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Original Research Article

Learning from Ambiguous Drawings: The Role of Design Tasks in Improving the Effect of Ambiguous Drawings on Students' Design Ideation

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Abstract

Problem statement: Ambiguous drawings play a significant role in design education, and it has been extensively studied in previous literature. The present research seeks to explore the effects of design tasks on using ambiguous drawings.

Research objective: The purpose of research is to enhance idea generation in students, especially novice students (second-year students) through the assistance of design tasks.

Research method: In this experimental study, second-year architecture students engaged in three design sessions, each with distinct tasks and instructions involving ambiguous drawings. In the first session, ambiguous drawings were used as a source of inspiration, in the second as a design solution, and in the third, those drawings were incorporated to serve as a part of the design solution. Design ideas from the students were assessed by three judges, and scores related to novelty and quality were subjected to statistical analysis using the analysis of variance. The study's findings were then compared and analyzed in the context of existing research.

Conclusion: The results of the study demonstrated that the use of ambiguous drawings in design tasks led to an improvement in the quality of design ideas among students. This positive impact was particularly notable in relation to enhancing the functional aspects of design ideas and convergent thinking. It also extended the results of previous research, especially in terms of the effectiveness of ambiguous drawings on the ideation of novice students. Additionally, the influence of the design tasks, along with other factors, on the ideation of students when using ambiguous images was deeply explored and discussed.

Keywords: *Ambiguous drawings, Design tasks, Design education, Architecture students.*

Introduction

Ambiguous drawings play a crucial role in the ideation phase of the design process. Expert designers use these free-hand sketches at the outset of the design process and manipulate them to generate design solutions. The key characteristic of these drawings is ambiguity (Goel, 1995). They are incomplete and cannot be directly used as a

solution to a design problem. Expert designers use them as a design tool to explore design ideas (Suwa et al., 2000). Research indicates that novice designers, compared to experts, tend to focus more on the superficial features of free-hand sketches (Jia et al., 2023). However, experts spend more time interpreting the design shapes, considering different aspects of these drawings (Kavakli & Gero, 2003). Other research findings

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show that novice students from various design disciplines do not pay attention to the functional aspects of ambiguous drawings. Therefore, it is essential for novice designers, especially students, to consider different aspects of these drawings (Yuan et al., 2018) to lead them toward behavior resembling that of expert designers.

The research examines how the effect of ambiguous drawings can be improved by different design tasks. The structure of the article is that, in the literature review section, the review of the literature, the role of the design task and then the research question are discussed. The research method section explains about the participants and the research process. The next section presents the findings related to the novelty and quality, and the role of design tasks is explored in the discussion, comparing results with previous research. Finally, the research results are presented in the last section.

Literature Review

In design education, various studies have examined the impact of images on students design ideas (Borgianni et al., 2020; Jang et al., 2019; Jia et al., 2023; Wang & Han, 2023). By comparing the use of complete and ambiguous images, it was found that ambiguity had a better effect on increasing the creativity of students (Wang & Han, 2023). Similarly, Cheng and colleagues observed that the use of incomplete images was more effective in increasing creativity than complete images related to design examples (Cheng et al., 2014). This result aligns with another study that showed images related to similar examples of the design problem hinder creativity (Cardoso et al., 2009), and more accurate drawings may impose limitations on generating design ideas (Toh & Miller, 2014). In another study, it was revealed that using more images could increase innovation and divergent thinking, while a limited number of images enhance the quality of design ideas and convergent thinking (Sio et al., 2015). Subsequent research indicated that ambiguous images from a specific domain contribute to convergent thinking and improving

the quality of design ideas, while ambiguous images from different domains contribute to generating new ideas and divergent thinking (Jang et al., 2019). However, in a study conducted with novice students, findings showed that the use of images was not effective in improving the quality of design ideas (Borgianni et al., 2020).

• The role of design tasks in utilizing ambiguous drawings

At the beginning of the design process, designers receive a brief related to a design problem. The problem statement includes a set of design requirements. Alongside the design problem, visual drawings can be provided as an inspiring source, accompanied by additional instruction for utilizing images. Research showed that students, without specific instructions on using images, are not able to enhance design ideas (Casakin, 2010). Several studies have been conducted on the impact of design tasks on design ideas among students (Casakin, 2010; Koronis et al., 2021). Based on the results, the use of design tasks can lead advanced students and not novices to generate better design ideas (Kapkin & Joines, 2020). Therefore, in previous research, design tasks have been unable to increase the effectiveness of ambiguous drawings for novice students. A summary of studies related to the role of ambiguous drawings in design research is presented in Fig. 1.

