Online-Journals.org

iJET International Journal of Emerging Technologies in Learning

iJET | eISSN: 1863-0383 | Vol. 18 No. 18 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijet.v18i18.42603

PAPER

Can AI Function as a New Mode of Sketching: A Teaching Experiment with Freshman

Hakan Tong, Ahmet Türel(✉), Habibe Şenkal, S. Feyza Yagci Ergun, Orkan Zeynel Güzelci, Sema Alaçam

Istanbul Technical University, Istanbul, Türkiye

turela@itu.edu.tr

ABSTRACT

This study investigates how artificial intelligence (AI) can be integrated into first-year design education. The goal of the study is to examine how students combine orthographic projections with AI-generated images. To answer this question, a design representation course called Visual Communication I (VC-I), taught at Istanbul Technical University's Faculty of Architecture, was selected. A three-step assignment called "ISO-meets-AI" was planned and implemented in the VC-I. The steps of the assignment were as follows: (i) producing orthographic projections of created physical compositions; (ii) generating image output from text input using an AI program (Midjourney); and (iii) combining the AI-generated images with the orthographic projections. The assignment was completed by 50 students from the departments of architecture, interior architecture, and industrial design. Tutors defined the evaluation categories and sub-criteria based on an initial analysis. While tutors evaluated every submission based on the established categories and sub-criteria, students only assessed their own work through a survey. Lastly, a second survey was given to the students in order to better understand their willingness to employ AI in their future studies. The first survey's comparative evaluation results of the tutors and students, as well as the results of the second survey, are presented.

KEYWORDS

design education, design representation, visual communication, artificial intelligence (AI), Midjourney

1 INTRODUCTION

In the literature on design studies, it is often emphasized that the process of design is characterized by an ill-defined or wicked structure and a cyclical nature. In this process, designers mostly employ a problem-solving approach by tackling ambiguous questions and goals and putting effort into connecting new relations between varying data obtained from different domains. Different from a well-defined process, design goals continue to convey uncertainties throughout the process. Starting from ambiguous questions in the mind and bringing together a lot of information to reach goals,

Tong, H., Türel, A., Şenkal, H., Ergun, S.F.Y., Güzelci, O.Z., Alaçam, S. (2023). Can AI Function as a New Mode of Sketching: A Teaching Experiment with Freshman. *International Journal of Emerging Technologies in Learning (iJET)*, 18(18), pp. 234–248. https://doi.org/10.3991/ijet.v18i18.42603

Article submitted 2023-04-26. Revision uploaded 2023-06-18. Final acceptance 2023-06-25.

designers are expected to create new relationships between varying data obtained from different domains [1]. Designers frequently turn to sketching as a means to visualize, solidify, and make sense of this ambiguous process within their minds. Sketching, as a traditional representation technique, facilitates design thinking and enables designers to rediscover and refine ideas by drawing inspiration from the visual traces reflected on the paper [2] [3] [4] [5] [6] [7]. In this context, sketching can be considered a tool for both “visual thinking” [2] [3] [7] and “visual communication” [8] [9] [10].

With the advancements in digital technologies, there is a growing diversification in the process of converting design ideas into visual representations and subsequently transforming these representations into models that can be compared and evaluated. The emergence of digital tools and environments in design has brought their potential to revolutionize traditional techniques used for representing designs to the forefront. However, despite this potential, sketching in the early stages of design maintains its validity and dominant role today [11] [12]. The ongoing discussion regarding the importance of sketching in the field of design is primarily focused on the role it plays as an interface between design thinking and the final design outcome [13]. Belardi [11] describes sketching as the essence of thought, highlighting its ability to merge existing knowledge with the creation of new ideas. Similarly, Goldschmidt [12] emphasizes the cognitive advantages of sketching that cannot be easily replicated by computational tools. It is argued that sketches will continue to hold value in design studios alongside the possibilities offered by digital technology.

In the context of the interaction between designers and digital technologies, Schmitt [14] proposes a critical perspective that goes beyond simply accepting or rejecting the new technologies. This proposition is rooted in a thorough analysis of the causes and effects of relationships between design tools, actions, and outcomes. According to Schmitt [14], the impact of digital technologies on design can be categorized into three stages: (i) the computer as a tool, (ii) the computer as a medium (or environment), and (iii) the computer as a partner. As a “tool” or “instrument” in Schmitt’s [14] definition, the computer refers to the period in which the cursor replaces the pen and the traditional design process is copied and repeated in the digital environment. The transformation of the computer into a medium occurs when it provides opportunities for interactive engagement among various layers of knowledge and skills in design. These layers may include data, processes, procedures, graphical or geometric representations, algorithms, physical components of the space, and even the people who interact, perceive, and experience within that space. In the period of “computer as a partner”, one can observe the emergence of expert systems, decision support systems, artificial learning-based tools, and design interfaces [14]. In this way, Schmitt’s notion of the “computer as a partner” actively acknowledges the computer’s role in shaping and contributing to the design process as an active participant.

There are ongoing efforts to comprehend the paradigm shifts in design representation and application brought about by digital technologies and to define the current era we are living in. Picon [14] investigates these changes through the lens of “digital culture” and compares them to transformations experienced in the previous century. According to Picon [15] [16], the integration of knowledge and experience acquired from mechanized weaving into the design, along with the utilization of fabrication tools with digital layers in contemporary production processes, entails collaborations concerning information representation, transformation, and processing. However, these partnerships are not direct continuations of each other. Carpo [17], on the other hand, introduces the concept of a “turn,” representing the digital age or a significant focal point. Carpo analyzes the transformations occurring in the digital age by drawing comparative parallels with the Renaissance period.

He argues that thinking and designing with algorithms have become the new literacy for architects [17]. Further to the discussion of "algorithms" by Carpo, today it is seen that artificial intelligence (AI)-based technologies, which are developing with increasing momentum, are becoming widespread. These AI-based technologies are reducing the need for coding and algorithmic knowledge, making them more accessible and user-friendly through graphical user interfaces and auxiliary platforms. Consequently, in accordance with the perspectives of Carpo [17], Picon [15], and Schmitt [14], AI technologies have the potential to act as transformative partners at the crossroads of digital culture and design practices.

