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# THE INTEGRATION OF ONLINE AI TOOLS INTO THE PRODUCTION PROCESSES IN ARCHITECTURAL EDUCATION: AN EMPIRICAL INVESTIGATION

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**Abstract.** Advancements in artificial intelligence (AI) technology have led to its widespread use across various domains, driven by its processing speed, creative potential and ability to generate infinite variations. Incorporating AI into design and architecture education is crucial. It will enable future generations to produce in harmony with this fast-evolving technology. This research focuses on a one-semester experimental studio study that explores the integration of online artificial intelligence tools (AITs) into production processes within architectural education and its implications. The study aims to investigate the contribution of these tools to different stages of architectural production processes (APP). To achieve this, multiple research methods, including observation, questionnaires and surveys, were employed. The findings indicate that AITs hold substantial potential to enhance traditional architectural design processes. AI applications inspire the designer by generating new design scenarios. This marks the beginning of a new stage in architectural production. Observations and questionnaire results revealed that user-controlled online AITs are not merely plagiarism devices. Instead, they serve as creative instruments that allow students to express themselves and experiment with innovative design approaches. This pioneering study provides valuable insights into the implementation of AITs in architectural education. It underscores the importance of adapting this rapidly evolving technology to the production processes of architectural design. By doing so, educators and students can utilize AI as a source of creativity, innovation and a means of expression in the APP.

***Keywords:*** *Artificial Intelligence, AI tools, architectural design education, architectural production processes, new design approaches.*

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## 1. Introduction

Artificial intelligence (AI) technologies have advanced significantly in recent years, enabling faster production and offering alternative solutions. These innovations have made AI widely applicable, including in the design discipline. In architectural design, AI is used in processes such as idea generation, design stages, visualization and evaluation (Ploennigs & Berger, 2023; Liao *et al*., 2020). The advancement of AI, including machine learning, deep learning, generative networks and computer-aided design, has led to innovations in architectural production and evaluation processes (Almaz *et al*., 2024; Horvath & Pouliou, 2024; Bernstein, 2022).

Recent studies investigate the contributions of AI to architectural production processes (APP), both conceptually and empirically. Researchers measure the limits of different AI applications and discuss how architectural design can be affected by these new tools. In many studies, the impact of AI (Midjourney, Dall-e etc.) on the design phase has been empirically examined (Shin, 2024; Ploennigs & Berger, 2022). In

addition, there are studies using machine learning algorithms with software codes and collected data (Almaz *et al*., 2024; Horvath & Pouliou, 2024; Li *et al*., 2024). Going beyond the design phases, researches are also carried out in areas such as building life cycles, project management, etc. (Yussuf & Asfour, 2024; Seyman-Güray, 2023). The literature on the use of AI in architectural education has also increased in recent years (Scopus, 2024). Research has been conducted on how students use artificial intelligence tools (AITs) in design phase with different limitations. These studies focused on production results, methods and opportunities of AI used in the design process (Stigsen *et al*., 2023; Tong *et al*., 2023).

There is limited research on how AITs can be used in architectural education to contribute to different stages of the production process. In the traditional APP, sketches, maquettes, 3D modeling and CAD tools are used. AI has the potential to bring new perspectives to traditional design methods. Strengthening the relationship between the designer and artificial intelligence is critical for architecture in the future. To reinforce this relationship, AITs need to be integrated into architectural education.

This study is based on the hypothesis that AI can be a valuable educational tool in architectural education at different stages of the production process. Through a structured experimental study, it aims to investigate the contributions of AITs to production in the stages of analysis, synthesis, design, planning and visualization within the architectural studio. Additionally, the research seeks to increase students' interactions with AI. Architectural production is a multidimensional, multilayered and multi-parameter process without absolute truths. The incorporation of AI into this duration has the potential to enrich, accelerate, or complicate it. As a pioneering investigation, this study offers new perspectives to the field. Specifically, it provides significant data and insights into the adaptation of AITs within architectural education.

