (3.4/5).

[3] According to Pimentel, the five-point Likert scale is considered an interval scale. "Strongly disagree" is measured between 1 and 1.8, while "disagree" is measured between 1.81 and 2.60. While "undecided" is evaluated between 2.61 and 3.40, "agree" is between 3.41 and 4.20, and "strongly agree" is between 4.21 and 5 (Pimentel, 2010).

Table 2 Likert scale questions and response averages

Section	Question	Mean
General	I was satisfied with the results of the Artificial Intelligence Workshop; I got the results I wanted	3,6/5
Inputs	The 9-frame sketch practice was useful for me in improving my project	3,1/5
	The scenario writing practice was useful for me to develop my project	3,6/5
	Producing a section model was useful for me to develop my project	3/5
Seminar	The seminar helped me to learn about the relationship between artificial intelligence and architecture and to think critically about this relationship	4/5
	The seminar helped me in my production during the workshop	3,4/5
About the tool	I plan to use Midjourney in my different design processes in the future	3,9/5
About the integration of the tool into the design	I integrated the image I produced with Midjourney into my project	2,6/5
	Producing images with Midjourney helped me develop my project spatially	3,4/5
	Creating images with Midjourney helped me express my ideas about my project	3,3/5
	Creating images with Midjourney did not limit my imagination	4,2/5
	Producing images with Midjourney helped me to generate ideas for my project	3,6/5
	Creating images with Midjourney made my design process more efficient	3,4/5

Ten students (7W, 3 M) who attended the studio course throughout the semester and completed the final submission participated in the survey

- *Use of the Midjourney tool.* Some participants stated that the visuals they obtained in the MJ tool were not as they imagined. Six participants (6/10) stated that the visuals produced at the end of the first stage (MJ1) were not as they thought because they could not choose the concepts they wanted while writing the prompt. For example, one participant stated, "It was a bit difficult to choose keywords properly and understandably." In contrast, another participant said, "I had difficulty choosing words just when I was expressing the thought in my head." On the other hand, some users stated that using MJ nourished the process: "(Midjourney) expanded my imagination, made me think of different things". Three participants also stated that they benefited from Midjourney in externalising their thoughts. Overall, the participants indicated they would consider using the tool in future studio processes (3.9/5).
- *Integration of workshop production into the studio process.* The participants were asked to evaluate the advantages of using MJ for project development. It was observed that the results of the evaluations of its contribution to the spatial development of their projects and giving ideas about creating atmosphere (3.4/5), helping to generate ideas in their projects and giving ideas formally (3.4/5), and helping them to express their ideas in their projects (3.3/5) were very close to each other. The average value of 3.4/5 in the question evaluating whether the participants made their design processes more efficient in general is confirmed by the fact that it reaches the same result as the general averages in the previous evaluations. In addition, when the participants were asked to evaluate whether the last visual produced with MJ (MJ2) restricted their dreams, it was observed that the evaluations that did not restrict the participants reached the highest average (4.2/5) among the Likert scale questions.

In the last two questions in this section, the participants were asked to evaluate MJ1 and MJ2 productions internally. Accordingly, 70% of the MJ1 productions were found to be different from what they imagined, and 30% were found to be close to what they imagined. Regarding the MJ2 productions, 60% of the participants answered that they were different from what they imagined, 20% were close to what they imagined, and 20% were exactly as they imagined. In addition, for both MJ1 and MJ2 productions, 70% of the participants stated that they were satisfied with the final image. According to these results, with the MJ2 method, compared to MJ1, students could make productions closer to the final visual they imagined.

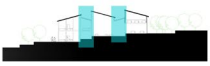
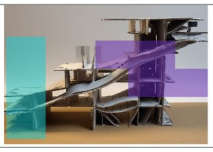
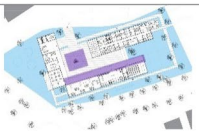
Spatial association diagram

To evaluate the workshop, students were asked to produce a diagram. In this diagram, the participants were expected to visualise and explain how the Midjourney productions were reflected in the final product of the studio by evaluating the two-dimensional representations of the workshop outputs and the final projects together.

In the production of these diagrams, it was aimed to observe the transformation of some spatial abstract ideas presented by the Midjourney prompts and visuals (MJ1), which were developed based on the concepts developed by the participants in the first stages of the studio, such as section-model, 9-frame, and scenario writing, and the visuals produced by combining them with the section-model visual (MJ2), into architectural space with the designer's interpretation. Table 3 shows the students' spatial associations and explanations.