While it is inevitable that the transformations in design representation and application brought about by AI-based technologies will impact design education, the integration of AI technologies into design education is still relatively limited [18] [19] [20] [21] [22] [23]. AI is viewed as a tool that can contribute to the development of students' skills, including problem identification and solving, creative thinking, data collection, data analysis, modeling, and interpretation. To enable design students to engage with machine learning (ML) algorithms and understand their principles and applications, various strategies and materials are employed in design education. Van Der Vlist et al. [18] introduced AI and robotics technologies to design students using a physical environment that included sensors and LEGO components. Through the integration of machine learning algorithms, robotic parts in the real world are transformed into learning machines, enabling user interaction with tactile outputs. Khean et al. [19] proposed an innovative education model for introducing machine learning techniques to architecture students. This model consisted of four main components: computational intelligence—artificial neural networks; dataset preprocessing and analysis; training and evaluation; and spatial representation. Yang and Sha [23] explored the advantages and challenges of AI-based innovative design education. They highlighted that while AI can enhance the efficiency of the design process with its data-driven and predictive approach, careful planning and implementation are necessary to avoid stifling the creativity of designers. There are also studies focused on employing ML to search for design problem solutions and interpret the obtained results. Akcay et al. [20] presented an approach to integrating AI into design education with a pedagogical focus. In Akcay et al.'s [20] work, students engage in a series of activities and assignments to explore the applications of AI that go beyond the limitations of traditional design methods.

In the context of integrating AI technologies into design education, this study presents experimental research that was conducted with first-year design students. The study specifically focuses on the integration of AI technologies with visual representation and visual communication techniques in design education. The aim is to address the following research questions through a teaching experiment:

1. Can artificial intelligence technologies (AI) create a new dialogue environment between design representations produced in digital and physical environments?
2. How does the integration of orthographic projection techniques in design education, along with AI technologies, transform students' productions?

2 ORTHOGRAPHIC PROJECTION IN THE TRADITIONAL AND DIGITAL REPRESENTATION OF DESIGN OBJECT

Throughout history, the relationship between the design object and the representation of the design object, the building or object, and the drawing has been ambiguous [24]. In the Vitruvian period, projection-based abstraction was used to present a ground where the proportions of a building's façade and design principles were discussed and, in the words of Perez-Gomez [24], "theory was explained". During the Renaissance period, the interaction between art, design, and science increased significantly with advancements in mathematics and geometry. This led to further developments in design representation and projection techniques. Projection techniques became widely used, and new techniques like perspective emerged. While the 3-dimensional design object is transferred to the 2-dimensional surface with perspective techniques, it has gained a more realistic expression while preserving the sense of depth. Some of the leading artists of the period, such as Alberti, Brunelleschi, Francesca, Mantegna, and da Vinci, played a leading role in the development of these techniques by using perspective and projection techniques in their works. The growing effect of projection techniques in the representation of design objects has made the correct use of these techniques important. For this reason, representation techniques and applications are presented in detail in many sources, with different aspects such as drawing basic geometries, toning and shading in drawing, perspective, and orthographic and isometric projection [24] [25] [26] [27] [28] [29] [30] [31].

Orthographic projection techniques have facilitated accurate scaling and 3-dimensional representation of design objects. The orthographic projection technique involves placing the object at a fixed angle on a flat plane and projecting each point onto the plane with a perpendicular line. This technique, which helps to represent objects at the right scale, is widely used, especially in 2-dimensional technical drawings such as plans, sections, and views. The isometric projection, on the other hand, offers a 3-dimensional representation of the object within a cube. It is achieved by scaling along the x, y, and z axes with equal angles and ratios. Thus, by presenting views of the design object from different angles, the actual dimensions of the object are better understood [27] [32] [33].

The use of projection techniques has also played a significant role in the measurement of graphic representation in the computer environment. The representation of design objects using 3-dimensional solid models in computer software, along with transformation processes involving addition-subtraction operations (Boolean operations), has introduced novel opportunities for representation, information storage, information processing, and simulation. These advancements were prominent until the 1990s. Starting in the 1990s, the computational representation of non-uniform rational B-splines (NURBS) had a transformative impact on the efficiency of file-to-production time. However, during this period, there were limitations in representing complex geometries (double-curved surfaces) in computer models. As Lonsway [34] points out, computers have the potential to go beyond predictive computational multidimensional solid 3D modeling and offer much more in terms of transformative capabilities.

Today, representation techniques based on orthographic projection leave their place for new representations and models. As Oxman [35] puts it, typology is giving way to topology, and the focus is shifting from the form itself to the rules that generate the form. Traditional representation techniques such as plan, section, view, and isometric projection, which played a crucial role in transferring design information in the past, are considered insufficient in today's design processes conducted with contemporary tools and environments. Beauce and Cache [36] provide a broader perspective on this shift and discuss the classification of isometry, similarity, projection, and topology, which originated from the Erlangen Program of 1872. They associate projection techniques with the industrial era and topology with the digital era. In the digital age, approaches such as topological modeling, computational modeling, generative modeling, and performative modeling come to the forefront, necessitating a reconsideration of traditional representation techniques such as sketches, drawings, and models. However, the emergence of new tools and techniques has also raised new questions and challenges. Repetition of predefined procedures in design representations can lead to similar outputs, diminishing designers' control over the design process. The multi-modal interaction between designers and their representations, encompassing visual, tactile, and kinesthetic aspects, weakens, and designers can feel disconnected from the outputs produced by computers. On the other hand, in sketches and orthographic projection drawings, the meanings of the lines may be limited, and there may be interruptions in the transfer of thoughts on paper to a dynamic simulation model. Therefore, the fact that the representations produced with traditional approaches are formed as an ambiguous result of an ambiguous process, and consequently, their polysemy, being a unique process in which a different output is produced every time, even if it is done by repeating the same procedures, creates the problem of not being able to be transferred to the digital environment with the same richness.