**Table 1.** Architectural production stages and instruments in architecture education

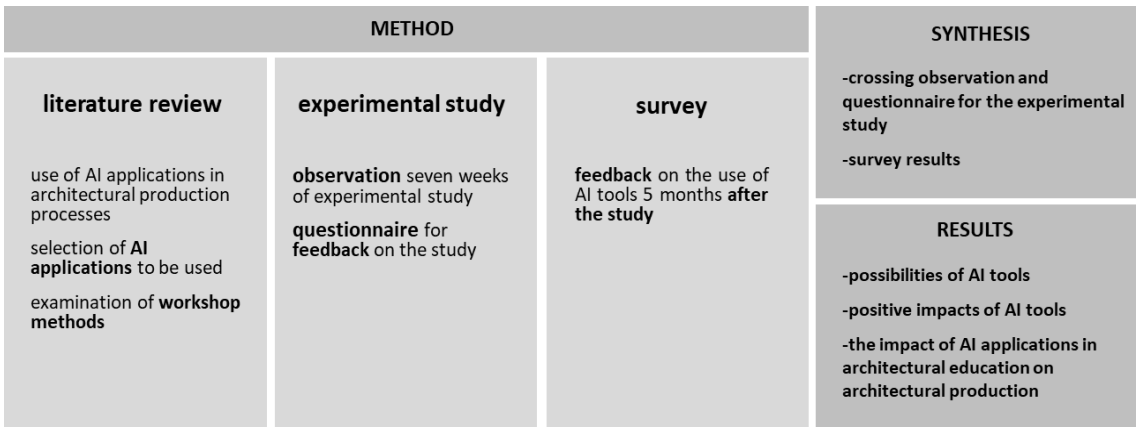
| types of activity | ANALYSIS | CONCEPTUAL | | PROJECT | | PRESENTATION |
|---|---|---|---|---|---|---|
| project stages | research | creative phase | preliminairy design | initial project | project | visualization |
| instruments | printed and online data search<br>fieldwork<br>AI Tools ? | pencil<br>modeling and display tools<br>AI Tools ? | | modeling and display tools<br>CAD tools<br>AI Tools ? | | modeling and display tools<br>CAD tools<br>AI Tools ? |

**Source:** Developed by author

## 2. Material and Methods

The research was designed as a 7-week experimental study to explore the potential contributions and threats posed by AI to the APP in architectural education. Data were collected on the outputs produced by students using AITs at various stages of architectural design. Additionally, information regarding the students' production processes was gathered. The findings are presented as a systematic evaluation of advancements in integrating this emerging tool into architectural education.

**Table 2.** Research methodology flowchart




**Source:** Developed by author

The study consists of 3 stages: literature review, experimental study and survey for collecting feedback responses (Table 2). The scope, limitations, data collection and analysis methods were defined through the literature review. Various methods, including observation, questionnaires and surveys, were employed to gather data. Both quantitative and qualitative analysis techniques were used in tandem. Initially, online AI tools were examined and those suitable for the study's limitations were selected. In this research, online AITs that provide free tokens (ChatGPT, Leonardo AI, Maket AI, Dreamstudio, Veras AI) were used. This restriction aims to reveal what students can do with these tools that they can access for free.

The student sample to be selected within the scope of the study should have experienced traditional APP. For this reason, final-year students were chosen as the sample group. The online AI applications were integrated into the first 7 weeks of the 7th-semester elective course, Computational Design Studio, in the Department of Architecture at Beykoz University. A total of 10 students enrolled in the course during the fall semester of 2023-24.

In this experimental study, students were introduced to the relevant online application and its features at the start of each 4-hour class for five weeks. The exploration of the program's capabilities and tools was left to the creative use of the students throughout the lesson. During this period, the students' work was observed. Students used the online AITs both to improve their design projects in the current semester and in their portfolios. They were also allowed to interact and help each other during the production process. In the studio, different AITs were used in the analysis, design, planning and visualization phases respectively. Student works, which are visual data, were saved in a common Google Drive folder every week. In the results section, the relevant data were evaluated with qualitative methods.

In the 7th week, students were given a questionnaire to evaluate the positive and negative aspects of the online AI applications they used. The written data obtained were cross-referenced with other data presented in the results and discussion section.