When the students' spatial associations and explanations were analysed, it was observed that MJ2 productions gave students ideas about the relationship with

Table 3 Spatial associations diagrams and student explanations

	Workshop output	Section of the final project	Plan of the final project	Description
S1				*"The effect on the building's outer shell in section; the creation of a large gallery space on the ground floor in the plan plane."*
S2				*"The use of the slope of the land and different elevation relationships in the cross-section; the reflection of the multiple relations of spaces in the plan plane as unrestricted spaces."*
S3				*"Creating spaces in the intermediate spaces connecting the masses in section; creating a central common interaction area in the plan."*
S4				*"Creating different heights in section, creating a central space in the plan plane."*
S5				*"Similar overlapping voids in section; the relationship of voids in the design of rooms and corridors in the plan plane."*
S6				*"Combining spaces by establishing different elevation relationships in section; proposing spaces of different sizes in the plan plane."*
S7				*"The relationship between different levels in cross-section, circulation areas, using open, closed, semi-open forms of these areas; the articulation, dissimilarity, and connection of spaces on the plan plane."*
S8				*"Effective use of the elevation difference in the cross-section, connecting it with ramps; circulation line in the plan plane and its enabling interaction areas."*

topography, the shell of the building, the relationships between spaces, and the size of spaces. For example, S2 used MJ2 productions in the relationship with topography; S1 in the formation of the building shell; S2, S4, S5, S6, S7, S8 in the relationship between spaces; S1, S3, S4, S6 in the design of space sizes.

Observations and discussion

The implementation in the workshop is integrated with the studio process and interacts with both the early design and forward design phases. For this reason, this section is discussed in three stages: (1) before the workshop, (2) during the workshop, and (3) after the workshop concerning the process, and the views of students and instructors are discussed together.

In preparation (AI is a pre-active agent): In this stage, the workshop's setup is created in line with the workshop's aims, and the production in the studio's early stages is made. The productions in this process were interpreted and used as MJ input by the students, especially the scenarios written by the students before the workshop, which played a significant role in forming MJ data. In addition, the students stated that they found the MJ2 productions, in which the effectiveness of the early-stage productions was higher, closer to their imaginations than MJ1. Among the components produced in the pre-workshop phase, the most effective MJ input was the scenario. Although the section model is second in terms of prompt writing, it is a direct input when using the "blend" command for MJ2 production, and therefore its effectiveness is high. The 9-frame sketch productions provided less data for the following stages and prompt writing than the other components.

In production (AI is an active agent): In this stage, students were introduced to the tool and had their first experience. This process is important to reveal the potential and problems of both the tool and the implementation in the workshop. In open-ended questions, students stated that encountering a new tool increased their motivation in the studio process and that the AI tool attracted their interest.

The students also experienced a new interface called Discord, produced on the shared Midjourney server, which encouraged the exchange of ideas and learning together. The AI tool can be used not only as a tool that gives ideas to the student during the design process but also to trigger the studio instructor to generate new ideas for the student's project. Studio coordinators must create an environment where students can express their characteristics and perspectives (Ozorhon, 2016). This can expand the solution space in the design process.

Considering that one of the contributions of Midjourney to the design process is to expand the designer's solution space, it may be advisable to produce more images in this case. For example, in the study, participants made two trials on average in producing MJ1 and MJ2. However, increasing the number of trials may be necessary to trigger new ideas. In addition, using the right prompt to produce the desired visuals is very important. For this, it is necessary to master the interface used and to learn how to write the prompt. Text-to-image AI models are easy-to-use tools thanks to the ability to respond to natural language commands. However, the creativity of text-to-image generation still depends on its users' skills. In AI-a-ADS, commands are associated with concepts discovered in the architectural design process. Concepts guide the creation of prompts. On the other hand, to control the output, users have to refer to unique keywords in the prompts to produce images of a particular style or quality (Oppenlaender, 2023).

In the study, participants stated they had difficulty producing the images they imagined. In future studies, it may be advisable to increase the duration of the seminar given to the participants on how to write prompts and to conduct research beforehand. It is advisable to allow students to explore the tool themselves to understand how it works. This learning can be supported with studies that do not necessarily have to be related to the project topic and allow users to access the visuals they imagine.

In output utilisation (AI is a passive agent): The workshop output was included as an assistive component for students to improve their designs. Students were encouraged during the critiques, but there was no obligation to integrate the output. According to the questionnaire results, students responded that they were undecided about integrating AI products into their projects (2.6/5). However, according to the data obtained from the diagrams they produced, all students got ideas from the visuals they produced. They could reflect their influences physically and conceptually in their spaces. This contradictory situation may be related to the retrospective collection of the data. There may also be cases where the student was intuitively inspired. In this respect, it is important that AI productions are a source of inspiration for the student and that the student uses them as a source of intuition rather than a source of direct information.