Despite the advancements in design tools and techniques, the orthographic representation technique continues to hold significance in design education. Perez-Gomez and Pelletier [37] emphasize that these methods, which are included in design education, are insufficient due to the reductionist approach they adopt, considering the complexity of human senses and the diversity of spatial experiences. Perez-Gomez [38] further emphasizes that even with sophisticated digital technologies, there is a tendency to overlook the essential aspects of materials, craftsmanship, human perception, and experience. She views architectural drawings and models as fertile ground for "interdimensional" explorations, where the connections between space and time, architectural thought and experience, universal concepts and specific contexts, and theory and practice can be explored beyond conventional limitations. In this context, Perez-Gomez [38] sees projection as an approach that can bridge these gaps and foster a deeper understanding of the interplay between various dimensions. By transcending reduced conventions, projection can facilitate a more holistic and integrative approach to architectural design that encompasses the richness of human experience and the multifaceted nature of architectural thought.

3 TEACHING EXPERIMENT

3.1 The course: VC-I

The Integrated Foundation Studio (IFS) is an educational model at Istanbul Technical University's Faculty of Architecture that aims to provide an interdisciplinary teaching and learning environment for first-year students of architecture, urban planning, industrial design, interior architecture, and landscape architecture. The IFS, which has been conducted for nearly a decade, consists of five courses (modules) that are taught over two semesters. Students enroll in "Project I", "Visual Communication I: Visualization and Technical Drawing", and "Basic Design and Visual Arts" in the first semester, and "Project II" and "Visual Communication II: Visualization and Perspective" in the second. Visual Communication I: Visualization and Technical Drawing (VC-I) is a 14-week (4-hour) course that aims to improve students' abilities in representing design outcomes using a variety of tools, techniques, and approaches. In general, VC-I students are expected to use conventional orthographic and isometric drawing approaches to represent simple and complex geometric compositions [39].

3.2 The brief: ISO-meets-AI

In the fall term of 2022–2023, a three-step assignment was planned for the VC-I course at Istanbul Technical University's Faculty of Architecture. This assignment's steps were as follows:

1. Producing representations using orthographic and isometric projection techniques
2. Generating image outputs from text inputs using an artificial intelligence (AI) program
3. Combining the AI-generated images with the isometric projections

In the first step of the assignment, which took place during the eighth week of the VC-I course, students were expected to create compositions using a set (minimum 5) of basic solids (Figure 1a) and to prepare orthographic and isometric projection drawings of these compositions (Figure 1b).

In the second step of the assignment, students were asked to generate images using an artificial intelligence algorithm. Students who had no prior experience with AI applications were given a 1.5-hour face-to-face tutorial by tutors and invited lecturers. Tutors chose the Midjourney program for the second phase since it allows multiple runs (for free) and generates various images for each run. Another motivation to select Midjourney was the program's ability to generate images based on text input. In addition, the face-to-face tutorial was supported by an online tutorial prepared by the guest lecturers (Figure 2a).

Fig. 1. (a) Created compositions; (b) Drawing the created compositions

Students were then given the opportunity to generate images in the Midjourney environment by using keywords or phrases. Considering the isometric projection and other representation techniques covered in the VC-I course, students were given a list of compulsory keywords and phrases to establish a common ground for Midjourney productions. Mandatory keywords and phrases were listed as "isometric projection", "detailed", "shade and shadow" and "8K rendering". As Midjourney can generate images with 6,000 character-long prompts, students were given instructions that they could compose their own text inputs to guide the algorithm in addition to the mandatory keywords and phrases.

In the final step of the assignment, students were asked to combine the isometric projection of the geometric composition they created with the image generated by Midjourney (Figure 2b). During the fusing phase, students were not taught any digital image-editing software (e.g., Adobe Photoshop), nor were they instructed on which elements to use or interpret from the AI-generated images. There were also no restrictions on the fusing techniques that could be used. During the ninth week of the VC-I course, students were asked to upload the outcomes of each step of the assignment as separate files to the cloud-based folders that the tutors announced.

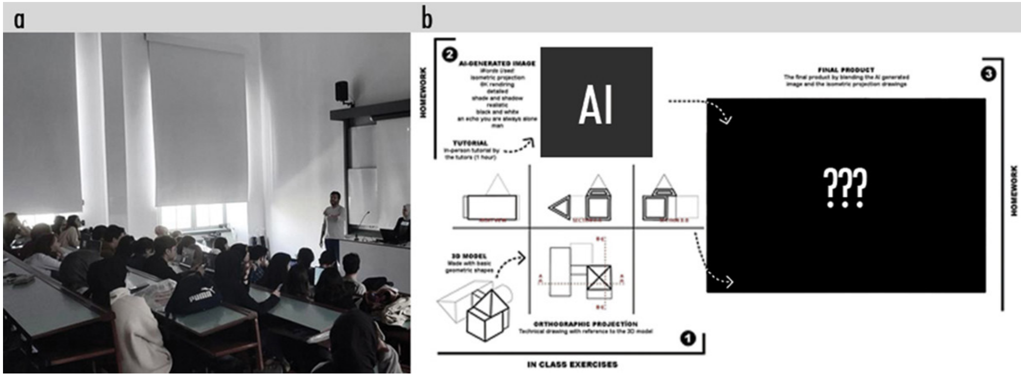

Fig. 2. (a) Face-to-face tutorial; (b) Assignment brief

4 THE STUDENT WORKS

4.1 The development: phases of student works

During the eighth week of the VC-I course, the 50 students who participated in the 1.5 hours of face-to-face tutorial (Figure 2a) and took the assignment brief (Figure 2b) created physical compositions in the studio during the remaining 2.5 hours (Figure 1a) and produced orthographic (Figures 3a and 4a) and isometric (Figures 3b and 4b) projections of their compositions. Students worked individually during the composition creation and drawing phases, using traditional drawing equipment such as a T-ruler, miter, and compass and benefiting from the skills they had learned in previous weeks of the course (Figure 1b).