5 months after the course, a survey was conducted with the students. The survey aimed to collect data on students' current interactions with AITs in APP. A 5-point scale was used to collect the current AI usage data of the students at different design stages. Microsoft Excel programme was used for the statistical evaluation of the results. The

survey also included an evaluation section where students could express their thoughts on the use of AI. No special personal data of the participants were collected.

**Table 3.** Schedule of the first 7 weeks of course

| Weeks | Syllabus | Tools | Learning Outcomes |
|---|---|---|---|
| Week 1 | Introduction<br>AI applications in architectural design<br>Information about the 7-week study and syllabus | syllabus, lecturer presentation | discussions |
| Week 2 | Use of AI applications as analysis tools | chatGPT | quick and practical data collection |
| Week 3 | Use of AI applications as design and visualization tools | leonardo AI | produce designed visuals by text<br>produce designed visuals by visuals |
| Week 4 | Use of AI applications as design and visualization tools | maket AI | produce designed visuals by visuals |
| Week 5 | Use of AI applications as design and visualization tools | dreamstudio | produce designed visuals by text<br>produce designed visuals by visuals |
| Week 6 | Use of AI applications as design and visualization tools | verasAI | produce designed visuals by text<br>produce designed visuals by visuals |
| Week 7 | Evaluation of the study by the participants | questionnaire | evaluation |

**Source:** Developed by author

## 3. Results

Throughout the research period, it was closely observed how students interacted with the AI, at what phases they used the applications, how they explored the new tools and what results they gathered from the AITs. This chapter presents the findings from the course observations, questionnaires and surveys.

### *3.1. Analysis Phase*

It is the research stage carried out to comprehend the context and collect data related to the field. Printed and online sources and fieldwork are used at this phase in the traditional APP. In the analysis phase, AITs were used by the students to collect data on the history of the project site, determine functional requirements, examine designs produced in different concepts, obtain data from regulations, etc.

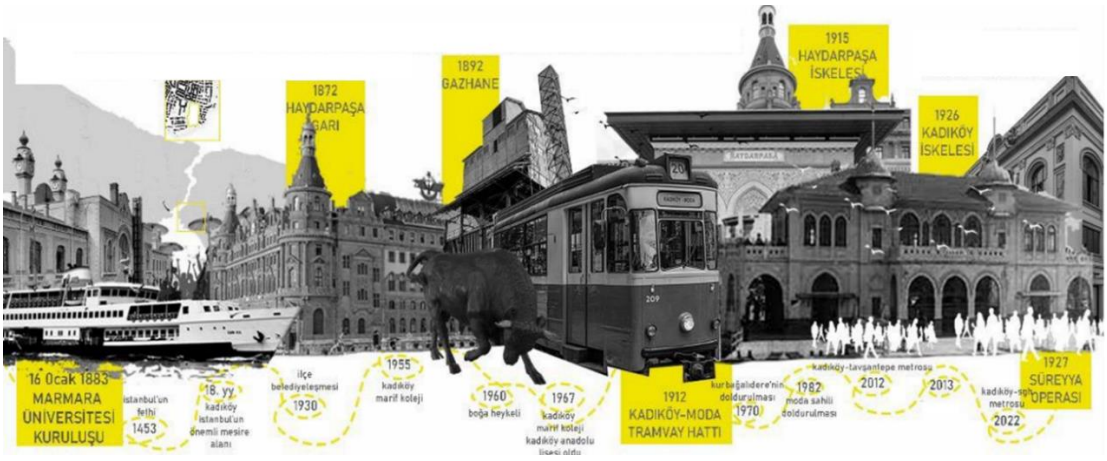



**Figure 1.** Collage Data Get from ChatGPT
**Source:** Produced by Stu Miray Topaloğlu

Figure 1 shows the timeline developed by a student for the history of the project area. The student quickly gathered the data used in preparing this timeline through ChatGPT. Students evaluated the use of ChatGPT in the analysis phase positively because they could quickly access the data they needed. In the 7th-week questionnaire, the AI was criticized for several reasons. First, the information provided was not always from reliable sources, such as blog posts or Wikipedia. Additionally, the data was not presented visually. There were also issues with the AI's understanding of questions and it often took too long to ask the right question.

