Guided Mind Mapping for Enhancing Spatial Thinking in First-Year Architectural Design Studios / Original Article

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الخرائط الذهنية الموجَّهة لتنمية التفكير المكاني لدى طلبة السنة الأولى في استوديوهات التصميم المعماري

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Abstract

Spatial thinking constitutes a core cognitive ability in early architectural design education, enabling students to interpret, organize, and transform spatial relationships into coherent architectural configurations. Despite its importance, studio practice often indicates that first-year students rely on surface-level representation rather than engaging in structured spatial reasoning, which leads to fragmented compositions and weak spatial coherence.

Accordingly, this study investigates the following research question: *To what extent can guided mind mapping support the development of spatial thinking in early architectural design studios*? A quasi-experimental design was adopted to examine the impact of structured visual–cognitive guidance on students' spatial reasoning. The study involved two groups of first-year architecture students: an experimental group trained using guided mind mapping (n = 133) and a control group receiving conventional studio instruction (n = 127).

Students' performance was evaluated through a house design task using standardized descriptive–quantitative assessment rubrics, and statistical analysis was conducted using paired-samples and independent-samples t-tests at a significance level of $\alpha = 0.05$. The results reveal a statistically significant improvement in the experimental group (Sig. = 0.000), with mean scores increasing from 26.761 in the pretest to 89.445 in the posttest, whereas the control group demonstrated a limited and non-significant improvement (Sig. = 0.089). Although posttest differences between the two groups did not reach statistical significance (Sig. = 0.068), qualitative analysis indicates that the experimental group achieved higher levels of spatial coherence, clearer organization of spatial relationships, and stronger integration between form and function.

The findings confirm that guided mind mapping operates as a cognitive mediator that supports the transition from spatial perception to structured spatial reasoning. It enhances students' ability to regulate spatial transformations and contributes to the production of more coherent and conceptually grounded architectural design outcomes in early design education.

Keywords: Architectural education, spatial thinking, mind mapping, design cognition, Visual–cognitive frameworks, design studio

المستخلص

يمثل التفكير المكاني إحدى القدرات المعرفية الأساسية في تعليم التصميم المعماري المبكر، إذ يتيح للطلبة تفسير العلاقات الفراغية وتنظيمها وتحويلها إلى تكوينات معمارية متماسكة. وعلى الرغم من أهميته، تكشف ممارسات الاستوديو أن طلبة المرحلة الأولى غالبًا ما يعتمدون على التمثيل الشكلي السطحي بدلًا من تبني تفكير مكاني منظم، مما يؤدي إلى تكوينات مجتزئة وضعف في الترابط الفراغي.

وعليه، تهدف هذه الدراسة إلى الإجابة عن السؤال الآتي: إلى أي مدى يمكن للخرائط الذهنية الموجَّهة أن تسهم في تنمية التفكير المكاني لدى طلبة التصميم المعماري في المراحل المبكرة؟ تم اعتماد منهج شبه تجريبي لتحليل أثر التوجيه البصري–المعرفي المنظم على قدرات الطلبة. شملت الدراسة مجموعتين من طلبة المرحلة الأولى: مجموعة تجريبية دُرِّبت باستخدام الخرائط الذهنية الموجَّهة ($n = 133$)، ومجموعة ضابطة تلقت التعليم التقليدي في الاستوديو ($n = 127$).

تم تقييم أداء الطلبة من خلال تمرين تصميم بيت باستخدام معايير تقييم وصفية–كمية موحدة، كما تم إجراء التحليل الإحصائي باستخدام اختبار (T) للعينات المرتبطة والمستقلة عند مستوى دلالة ($\alpha = 0.05$) .أظهرت النتائج وجود تحسن دال إحصائيًا لدى المجموعة التجريبية (Sig. = 0.000)، إذ ارتفع متوسط الأداء من (26.761) في الاختبار القبلي إلى (89.445) في الاختبار البعدي، في حين أظهرت المجموعة الضابطة تحسنًا محدودًا غير دال إحصائيًا (Sig. = 0.089) .وعلى الرغم من عدم وجود فروق دالة إحصائيًا بين المجموعتين في القياس البعدي (Sig. = 0.068)، إلا أن التحليل النوعي أظهر تفوقًا واضحًا للمجموعة التجريبية من حيث تنظيم العلاقات المكانية، واتساق التكوين الفراغي، والتكامل بين الشكل والوظيفة .