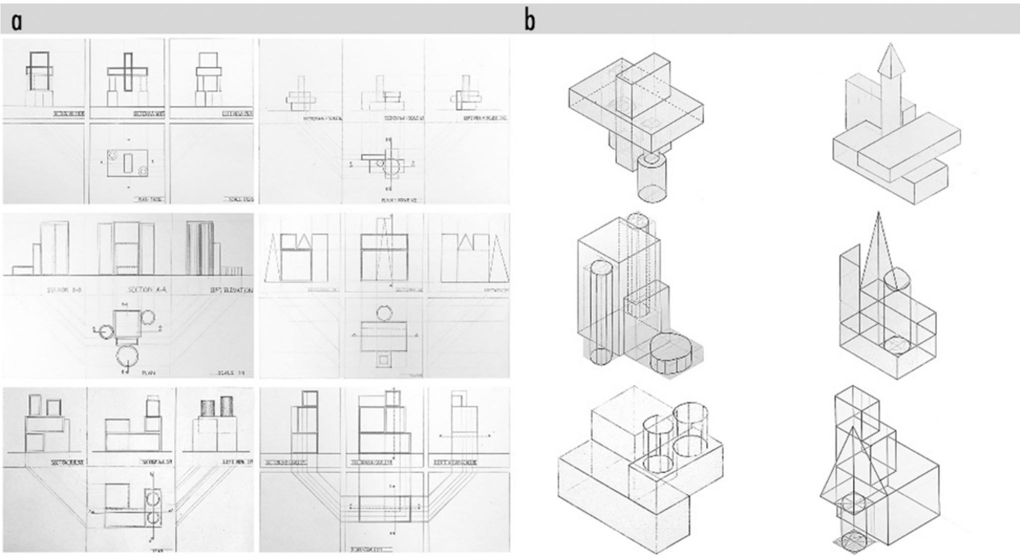

Fig. 3. (a) Orthographic projections; (b) Isometric projections

Following the studio hours, students continued their individual study on their personal computers using the Midjourney algorithm via the Discord application. In Discord, students generated images for their text inputs and accessed images generated by other Midjourney users for their text inputs. The students kept the compulsory keywords and phrases fixed and used other prompts as input, and as a result of each run of the algorithm, four different images were obtained. The students proceeded to the next step of the assignment by selecting one of the images and expanding its size with the "upscale" operation (Figure 4c).

The students completed the assignment by combining visual elements extracted from Midjourney images with isometric projections using physical, digital, or both means (Figure 4d). They submitted their completed assignments by uploading the produced works at each phase (Figure 4) to the course's cloud folder, along with the text-based inputs utilized for AI generations.

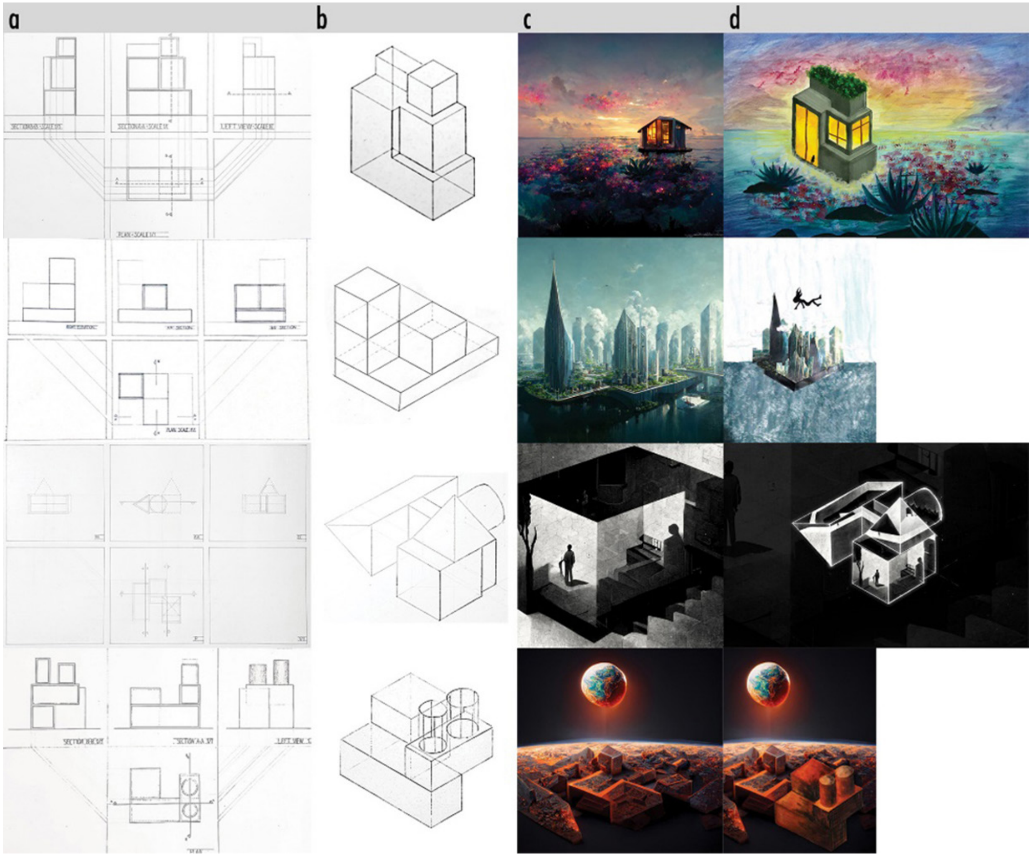

Fig. 4. Sample submissions (a, b) Orthographic and isometric projections; (c) AI-generated images; (d) Final products

5 THE RESULTS: EVALUATION AND REFLECTION OF STUDENT WORKS

5.1 Evaluation

Upon reviewing the 50 end products, where students integrated their isometric drawings with the visuals they generated through Midjourney (Figure 4d), a range of combination techniques and methods of blending existing elements in AI-generated images were observed. Based on qualitative preliminary analysis, the tutors created these two primary categories and five sub-criteria within these categories. In this regard, the combination strategies were divided into two categories: "composition techniques" and "use of elements."