### *3.2. Conceptual/Design Phase*

This stage of the architectural production process is characterized by creativity, uncertainty and originality. In the traditional APP, tools such as sketches, maquettes and models are used. In contrast, during this phase with AITs, production is carried out through different methods, including text-to-image, image-to-image.

#### *3.2.1. Image Generation by Text*

**Figure 2.** Dolmabahçe Gazometer Design Ideas
**Source:** Produced by Stu Nihal Başıeğri via Leonardo AI

**Figure 3.** The Design Ideas That The Student Receives From AITs (via Leonardo AI) and How These Ideas Are Reflected in Her Project
**Source:** Produced by Stu Birgül Demirbağ

AI applications at the design stage enable the creation of many design alternatives in seconds, using keywords determined by the students. Students entered prompts related to their design projects into online AITs, generating different design scenarios based on the context. Using AI that produce 2D visuals, design alternatives were developed based on design concept keywords. Additionally, new alternatives were generated by adjusting the level of influence of the AI prompt on the uploaded image. Lenardo AI was preferred

more frequently by the students in the design phase. Because it produces dozens of different results with the same prompt.

### *3.2.2. Image to Image Generation*

Another method of design generation with AI is image-to-image. This method was used in different ways during the design and visualization phase of the study. Students uploaded a photo of the project area to the AI application and were able to produce new design scenarios with prompts. Thus, the design scenario started to relate to the context, even through a 2D visual. By uploading the image of the preliminary design mass to the AI application, students could quickly see how different masses would impact the field. They achieved this by altering the keywords or adjusting the influence of those keywords on the image. These results, produced in just a few seconds, show how various mass effects can be realized after the main design decisions are made. Students, often so focused on their own designs, may find it challenging to envision alternative possibilities. In this context, the ability to quickly generate various design options through AI provides significant stimulus. It encourages them to shift away from a limited focus and explore new creative avenues.

In Figure 4a, various alternatives for the student project in the first image were generated by modifying the impact values of both the image and the keywords. Figure 4b presents different alternatives for the mass on the left, created by adjusting the keywords and the AI's modes.


**Figure 4a.** Different Alternatives of the Student Project
**Source:** Produced by Stu Selin Sarı via Leonardo AI

**Figure 4b.** Different Alternatives to the Mass on the Left
**Source:** Produced by Stu Birgül Demirbağ via Leonardo AI

Different alternatives for the facades of the project can be practically created by adjusting keywords and the visual impact value using online AI applications. By modifying both the impact value of the keywords and the AI's design mode, diverse variations can be rapidly generated. These options can alter elements such as transparencies, materials and building components on the facade (Figure 5a, 5b). AITs employed in this context stimulate the designer and significantly reduce time spent on design. Facades that are difficult to model in modeling programs can be produced quickly using AI. Figure 5b presents an alternative where the openings on the facades of a student's kindergarten project have been redesigned with curvilinear forms using AITs.


**Figure 5a.** Production of New Facade Alternatives
**Source:** Produced by Stu Nihal Başıeğri via Leonardo AI


**Figure 5b.** The Redesign of the Facades of a Student's Kindergarten Project
**Source:** Produced by Stu Nihal Başıeğri via Leonardo AI

### *3.3. Project Phase*

This phase includes the initial project, planning, project, detailed design, etc. 2D and 3D drawing and modeling tools are used in the traditional APP. As shown in the figures, AITs contribute to the generation of mass forms. However, this production is not entirely under the designer's control. It is a creative process that depends on prompts and the programme's capabilities. Based on the research period, it cannot be said that these tools can be directly applied in the project stage.

Maket AI and other online AITs capable of generating architectural models and plans were tested for creating single-story house plans. However, none of the tools produced satisfactory results. Figure 6 illustrates a study conducted on architectural plan generation. It was observed that the relationships between spaces, as well as between the space and the hall, could not be designed consistently. Although multiple spaces can be produced in different ways in a single space, AITs developed to generate plans perceive creating different spaces as creating different rooms. There is a need for improvement in AI in this phase.