• Design task and different use of ambiguous drawings

As mentioned in the previous section, design tasks could not enhance the use of ambiguous drawings among novice students. Therefore, in the current research, the objective is to increase the effectiveness of those visuals by design tasks. In this regard, a different method is proposed, which might enhance the idea generation of novice designers. In past research, students typically found a solution based on a set of functional requirements related to the problem. However, the new method introduces a reverse process where a form related to the design solution is presented. This form is interpretable and can lead designers

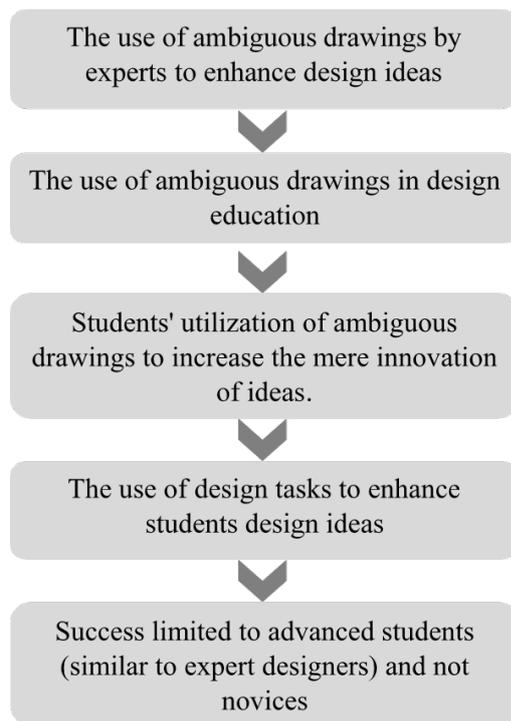


Fig. 1. Based on past research, the role of ambiguous drawings and design tasks in design education has been identified. Source: Authors.

to find appropriate functions that correspond to that form (Ball & Christensen, 2022). Considering the limitations of previous research about the effectiveness of design tasks, the proposed method in this research involves defining new design tasks, experienced by novice students.

Research Question

Based on previous research, it was observed that, unlike expert designers, students, especially novice students, are unable to utilize ambiguous drawings to improve their design solutions (Borgianni et al., 2020; Koronis et al., 2021). Additionally, there have been limited studies on the role of design tasks in relation to novice students. The main objective of our research is to extend the use of ambiguous drawings in design education. This study focuses on ambiguous drawings and their impact using various design tasks. Therefore, the research question is What is the impact of design tasks on the effectiveness of ambiguous drawings in the design ideation of novice students?

Research Methodology

The study aims to address the research question by conducting design tasks in two forms. Initially, a literature review-style design task will be given to novice students using ambiguous drawings (control group). In the subsequent sessions (experimental group), a different method will be employed, where ambiguous drawings can lead students to emphasize function. It is hypothesized that when ambiguous drawings visually resemble the design problem solution, less time will be spent on shaping the form, allowing designers to allocate more time to focus on the function.

To address the research question, 35 undergraduate architecture students ($SD=0.24$, $M=20.06$, 12 males, 23 females) volunteered for the study. The sample size of 35 aligns with previous research (Borgianni et al., 2020; Koronis et al., 2021). The design exercises of the study were conducted in the middle of the semester, and the topic of the design tasks resembled the design of an educational space, ensuring that students had basic knowledge of designing educational spaces. Students were not informed about the research topics to avoid bias in the results' validity. In each session, a design task was provided to the students, and they were required to ask any questions before starting the exercise. Each design session lasted for 60 minutes, with announcements made at 30 and 45 minutes. Students were instructed to sketch and take notes on all their design ideas during the design sessions. An additional five minutes were given for participants to add further comments on their design ideas.

The design sessions were spaced two weeks apart. All participants were in their second year of study and were experiencing their first architectural design. The instructions for using ambiguous drawings were altered in each session. The first session (control group) involved using ambiguous drawings as an inspiring source, similar to previous research (Casakin et al., 2023; Goldschmidt & Smolkov, 2006). In the second and third sessions, the presented drawings had visual similarities to

the design solution, resembling an architectural plan related to the problem solution.

• Design tasks

Each design task included the requirements for an educational building, site properties, ambiguous drawings and instructions on how to use images. Minor variations were applied in the requirements and site features for each of the three design tasks. Additionally, the instructions on how to use ambiguous drawings were modified for each design task.

- Design task 1

As previously mentioned, the instruction for using images in the first design session was based on utilizing ambiguous drawings as an inspiring source (Fig. 2). These drawings were related to two international architects, Renzo Piano and Zaha Hadid (Fig. 2). Students were required to present their ideas regarding the plan, volume, and building elevations.