In this study, composition techniques covered the assessment criteria of (i) modification types and (ii) visualization techniques utilized for creating final products. The modification types were evaluated based on whether students used isometric drawing (ISO) or AI-generated images directly or used one or both through interpretation. For the visualization techniques category, the preferred techniques by the students, such as drawing, painting, and cutting or pasting, as well as their combinations, were assessed.

In the second category, the elements observed in AI-generated images are described as "atmospheric elements." The sub-criteria for atmospheric elements were defined as textures, colors, and forms in the image. In other words, these sub-criteria were used to determine whether the texture, color, and/or form of the AI-generated image transferred to isometric projection. The use of texture and color, in particular, on the composition's background and/or surfaces was reviewed.

Based on the defined categories and sub-criteria, both tutors and students evaluated the final products. While tutors evaluated each final output collectively and made a decision, students completed a survey to do the same assessment only for their individual outcomes (Table 1). The evaluation results of the final works by the tutors are given in Figure 5 [40], and the students' evaluation results are presented in Figure 6.

Table 1. Survey presented to students to evaluate their own work

Section 1: Please answer with either "Yes" or "No".	Yes	No
When combining the AI-generated image and isometric projection, I used the isometric projection directly.		
When combining the AI-generated image and isometric projection, I used the AI-generated image directly.		
When combining the AI-generated image and isometric projection, I used drawing techniques (e.g. pencil, ink).		
When combining the AI-generated image and isometric projection, I used painting techniques (e.g. dry pastels, watercolors).		
When combining the AI-generated image and isometric projection, I used the cut and paste technique.		
When combining the AI-generated image and isometric projection, I used the texture from the AI-generated image as the background of my final work.		
When combining the AI-generated image and isometric projection, I used the texture from the AI-generated image on the surface of my isometric projection in the final work.		
When combining the AI-generated image and isometric projection, I used the color from the AI-generated image as the background of my final work.		
When combining the AI-generated image and isometric projection, I used the color from the AI-generated image on the surface of my isometric projection in the final work.		
When combining the AI-generated image and isometric projection, I adapted the form (three-dimensional mass) I created in the isometric projection to incorporate elements from the AI-generated image into my final work.		

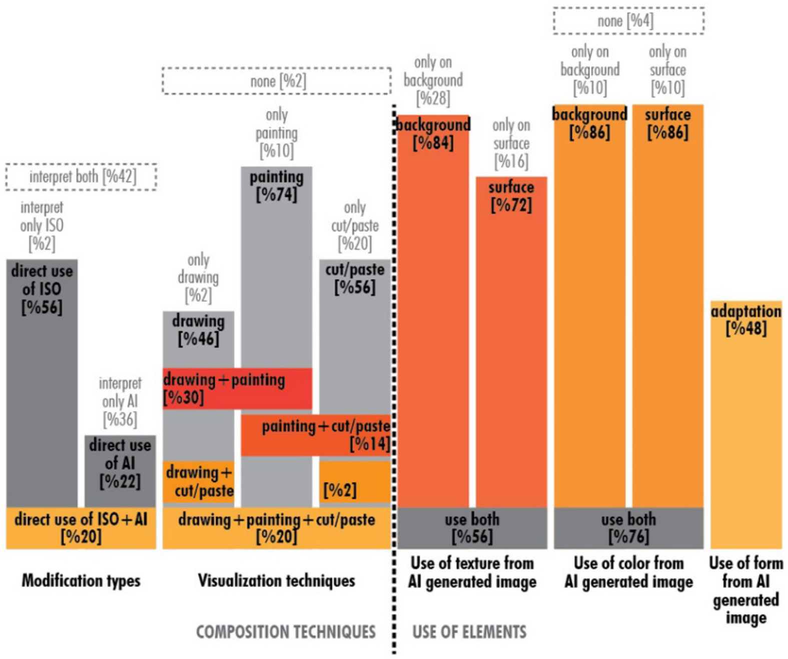

Fig. 5. Evaluation results of student works by tutors

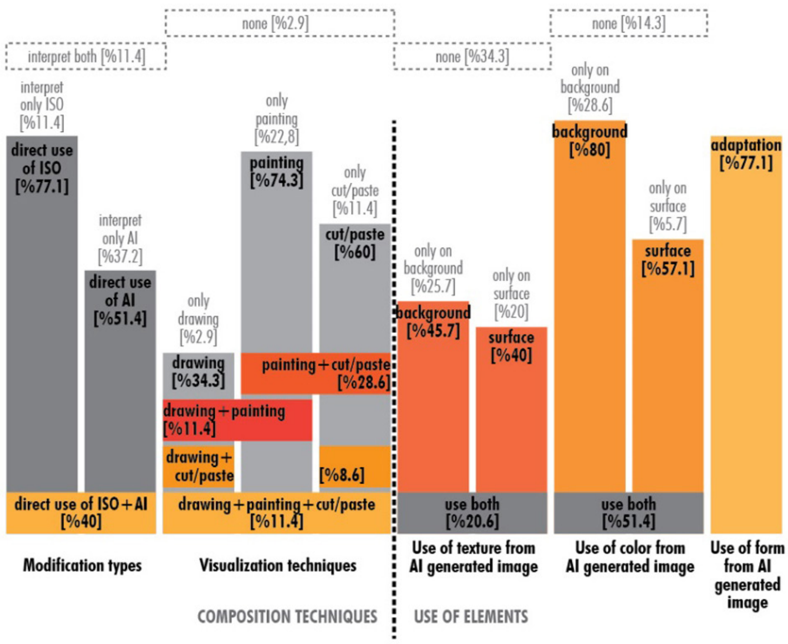

Fig. 6. Evaluation results of student works by students

5.2 Comparative results of tutors and student assessments

Table 2 compares the tutors' and students' evaluations, which are illustrated separately in Figures 5 and 6. According to Table 2, the results of the students' and tutors' evaluations tended to be close, although there was a clear disagreement in terms of texture usage and form adaptation between the observation of tutors and the declared intentions of the students. Tutors, for example, stated that in the final product, all students used a texture from the AI-generated image on the surface or the background of the isometric drawing. However, 34.3% of students reported in the survey that they were unable to transfer the texture. As a result of another question, while the tutors found that 48% of the final images involve a form transfer from the generated image to the isometric drawing, 77.1% of the students claimed that they made such an adaptation.