The purpose of using section model visuals as a data source in MJ2 productions is to utilise contextual data and to observe spatial relationships more clearly. However, according to the data obtained from the spatial association diagrams, it is understood that only one of the ten students benefited from the MJ2 production in their relationship with topography. However, six out of ten students stated that the MJ2 productions gave an idea about spatial relations. It may be possible to strengthen the site-specific data by including a broader context in the section model. In addition, feeding the MJ2 production with more section-model visuals may mean that more data about the land can be included in the process.

Conclusion

Students use tools for a variety of tasks during their studio experience. Tools and their use play a vital role in the architectural design studio. Students use tools for various tasks during their studio experience. Some tools support creative design, some support creative design communication, while another group supports teaching and learning in design studios (Hettithanthri & Hansen, 2022). So, how does AI as a tool assist the studio? This research aimed to develop a methodology for integrating AI into the ADS and to examine the contribution of this integration to the development of design by enriching the production environment.

For this purpose, a method called AI-a-ADS has been developed. This method involves the participation of AI as a creative agent in the architectural design studio through a workshop. In this method, in AI-a-ADS, AI is involved in the architectural design process at the early stage of design by producing abstract images. AI is the element that helps students transfer the data they produce in the research, comprehension, and idea development stages to the design in the project development stage.

In the article, the method is tested with a case study. Thus, the potential and problems of the instrumentalised involvement of AI in the architectural design studio are evaluated. The findings showed that organising the workshop time so that more experimentation can support the process. This can increase AI's effectiveness in the design process and enable students to develop alternative images. In addition, this process allows students to both develop their creativity and explore different perspectives by cooperating in a team.

The findings showed that for the effective participation of AI in the architectural design process, it is important to enable students to get to know and experiment with the AI tool before the application. In addition, it is necessary to question the potential of the data that will be input to AI to establish a dialogue with AI. In this context,

according to the data obtained from the survey results, it is recommended that students' prompt writing skills should be improved, and more comprehensive guidance should be provided in advance. Students' prior experience with the tool may help them achieve more creative and effective project results.

On the other hand, AI applications continue to develop rapidly and are enriched with new tools and possibilities every day. From this perspective, it can be said that AI may occupy an important place in our lives in the future. Therefore, it is important to reflect on the possible roles of AI for the world of the future in general and for design studios in particular, as well as to improve our knowledge and experience regarding alternative strategies. In conclusion, this study emphasises the importance of the evolution of architectural design education in parallel with technological developments. It presents an experiment on the restructuring of studio processes with technological tools. The research on integrating AI into architectural design studios shows that technological tools can play an important role in transforming educational methods and content.

The contribution of this study to the literature is that it presents the use of image-generator AI tools to produce abstract images (not directly referring to space production) that combine preliminary design/concept studies in the studio process, focusing on supporting idea generation and creativity by avoiding a method that will directly guide students. When the existing studies in the literature on the use of image-generator AI tools in architectural design are analysed, it can be said that the production of concrete images that give direct clues about space and structure is adopted as a common approach (Enjellina et al., 2023; Paananen et al., 2023). The research results indicate that the effective use of AI tools in design studios enhances success, particularly in direct proportion to the diversity of data generated by students during the research and concept development stages. This highlights the need for future workshops to improve students' ability to expand their design inputs and guide AI tools based on these inputs.

Thinking through concepts during the idea development phase of architectural design offers strong potential, as concepts are the tools for constructing the world. AI-a-ADS lies at the intersection of design thinking and artificial intelligence, as it proposes using text-to-image AI tools. In this context, concepts guide the generation of images through prompts. According to the data obtained from survey results, students could visualise their conceptual thoughts and advance their creative processes more concretely, thanks to this guidance.

With this research, not only was an innovative product produced, but information about the construction and evaluation of this product was also generated. The article and the workshop (with its potential, limitations, and aspects that can be improved) are presented as a reference source for future studies. Moreover, AI-a-ADS provides a framework that can be adapted not only for architectural design studios but also for all design studios. Thus, the method can be applied in different studios in the future. Alternatively, it can evolve with the participation of different AI tools and the diversification of designer inputs.

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Declarations

Conflict of interest The authors declare that they have no financial or non-financial conflicts of interest to disclose. No external funding was received to prepare this manuscript. All authors confirm their adherence to ethical standards in the development of this work, ensuring that no external interests have compromised their integrity.

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