- Design tasks 2 and 3

The ambiguous drawings used in the second and third sessions were different from the figures in the first session. Generally, lines used in design drawings can be formal and symbolic (Menezes & Lawson, 2006). Formal lines describe geometric or shape features like circles or squares. Symbolic lines are related to architectural symbols such as lines representing walls or windows. To create an ambiguous drawing, symbolic features were removed from the drawings (Fig. 3). The resulting combination of formal shapes has the potential for various interpretations. Since students may not use drawings with a high rate of ambiguity (Tseng, 2018), the drawings used in the second and third design tasks had relatively low levels of ambiguity, as essential perceptual features such as shape vertices were not removed (Biederman, 1987). Each student was required to interpret the drawings and transform them into architectural plans based on given requirements while also presenting design ideas related to the building's volume or façade (Fig. 3).

In the second design session, students were

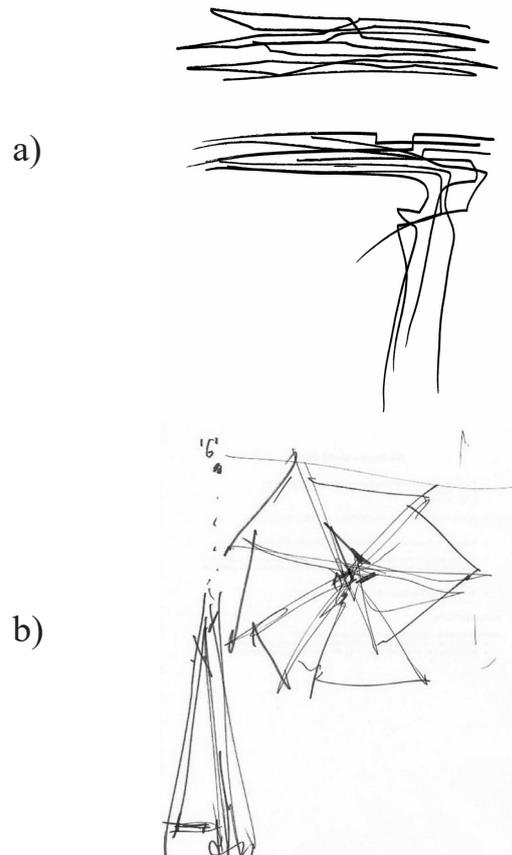


Fig. 2. Design brief 1 and ambiguous images, the description and sketches. a) a free-hand sketch by Renzo Piano. Source: <https://www.pinterest.com/pin/373306256583367243/> b) a drawing by Zaha Hadid. Source: <https://www.pinterest.com/pin/381750505883555909/>

A library with following requirements is needed: 2 reading rooms (each one about 150 m²), storage about 80 m², 3 rooms (librarian office, registration room and service desk about 20 m²), 1 copy room about 20 m², 1 room for journals about 60 m², 1 room for reference books about 100 m², pantry about 6 m², 2 restrooms about 50 m², conference hall about 150 m².

In addition of the above list, circulation spaces consist of entry foyer, reception of conference hall, and a waiting space near borrow desk is needed.

Site: The north and south dimensions are 40 meters and the other sides are 80 meters. Accessory is in the west side of the site and the other three sides are residential and commercial spaces.

instructed to use ambiguous drawings, which were based on architectural plans, as part of their design solution. Based on the design problem requirements, these images could be transformed into architectural plans. Since the design problem pertained to designing a library, the provided ambiguous drawings were related to the architectural plans of a library (Figs. 3 & 4).