These findings show that there may be differences in the perceptions and opinions of tutors and students who have just begun their design education. Table 2 also shows that the tutors evaluate the works with a more comprehensive attitude in all areas except adaptation. Tutors gave critiques based on the students' knowledge level and the visualization tools they utilized, since the students might not be able to represent the intended result completely in the final outputs.

Table 2. Comparison of tutors' and students' evaluation

Categories	Sub-Criteria	Tutors' Evaluation	Students' Evaluation
Composition Techniques	Modification types	80% of the works had at least one type of interpretation.	60% of the works had at least one type of interpretation.
	Visualization techniques	Relatively close results were observed for the use of drawing, painting and cut/paste techniques.	
Use of Elements (Atmospheric Elements)	Use of texture from AI-genereted images	In all works, students transferred the texture.	65.7% of the students transferred the texture.
	Use of color from AI-genereted images	96% of the students transferred the color.	85.7% of the students transferred the color.
	Use of form from AI-genereted images	48% of the students adapted the form.	77.1% of the students adapted the form.

5.3 Reflection

Following the evaluation of the final outputs, the next step was to assess the impact of the assignment on students' representation skills and end products. Therefore, students were asked to complete a second survey, including three questions using a 5-point Likert scale. The survey was scaled from 1 to 5, with 1 referring to significant disagreement and 5 corresponding to strong agreement (Table 3). Out of the 50 students who submitted the final work, 40 took the survey.

Table 3. Reflection survey

Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1. Did you achieve the representation you intended when trying to combine isometric drawing and AI-generated image?					
Q2. Did your lack of experience with traditional and digital representation techniques limit your ability to achieve the intended representation?					
Q3. Would you consider using AI as a representation tool in the future?					

The results of the second survey showed that students are interested in using AI as a representation tool in the future (Q3). However, due to their lack of experience with the AI interface, digital tools, and physical composition creation, they have difficulties fully expressing themselves and representing ideas visually. Consequently, students tended to remain neutral to the questions (Q1 and Q2) related to these topics (Figure 7).

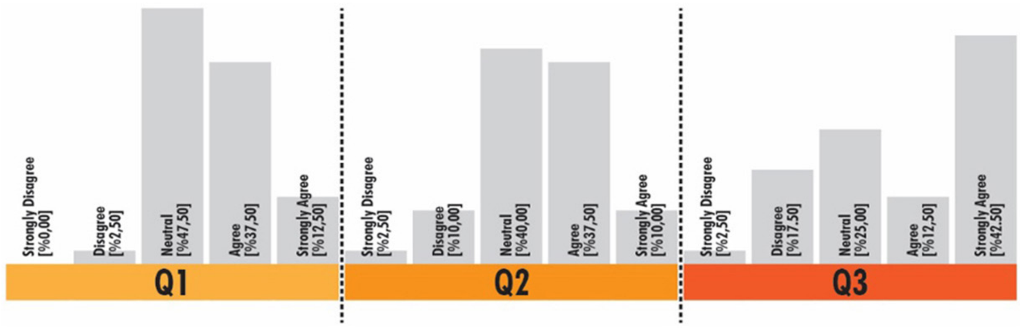

Fig. 7. Results of the reflection survey

6 CONCLUSION

Artificial intelligence-assisted visualization tools are diversifying and multiplying with increasing acceleration. It is inevitable that this situation will be reflected in design education through many discussions. Therefore, there is a need to increase scientific studies on how tutors will take a position regarding this situation in the near future, as well as gain a deeper understanding of their impact on the way students' design representations are generated.

With these concerns in mind, this study explores the integration of AI into first-year design education, specifically focusing on the combination of orthographic projections with AI-assisted generated images. A teaching experiment, titled "ISO-meets-AI," was implemented in the VC-I course at Istanbul Technical University's Faculty of Architecture in the 2022-2023 Fall semester.

In addition to an initial analysis of the students' work, the tutors defined the categories and sub-criteria for evaluation. The assessments of students own works were obtained through a questionnaire. According to the results, the students benefited from AI tools during the development of their work, and AI makes it easier for students to express their ideas by establishing relationships and using different techniques. However, it was noted that some limitations in using AI algorithms resulted in unintended outcomes. While students expressed themselves with keywords and phrases, it was observed that they encountered different results from their expectations due to their inability to find the appropriate prompts. This unexpected outcome is considered similar to the ambiguous nature of a sketch, which gives feedback to the designer rather than being a negative result.

The results of this study reveal insights into the potential of AI as a new mode of sketching. One of the key findings of the study is that, according to tutors, all students borrowed textures from AI-generated images for the final submissions, while 34.3% of the students stated that they did not transfer any textures. It is thought that this situation may result from an implicit or tacit mode of learning, and the AI-generated images implicitly reflect the next steps. Secondly, there was a difference between the students' comments and the tutors' inferences regarding the form transfer from

AI-generated images into isometric drawings. It is noteworthy to mention that the students adopted Midjourney in a relatively short time and stated that they would use similar tools in their future studies. While AI technologies offer new possibilities for design representation and visualization, there is still a need for careful implementation to ensure that they enhance, rather than stifle, the creativity of designers.