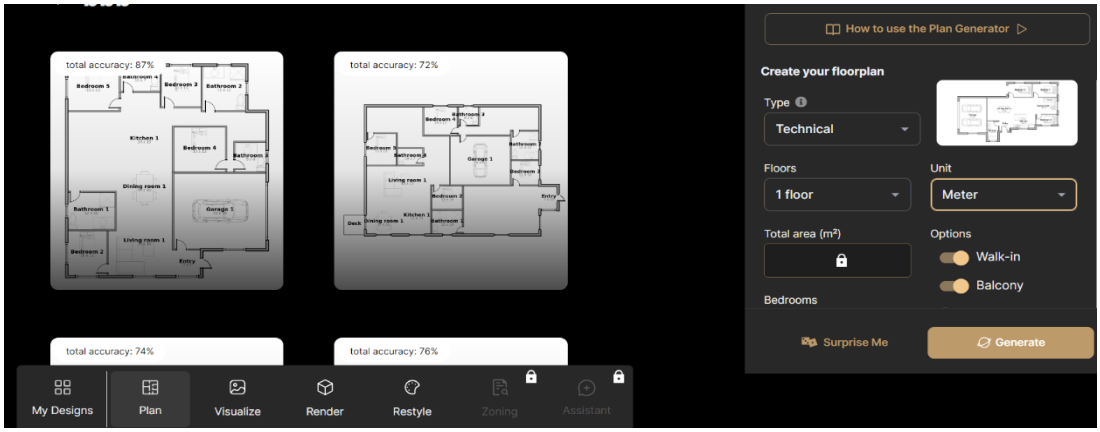



**Figure 6.** Single story-house plan generation with AIT
**Source:** Produced by Stu Birgül Demirbağ via Maket AI

### *3.4. Presentation/Visualization Phase*

In the traditional production process, sketching, modeling, drawing and rendering programmes are commonly used during this phase. After reviewing the experimental study data uploaded to the shared Google Drive folder, it was found that the most effective use of AITs occurred in the visualization stage. Classroom observations and survey results also confirm this finding. Online AI applications are generally successful in producing lifelike images. These tools were used by the students in this stage for rendering, collage production and coloring of project items for the poster.

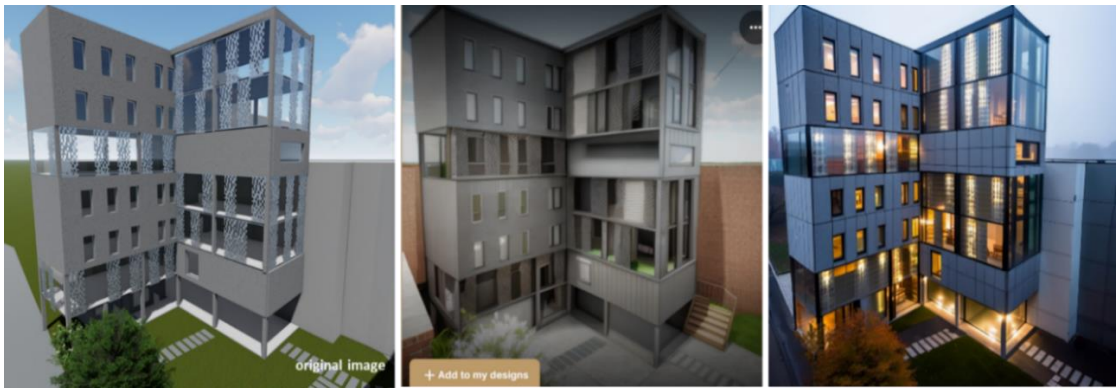



**Figure 7.** Different Visual Alternatives of the Same Image
**Source:** Produced by Stu Miray Topaloğlu via Sketchup, via Maket AI, via Leonardo AI

Students criticized the inability of online AITs to fully perceive the spatial elements in the uploaded image. Some AI applications enable users to select and edit particular segments of an image based on new keyword prompts. However, studies have shown that these tools do not work sufficiently. The visual rendered by the students with AITs was corrected with user-controlled programs such as Photoshop due to these errors. Figure 8 shows that the space designed as an office is visualized as a restaurant as a result of the misunderstanding of the interior elements by AI. The orange door in the first image is reproduced as a yellow wall in the bottom image. In the middle image, the AI incorrectly interprets the carpet as a coffee table and represents it as such. In the upper right image, the black cupboard doors and the transparent table are rendered as wood, despite the specified keywords.