In the third design session, an ambiguous drawing

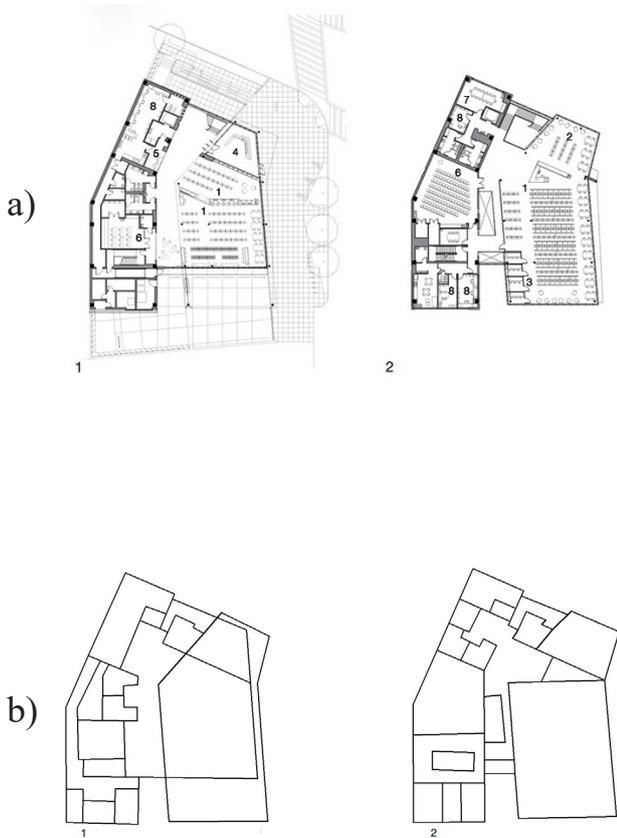


Fig. 3. The architectural plans and the ambiguous images produced from those plans. Source: <https://www.archdaily.com/403937/district-of-columbia-public-library-the-freelon-group-architects>. a) architectural plans of a library, b) the ambiguous images produced the plans. Source: Authors.

was utilized as a component of the design plan solution (Fig. 5). The image resembled the second session (Fig. 4), with a deliberate omission of a section of the plan. Students were tasked with adding elements to complete the architecture plan (Fig. 6).

- Measurement

To assess the “effectiveness”, four criteria are used (Shah et al., 2003). Images can impact the “quantity”, “novelty”, “variety” and “quality” of design solutions (Shen et al., 2021). These criteria measure the number of generated ideas (quantity), the level of unexpectedness (novelty), the amount of difference between the ideas (variety), and how well they meet the design requirements (quality) (McKoy et al., 2001). In the current study, diversity

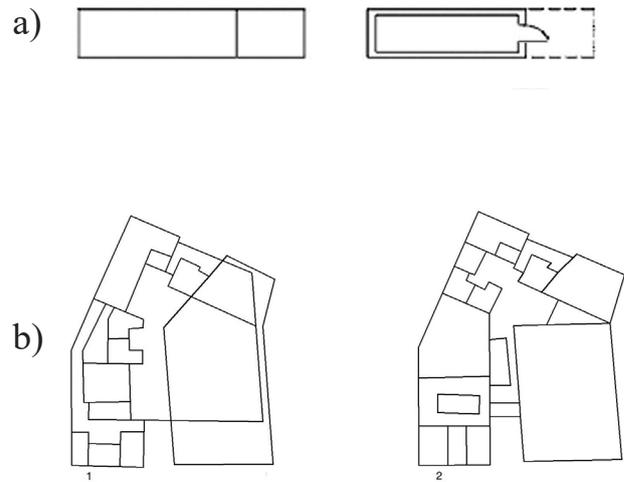


Fig. 4. Design brief 2 and the given images. a) The description and the ambiguous representations, b) the architectural layouts which can be the plans of first and second floors. Source: Authors.

It is required to design a library by using the architectural layouts (figure b). The images are similar to the architectural plans of design solution. The lines of the images can be interpreted as different architectural elements (walls, windows, doors, etc.). An example of how an architectural layout can be interpreted to an architectural plan is shown in figure a.

List of requirements:

1 reading room (book cases and tables are near each other), service desk, 1 storage, 1 office room, 1 meeting room, 2 rest rooms, patio, stairs, conference hall (with second accessory from outside), 1 computer room, 1 audio visual room, elevator, entrance hall.

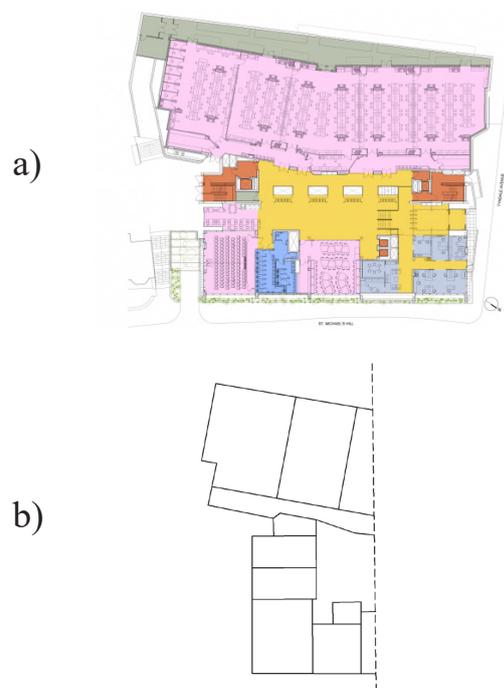


Fig. 5. An architectural plan and the ambiguous image produced from a part of that plan. a) architectural plan of a science center. Source: <https://www.archdaily.com/618167/bristol-life-sciences-building-sheppard-robson> b) the ambiguous image produced forms from a part of the plan. Source: Authors.