7 REFERENCES

[1] G. Goldschmidt, "Capturing Indeterminism: Representation in the Design Problem Space," *Design Studies*, vol. 18, no. 4, pp. 441–455, 1997. https://doi.org/10.1016/S0142-694X(97)00011-2

[2] G. Goldschmidt, "The Dialectics of Sketching," *Creativity Research Journal*, vol. 4, no. 2, pp. 123–143, 1991. https://doi.org/10.1080/10400419109534381

[3] D. A. Schön and G. Wiggins, "Kinds of Seeing in Designing," *Creativity and Innovation Management*, vol. 1, no. 2, pp. 68–74, 1992. https://doi.org/10.1111/j.1467-8691.1992.tb00031.x

[4] V. Goel, "Sketches of Thought," Cambridge, MA: The MIT Press, 1995. https://doi.org/10.7551/mitpress/6270.001.0001

[5] M. Suwa, J. S. Gero, and T. Purcell, "The Roles of Sketches in Early Conceptual Design Processes," In *Proceedings of the Twentieth Annual Meeting of the Cognitive Science Society*, pp. 1043–1048, 1998. https://doi.org/10.4324/9781315782416-188

[6] I. M. Verstijnen, C. van Leeuwen, G. Goldschmidt, R. Hamel, and J. M. Hennessey, "Sketching and Creative Discovery," *Design Studies*, vol. 19, no. 4, pp. 519–546, 1998. https://doi.org/10.1016/S0142-694X(98)00017-9

[7] B. Tversky, "What Does Drawing Reveal About Thinking?," In *Visual and Spatial Reasoning in Design*, J. S. Gero and B. Tversky, Eds. Sydney, Australia: University of Sydney, 1999.

[8] R. van der Lugt, "How Sketching Can Affect the Idea Generation Process in Design Group Meetings," *Design Studies*, vol. 26, no. 2, pp. 101–122, 2005. https://doi.org/10.1016/j.destud.2004.08.003

[9] M. Schütze, P. Sachse, and A. Römer, "Support Value of Sketching in the Design Process," *Research in Engineering Design*, vol. 14, no. 2, pp. 89–97, 2003. https://doi.org/10.1007/s00163-002-0028-7

[10] B. Buxton, "Sketching User Experiences: Getting the Design Right and the Right Design," Burlington, MA: Morgan Kaufmann, 2007.

[11] P. Belardi, "Why Architects Still Draw," Cambridge, MA: The MIT Press, 2014. https://doi.org/10.7551/mitpress/9968.001.0001

[12] G. Goldschmidt, "Manual Sketching: Why is it Still Relevant?" In *The Active Image*, S. Ammon and R. Capdevila-Werning, Eds. Cham, Switzerland: Springer, pp. 77–97, 2017. https://doi.org/10.1007/978-3-319-56466-1_4

[13] H. Tong and G. Çağdaş, "Towards a Global Design Studio," *Stüdyo: Tasarım, Kuram, Eleştiri Dergisi*, vol. 3, no. Bahar 04–05, pp. 1–9, 2004.

[14] G. Schmitt, "Design Medium—Design Object," In *Proceedings of the 7th Conference on Computer Aided Architectural Design Futures*, pp. 3–13, 1997. https://doi.org/10.1007/978-94-011-5576-2_1

[15] A. Picon, "Digital Culture in Architecture: An Introduction for the Design Professions," Basel, Switzerland: Birkhäuser, 2010.

[16] A. Picon, "Digital Technology and Architecture: Towards a Symmetrical Approach," *Technology | Architecture + Design*, vol. 6, no. 1, pp. 10–14, 2022. https://doi.org/10.1080/24751448.2022.2040297

[17] M. Carpo, "The Alphabet and the Algorithm," Cambridge: MA: The MIT Press, 2011.

[18] B. van der Vlist, R. van de Westelaken, C. Bartneck, J. Hu, R. Ahn, E. Barakova, F. Delbressine, and L Feijs, "Teaching Machine Learning to Design Students," In *Proceedings of Third International Conference, Edutainment 2008,* pp. 206–217, 2008. https://doi.org/10.1007/978-3-540-69736-7_23

[19] N. Khean, A. Fabbri, and M. H. Haeusler, "Learning Machine Learning as an Architect, How to?" In *Proceedings of the 36th eCAADe Conference*, vol. 1, pp. 95–102, 2018. https://doi.org/10.52842/conf.ecaade.2018.1.095

[20] A. Akcay Kavakoglu, B. Almac, B. Eser, and S. Alacam, "AI Driven Creativity in Early Design Education – A Pedagogical Approach in the Age of Industry 5.0," In *Proceedings of the 40th Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe 2022)*, vol. 1, pp. 133–142, 2022. https://doi.org/10.52842/conf.ecaade.2022.1.133

[21] M. Sciannamè, "Introducing ML in Design Education. Preliminary Experiments," In *Proceedings of the 24th International Conference on Human-Computer Interaction – Part 1*, pp. 447–455, 2022. https://doi.org/10.1007/978-3-031-06417-3_60

[22] A. Sorguç, M. K. Yemişoğlu, and O. Yetkin, "Demystifying Machine Learning for Architecture Students," *Eskişehir Technical University Journal of Science and Technology A – Applied Sciences and Engineering*, vol. 23, no. 16th DDAS (MSTAS) Special Issue, pp. 60–67, 2022. https://doi.org/10.18038/estubtda.1169816

[23] Y. Yang and Z. Sha, "Research on Innovation of Design Education Based on Artificial Intelligence Technology," *Journal of Physics: Conference Series*, vol. 2136, p. 012055, 2021. https://doi.org/10.1088/1742-6596/2136/1/012055

[24] A. Pérez-Gómez, "Architecture as Drawing," *Journal of Architectural Education*, vol. 36, no. 2, pp. 2–7, 1982. https://doi.org/10.1080/10464883.1982.10758306

[25] E. R. Norling, "Perspective Made Easy," Mineola, NY: Dover Publications, INC., 1999.