**Figure 8.** Interior Renderings with AIT
**Source:** Produced by Stu Miray Topaloğlu via Leonardo AI -1-, via Maket AI -2,3

Entering the correct keywords into AITs or selecting the appropriate mode offered by the application is crucial. In Figure 9, two distinct alternatives of the image on the left were generated - one as indoor and the other as outdoor - simply by changing the AI mode.


**Figure 9.** Renders of the Same Image in Different Modes
**Source:** Produced byMiray Topaloğlu via MaketAI

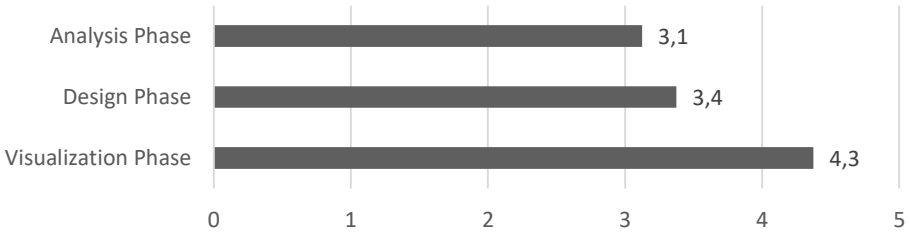
Within the scope of the study, AI were utilised to colour project outputs prior to the presentation. However, incorrectly interpreted elements posed challenges at this stage. For example, in the plan colouring shown in Figure 10, the bed in the second image and the entrance veranda in the third image were inaccurately rendered.


**Figure 10.** Visualization Phase Studies
**Source:** Produced by Stu Miray Topaloğlu via Maket AI, Veras AI

### *3.5. Survey*

Before the research, only one student in the course had used ChatGPT, while the others had never used any AI applications. A survey was conducted 5 months after the study to find out the current state of students' relationship with AI. In the survey, students were asked to evaluate their post-study interactions with AI for different stages of architectural design on a scale of 1 to 5 (1 being the least and 5 being the most). The survey also included an evaluation section where students could express their thoughts on using AI. The inability to fully control the AITs precluded their direct utilization in the project phase of in-class studies. Accordingly, this stage is not included in the survey. According to the survey data conducted 5 months after the research, students continued to use online AI applications effectively in analysis, conceptuall/design phase and visualization (Table 4). In the survey, students also reported using various AITs and sharing their experiences with peers from different academic years. In the evaluation part of the survey, some students mentioned receiving AI support in their architectural projects. They utilized AITs during both the mass design and the facade design process. The use of AI in the visualization phase was evaluated by students with a mean rating of 4.3 out of 5 (Table 4). Among all participants, only one student stated that he did not use AI in the visualization stage and found it incomplete (Table 5). The student justified this situation with a time loss stemming from the object detection challenge encountered by AI.

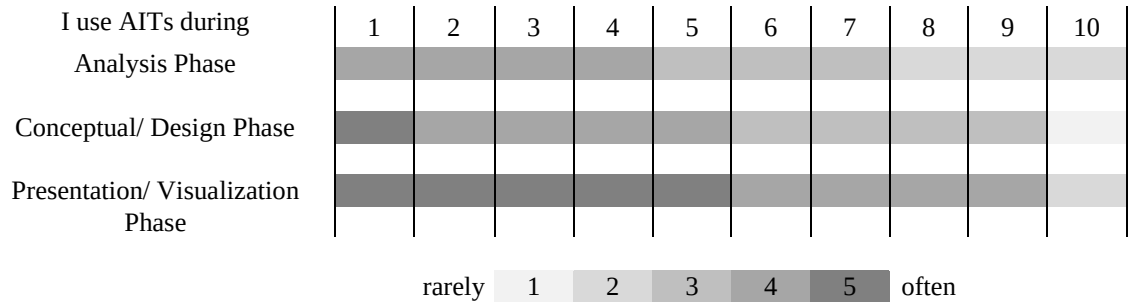
**Table 4.** Survey Results on Students' Interactions with AI in The Following Semester




As illustrated in Table 5, the analysis phase was identified as the least utilized stage by all participants. In the questionnaire and survey evaluation section, the tools used in

this stage were criticized for several reasons. These included concerns about their bibliographic reliability and the adequacy of the responses they generated. A comprehensive discussion of these findings can be found in the subsequent section.