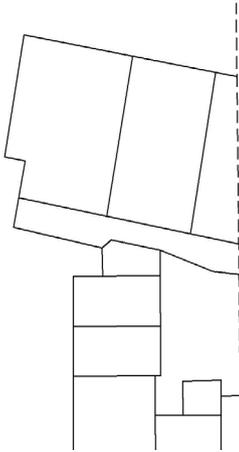


Fig. 6. Design brief 3 and its image. The description and ambiguous drawing, a part of an architectural layout. It is required to design a cultural center, in which the following architectural layout (figure a) is used as a part of the building plan. The lines of the images can be interpreted as different architectural elements (walls, windows, doors, etc.). There is landscape around the building of cultural center.

List of requirements: 6 studios, 3 offices, 1 meeting room, 1 storage, 2 rest rooms, patio, stairs, conference hall (with second accessory from outside), 1 audio visual room.

Site: Accessories are on the east and the west sides. Source: Authors.

was not examined as the focus of the design tasks in the second and third sessions was on developing solutions. Therefore, the measurement criteria include two factors: novelty and quality. Novelty relates to the form and spatial composition, while quality concerns meeting the problem requirements, including the physical program and site.

For evaluation, typically multiple judges are used to provide more accurate results (*ibid.*). Similar to previous research, the judges in this study were master's architecture students, and they were unaware of the research objectives (Goldschmidt & Smolkov, 2006; Zahner et al., 2010). Judges independently assessed each design idea (written descriptions and drawings) based on "novelty" and "quality". To familiarize judges with the evaluation process and enhance rating accuracy, they reached an initial agreement on the two criteria before starting the scoring.

• Examples of students' design ideations

Fig. 7 illustrates examples of proposed design ideas for three design tasks. In the first sample, the

designer mentions that the provided sketches evoke a sense of freedom in his design (average novelty score=4.33, average quality score=3.33). In another example related to the second session, the designer classifies spaces into public and private based on their functionality (average novelty score=3.00, average quality score=4.33). Finally, in the example from the third session, the designer focuses on accessories in spaces and their relationships (average novelty = 4.33, average quality = 3.67).

Analysis

To compare differences between different sessions, the reliability of the judges' scores needs to be established first. In this regard, the Pearson correlation coefficient is utilized. If enough association between judges' ratings exists, the average scores of judges for each presented design task are then determined. To compare the impact of each of the three conditions on the two factors of novelty and quality, analysis of variance (ANOVA) is employed. This method focuses on the difference in means between each pair of groups and assesses whether this difference is statistically significant or not. The variable "F" should have a value greater than 1, and the "Sig" or "P" value should be less than 0.05 to indicate that the difference between different sessions is significant (Lindman, 2012). ANOVA is commonly used in studies related to the influence of various types of images on students' creativity (Goldschmidt & Sever, 2011; Goldschmidt & Smolkov, 2006; Mohamed-Ahmed et al., 2013; Park et al., 2006; Yekhina, 2007).

Results and Findings

• Correlation between judges' scores

To assess the differences between different design sessions, the scores for each exercise were compared with scores from other exercises. The results of the Pearson correlation coefficient analysis indicate an acceptable level of correlation for all judges ($p > 0.05$). It can be expected that their scores have the necessary reliability for the next stage of analysis.