[26] T. E. French, C. J. Vierck, and R. J. Foster, "Graphic Science and Design," New York: City, NY: McGraw-Hill, 1984.

[27] F. D. Ching, "Architectural Graphics," Hoboken, NJ: John Wiley & Sons, 2015.

[28] A. L. Guptill, "Rendering in Pen and Ink: The Classic Book on Pen and Ink Techniques for Artists, Illustrators, Architects, and Designers," New York City, NY: Watson-Guptill, 1997.

[29] R. Yee, "Architectural Drawing: A Visual Compendium of Types and Methods," Hoboken, NJ: John Wiley & Sons, 2012.

[30] J. Richards, "Freehand Drawing and Discovery: Urban Sketching and Concept Drawing for Designers," Hoboken, NJ: John Wiley & Sons, 2013.

[31] S. Travis, "Sketching for Architecture + Interior Design," London, UK: Laurence King Publishing, 2015.

[32] L. Gürer, H. Tong, G. Gürer Alimgil, and E. İpçizade, "İzdüşümler," Istanbul, Turkey: Birsen Yayınevi, 2010.

[33] M. Zell, "Architectural Drawing Course: Tools and Techniques for 2D and 3D Representation," Hauppauge, NY: Barron's Educational Series, 2008.

[34] B. Lonsway, "The Mistaken Dimensionality of CAD," *Journal of Architectural Education*, vol. 56, no. 2, pp. 23–25, 2002. https://doi.org/10.1162/10464880260472549

[35] R. Oxman, "Theory and Design in the First Digital Age," *Design Studies*, vol. 27, no. 3, pp. 229–265, 2006. https://doi.org/10.1016/j.destud.2005.11.002

[36] P. Beaucé and B. Cache, "Objectile Fast-wood: A Brouillon Project," Wien, Austria: Springer Vienna, 2007.

[37] A. Pérez-Gómez and L. Pelletier, "Architectural Representation and the Perspective Hinge," Cambridge, MA: The MIT Press, 2000.

[38] A. Pérez-Gómez, "The Historical Context of Contemporary Architectural Representation 1," In *Persistent Modelling*, Phil Ayres, Ed. London, UK: Routledge, pp. 13–25, 2012.

[39] TES Foundation Studio, "TES I 2022–2023 Section 1," TES I 2022–2023 Section 1, 2022, [Online]. Available: https://tes.mim.itu.edu.tr/s1-tes112e/ [Accessed: June 1, 2023]

[40] H. Tong, G. Ülken, A. Türel, H. Şenkal, F. Yağcı Ergün, O. Z. Güzelci, and S. Alaçam, "An Attempt to Integrate AI-Based Techniques into First Year Design Representation Course," In *Proceedings of Cumulus Antwerp 2023 – Connectivity and Creativity in times of Conflict*, pp. 1–5, 2023.

8 AUTHORS

Hakan Tong received his B.Arch. (1985) degree from Istanbul Technical University and his M.Sc. (1988) and Ph.D. (2001) degrees from the Building Science Program of ITU. He worked as a Research and Teaching Assistant at ITU between 1988 and 2004, where he has been working as a full-time lecturer since 2004. He co-authored the book "Projections" in 2010. He teaches various undergraduate courses, including design studio, computer-aided design methods, as well as graduate courses related to digital design methods in architecture, multimedia and animation in architectural design, and virtual architectural design studio (E-mail: htong@itu.edu.tr).

Ahmet Türel received his B.Arch. (2013) degree from Karadeniz Technical University (KTU) and his M.Sc. (2017) degree in Architectural Design Program from Istanbul Technical University (ITU). He began working as a Research and Teaching Assistant at Bursa Technical University (BTU) in February 2014 and transferred to ITU in September 2014, where he holds the same position. He is currently a Ph.D. candidate in the Architectural Design Program at ITU. His research focuses on migration and space, the migration journey, and the impact of migration on urban space (E-mail: turela@itu.edu.tr).

Habibe Şenkal received her B.Arch. degree (2018) from Trakya University. Currently, she is a graduate student in the Architectural Design Computing Program at Istanbul Technical University. Her research focuses on the exploration of cultural heritage with deep learning, the inspiration of AI in architecture, and form finding with subtractive manufacturing methods (E-mail: senkal21@itu.edu.tr).

S. Feyza Yagci Ergun received her B.Arch. (2011) degree in Architecture and her M.Sc. (2013) degree in Restoration Program from Istanbul Technical University (ITU). She obtained her Ph.D. (2020) from the Architecture Department of the Technical University of Munich (TUM). She worked at TU Munich as a lecturer in 2017 and had research experiences at ETH Zurich (2013), TH Köln (2009), and TU Berlin (2022). Currently, she is an assistant professor at ITU (E-mail: fergun@itu.edu.tr).

Orkan Zeynel Güzelci received a B.Arch. (2010) degree in Architecture from Istanbul Kultur University (IKU), a M.Sc. (2012) degree in the Architectural Design Program, a Ph.D. (2018) degree in the Architectural Design Computing Program from Istanbul Technical University, and a Post-Doctoral Certificate (2021) from the University of Porto. Currently, he is an assistant professor at ITU and a researcher at FAUP+DFL/CEAU (E-mail: guzelci@itu.edu.tr).

Sema Alaçam received her B.Arch. (2005) degree from Istanbul Technical University (ITU), M.Sc. (2008), and Ph.D. (2014) degrees in the Architectural Design Computing Graduate Program from ITU. She had research experience from TU Delft, Hyperbody Research Group (2006–2007), ETH Zurich, Chair of Structural Design (2013–2014), University of Oregon, Department of Philosophy (2017), and Université de Versailles Saint-Quentin-en-Yvelines (2017–2018). Currently, she is an Associate Professor at ITU, Faculty of Architecture, where she has been the Departmental Vice Chair at the Department of Architecture between 2021–2022 and the Coordinator of the Architectural Design Computing Graduate Program between 2018–2021 (E-mail: alacams@itu.edu.tr).