**Table 5.** Survey responses distributions: Frequency




## 4. Discussions

This experimental study represents pioneering research and offers new insights into the integration of AI applications in architectural education. The observations and questionnaire studies conducted during the courses revealed that AI brings the potential to the traditional APP. In this context, it is of great significance to incorporate this emerging technology into the production process of architectural education.

The speed and practicality of AI at different stages of the APP are very valuable. Although the data was taken from AI in the analysis phase, the synthesis and evaluation of the data was seen to be the product of students' knowledge and competence. AITs spark the designer by producing new design scenarios. This is an indication that a new era has begun in architectural production. In the design phase, AI generates products based on keywords entered by users. The results are evaluated and eliminated by the designers. This process demonstrates that AI is not a plagiarism tool but an auxiliary tool in design. In addition, the study observed that with AITs, students could visually produce conceptual architectural designs that had difficulty expressing with their 2D or 3D production competencies. This shows that AI can be used as a facilitating tool for students to express themselves.

The ChatGPT used at the analysis stage was criticized for the following reasons by students:

- AI's inability to understand the questions;
- Unqualified bibliography of the data (e.g. Wikipedia, personal blogs, etc.);
- The quality of the answers;
- Lack of access to visual data.

AI applications used in the conceptual/design and visualization stage were criticized on the following grounds by students:

- It is difficult to write correct and successful keywords;
- Lack of perception of some structural elements;
- Detection errors cannot be corrected directly with keywords.

The online AITs used have different prompt, unprompt and select prompt properties. Prompt features need to be improved, for these tools to be more successful.

## 5. Conclusions

AITs in architectural education have yielded positive results at different stages of production by enabling rapid generation, opening different horizons for the designer with the inspiration it provides and contributing to the quality of visualization. After the 7-week study, it was observed that students adopted online AITs into their project production processes. Day by day, AI is being developed and integrated into computer-aided design programmes. It is becoming increasingly important for architects to interact with these technologies. This kind of engagement will enable the production of potential designs in these areas in the future.

Online AITs can't produce on their own without a user making and guiding decisions. This makes the use of online AI applications in architectural education useful and creative rather than dangerous. Nevertheless, it is also possible to talk about possible risks of plagiarism and sameness with the development of tools in the future perspective.

Architectural design is a production process to find the optimal design among infinite design alternatives that do not have a single truth. It is not just an image or mass design. It cannot be thought of apart from the context in which it is produced. There are thousands of parameters affecting the production of architectural design, such as environmental data, social data, the historical value of the place and the spirit of the place. In today's AI technology, these parameters are partially reflected in projects with keywords written in applications. Machine learning studies are carried out to transfer these parameters to AI. However, as it is used today, AITs simply produce an image, a mass, without evaluating these production parameters. This highlights that current AI technologies act merely as supportive tools rather than autonomous designers, as they do not yet integrate core design parameters.

This investigation was conducted using only online AI applications that provided a limited number of free tokens. Applications requiring servers, such as Discord, were not used due to the university's internet restrictions. Future studies could explore the development of the AI tools used in this research or the integration of alternative applications, offering new perspectives. The study was conducted with final-year architecture students who have experienced the traditional APP. A replication of the it with the participation of students from different periods will open new discussions. The results may be unexpected when conducted with lower-grade students, who are less familiar with concepts like human scale, space and context. This research was carried out with a group of 10 students. In establishing the quota, consideration was given to the number of final-year students at the university, the systematic progression of the process, the collation of data and the spatial and technological capacity of the course studio to facilitate flexible production and interaction. This time-constrained experimental study was added to the first 7-week curriculum of the Computational Design Studio in Architecture.

The research's multidimensional outcomes offer valuable insights, opening new avenues for discussion within architectural education and the development of AI applications. The survey results indicate that all students interacted with AITs following the course. As a recommendation, the integration of AI into design courses should be encouraged, even through small-scale projects, due to their potential. This approach provides a new pathway for production in architectural education to meet the demands of the new era in APP.

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