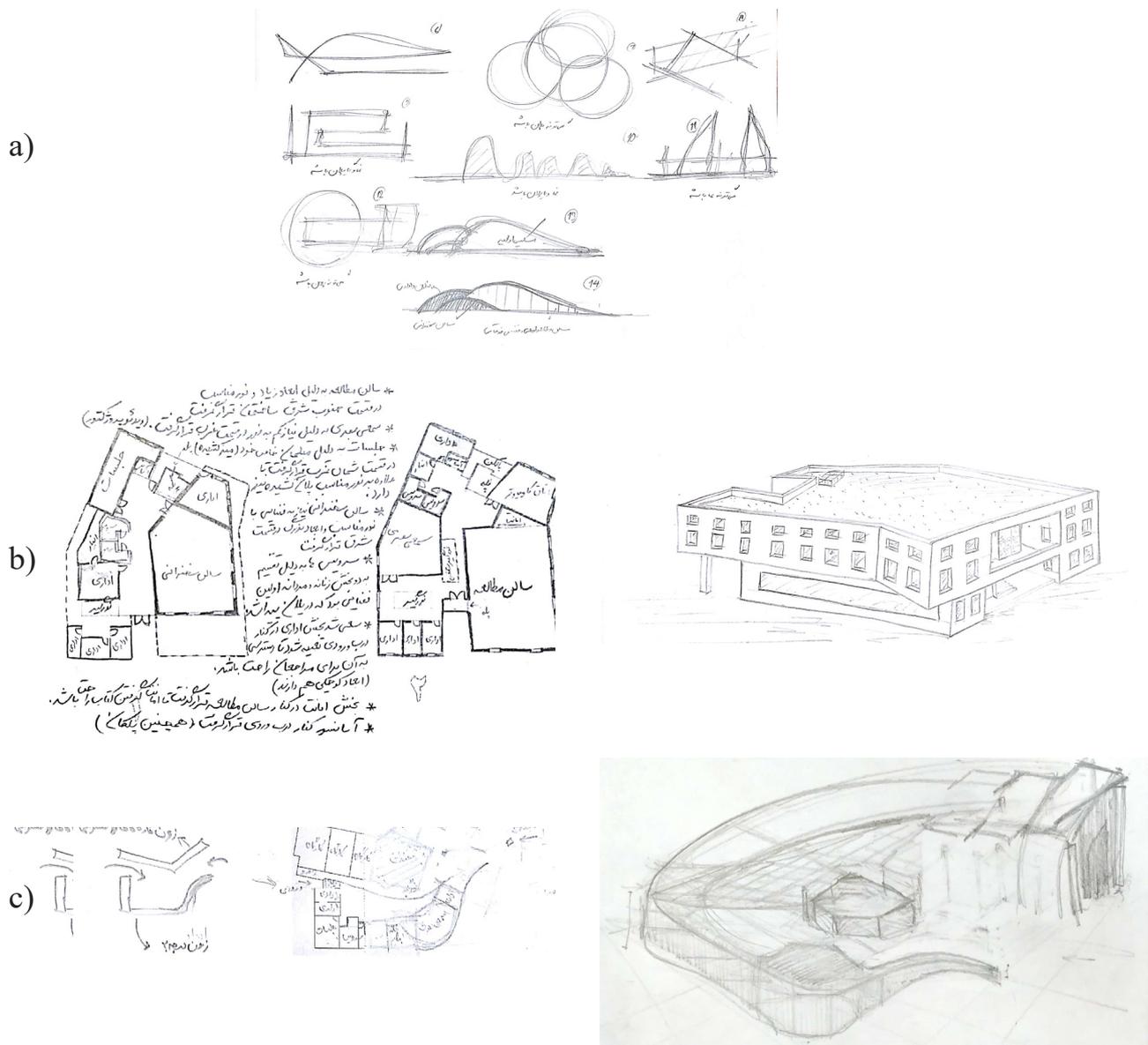


Fig. 7. Examples of design solutions, a) A part of a subject's drawings for the first design session (control group), b) An example of the second design session (experiment group), c) An example of the third design session (experiment group). Source: Authors.

• **Novelty factor**

The analysis of variance was conducted to assess the difference in the novelty score, revealing an F-value of 1.148 ($p < 0.05$). The results indicate that there is no significant difference among the exercises. Examining the average novelty scores for the three tasks (3.36, 3.08, and 3.42), it is observed that the novelty score's mean is highest in the first design session (control group) and the third session, while the second session has the lowest mean. No specific references were provided for this summary.

• **Quality factor**

The findings regarding the quality score revealed a significant F-value of 5.878 ($p < 0.05$). The mean quality scores for design tasks one to three were 3.15, 3.79, and 3.69, respectively. Employing the Bonferroni post hoc test, which considered the same participants across all three sessions, revealed significant differences between the second and first sessions ($p < 0.006$) and between the first and third sessions ($p < 0.025$). However, there was no significant difference between the second and third sessions ($p > 0.1$). These results suggest that

the design task influences the quality of design ideas. Sessions two and three prompted students to concentrate more on the functional requirements, resulting in the highest quality scores. The lack of significance between sessions two and three may be attributed to the similarity of design tasks.

Discussion

The study aimed to investigate the impact of design tasks on the use of ambiguous drawings, revealing significant changes in quality scores between the initial and subsequent design sessions. Interpreting functional aspects using ambiguous drawings proved challenging for students, aligning with previous research highlighting a preference for focusing on the novelty of design ideas (Borgianni et al., 2020; Goldschmidt & Smolkov, 2006; Koronis et al., 2021). Interestingly, none of the design tasks significantly altered the novelty score, suggesting that employing ambiguous drawings as a source of inspiration or solution did not lead to a meaningful difference. These findings emphasize the importance of design tasks in education (Fig. 8) and extend previous research that failed to enhance the quality of design ideas through such tasks (Kapkin & Joines, 2020).

Given that the present research has focused on the designs of students, alongside statistical analyses, some of the design samples are examined in more detail (Table 1). Participants in the first session consider more the form and geometry of each of the two given images, with less focus on functional aspects. In the second session, special attention was given to functional issues, resulting in less focus

on form. In the third session, although the plan geometry and its combination were considered, the emphasis was more on functional issues.

Fixation, a negative phenomenon in the design process, occurs when designers excessively rely on images or given examples, resulting in a decline in creativity through imitation. To prevent this, it is recommended to use images as a source of inspiration rather than a solution (Casakin et al., 2023). Utilizing images as the answer to a problem may lead to fixation. However, the ambiguity of images can act as a factor in increasing innovation and reducing fixation (Benami & Jin, 2002). When comparing the novelty score in the first task, where drawings served as inspiration, with subsequent sessions where images were used as a solution, no significant difference was observed. It can be inferred that fixation did not occur in the second and third sessions.

The findings demonstrated the superiority of the design task over the images' domain. Previous research suggested that the similarity between the image domain and the design problem could increase convergent thinking, whereas differences might enhance divergent thinking (Jang et al., 2019). However, in the current study, all images had the same domain and were related to architectural examples, the design task notably enhanced the quality of the last two exercises and convergent thinking.

One notable finding concerns the favorability of the design task over the number of images. Previous studies suggested that a greater number of images could boost novelty, while a smaller number might

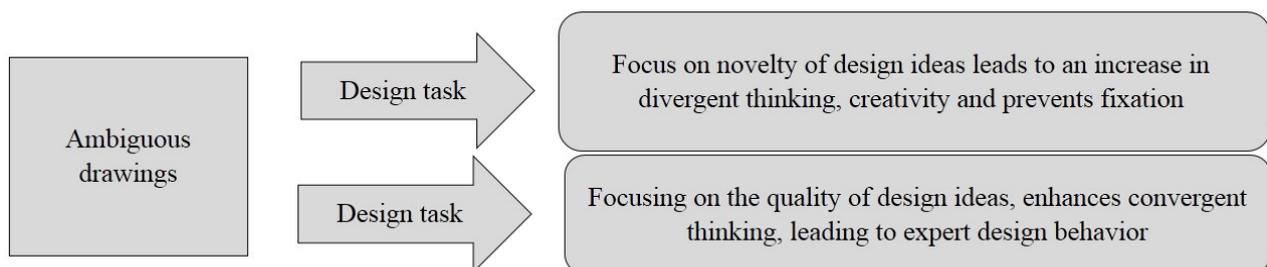
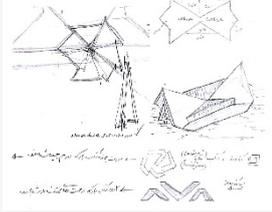
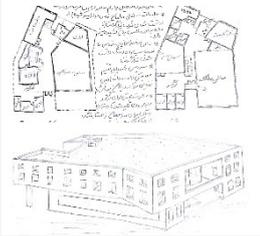
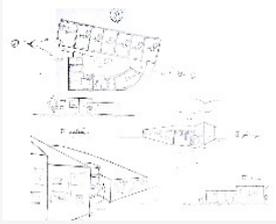
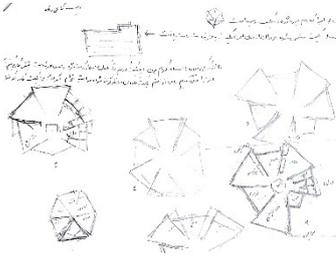
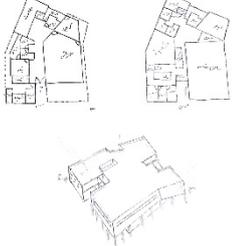
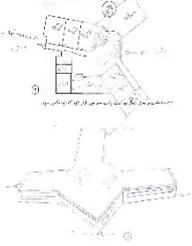
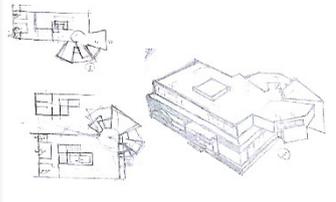
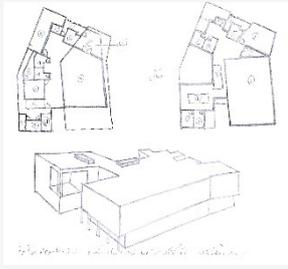
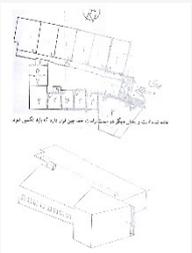
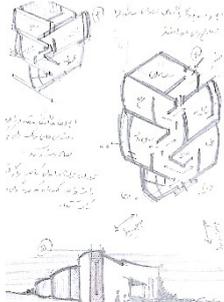
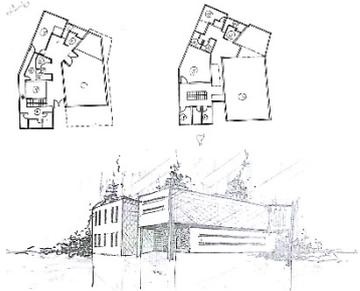
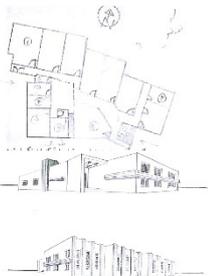


Fig. 8. Summary of results regarding the design task. Source: Authors.

Table 1. Examples of design tasks of 3 design sessions: Drawings and design ideas. Source: Authors.

Person	1st session	2nd session	3rd session
1	 <p>Combining the geometry of 2nd image with the form of a book.</p>	 <p>Considering proportions, lighting, accessibility, and sound</p>	 <p>Proportions, lighting, geometry, and acute angle of the image.</p>
2	 <p>Utilizing the geometry of 2nd image (transitioning from the part to the whole)</p>	 <p>Proportions, prioritizing accessibility on different floors.</p>	 <p>Proportions, lighting, and radial geometry</p>
3	 <p>Utilizing the radial nature of image 2 and the layered quality of image 1.</p>	 <p>Proportions of spaces, scale, lighting, and accessibility</p>	 <p>The angle between two geometries, lighting, and proportions</p>
4	 <p>Combining the geometry of 2nd image with the form of a book.</p>	 <p>Overall classification (study space, administrative area, service facilities), proportions, accessibility</p>	 <p>Geometry and its properties, accesses, and positions</p>

improve the quality of design ideas (Sio et al., 2015). However, in the initial session, utilizing only two images did not significantly influence solution quality. The design task emerged as the primary factor in enhancing solution quality, particularly in the last two design tasks.

An important finding of this research was the impact of design tasks on idea generation for first-year students. Previous research has indicated that first-year students might not be able to produce high-quality design ideas with the help of images (Borgianni et al., 2020). Second-year students, although more experienced than first-year students, couldn't focus on the quality of design ideas, unlike students in the later years (Ozkan & Dogan, 2013). Previous studies have also shown that instructions for using images can guide only senior students toward behavior similar to experienced designers (Casakin, 2010; Koronis et al., 2021; Ozkan & Dogan, 2013). However, the present research demonstrated that second-year students improved their design ideas, highlighting the importance of this aspect in design education. A summary of research findings has been compared with previous studies in Table 2.

The potential negative impact on internal validity due to the exercise effect, where improvement in subsequent exercises may be influenced by experience gained from previous ones (Gall et al., 1996), is acknowledged. To address

this, variations were introduced in problem requirements and site properties for each design session. Comparing grades across the sessions suggests that students leverage their experience, resulting in higher scores (1<2<3). However, no significant difference was noted between grades for the second and third tasks, particularly the third task, where students had more experience. Quality scores showed only 1<2 and 1<3, with no significant difference between 2 and 3. Additionally, the study acknowledges the limitation of the relatively small dataset (35 cases for each design session), deemed suitable for an exploratory study.

Conclusion

This research demonstrated the significant role of the design task when using ambiguous drawings. Various instructions for using images led to different experiences for students and answered the research question. Specifically, alongside using ambiguous drawings as a source of inspiration, these drawings were also used as a visual response to the design problem. This, in turn, enhanced the role of ambiguous drawings in the ideation process of novice students. Therefore, ambiguous drawings, with the assistance of a design task, can play a crucial role in design education. Novice students can improve not only the novelty aspect but also

Table 2. Comparison between research findings and previous literature. Source: Authors.

Number	Results of previous research	Results of current research
1	Students unable to increase the quality of design ideas by using images. (Borgianni et al., 2020; Goldschmidt & Smolkov, 2006; Kapkin & Joines, 2020)	Increase of design quality by applying ambiguous images
2	Effective design tasks for advanced students and not novices(Casakin, 2010; Koronis et al., 2021; Ozkan & Dogan, 2013)	The effectiveness of the design task for second-year students (novices)
3	The impact of the number of images on the quality of design ideas(Sio et al., 2015).	Preference for the effect of “design task” over the effect of “number of images
4	The effect of the domain of images on design ideas(Jang et al., 2019).	Preference for the role of the “design task” over the “domain of images” in enhancing the quality of design ideas

the quality of their design ideas. The results of this study can be valuable not only for educators but also for architecture researchers, helping them explore the impact of various types of images with different design tasks, particularly for novice students for whom design education is crucial.

Conflict of Interest

The authors declare that there was no conflict of interest for them in conducting this research.

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