تؤكد هذه النتائج أن الخرائط الذهنية الموجَّهة تعمل كوسيط معرفي يدعم الانتقال من الإدراك المكاني إلى التفكير التصميمي المنظم، وتسهم في ضبط عمليات التحويل الفراغي، وتعزيز إنتاج حلول معمارية أكثر تماسكًا واتساقًا في مراحل التعليم الأولى.

الكلمات المفتاحية: التعليم المعماري، التفكير المكاني، الخرائط الذهنية، الإدراك البصري، الاطر – البصرية المعرفية ، استوديو التصميم

1. Introduction

Architectural design education in its early stages is fundamentally concerned with developing students' ability to interpret and organize spatial relationships into coherent design systems. Spatial thinking constitutes a central cognitive process through which architectural form is perceived, structured, and transformed into meaningful configurations. Within this process, architectural knowledge is not understood as isolated formal elements but as an organized system of spatial relationships, hierarchies, and functional interactions that collectively define design logic and spatial experience.

Despite this theoretical foundation, evidence from first-year design studios consistently reveals a gap between perceptual recognition and structured spatial reasoning. Students tend to engage with architectural precedents at a visual level, often reproducing formal appearances rather than interpreting the underlying relational structures that govern spatial organization. This tendency frequently results in fragmented compositions, weak spatial coherence, and limited integration between form, function, and context. Such limitations have been widely discussed in recent studies, which indicate that novice designers often struggle to manipulate spatial relationships in a systematic and controlled manner [1], [2].

Recent research in architectural education has increasingly emphasized the importance of visual–cognitive tools in supporting design thinking processes. Diagrammatic and relational representations have been shown to enhance analytical reasoning by enabling students to externalize design relationships and structure complex spatial information [2], [3]. Similarly, studies highlight that structured visual frameworks can support the transition from perceptual observation to analytical interpretation, thereby improving students' ability to understand and reorganize spatial systems within design tasks [4], [5].

Within this context, mind mapping has emerged as a promising visual–cognitive tool capable of organizing design knowledge through relational visualization. Unlike linear note-taking, mind maps represent architectural elements, spatial relationships, and governing principles within an interconnected network, allowing students to construct integrated mental models of design problems. Recent studies suggest that such structured visual representations can enhance cognitive organization, support relational reasoning, and facilitate the manipulation of design variables during early design exploration [6], [7]. However, despite the increasing use of mind mapping in educational contexts, its application as a guided and structured framework for developing spatial thinking in architectural design studios remains insufficiently explored, particularly when evaluated through performance-based design tasks. Accordingly, this study investigates the role of guided mind mapping as a visual–cognitive framework for supporting the development of spatial thinking in a first-year house design studio. The study aims to examine how structured mapping can mediate the transition from spatial perception to spatial reasoning and contribute to the production of coherent architectural design outcomes. This approach contributes to addressing contemporary challenges in architectural education by enhancing students' ability to manage increasing design complexity and structured design reasoning processes.

2. Literature Review

2.1 Spatial Thinking in Architectural Education

Spatial thinking constitutes one of the fundamental cognitive capacities underlying architectural design activity. Within architectural cognition, the interpretation of form does not rely solely on visual recognition of shapes but rather on the ability to understand spatial relations, imagine transformations, and reorganize spatial configurations across multiple representational systems. Architectural drawings, models, and diagrams therefore function not only as visual representations but also as cognitive instruments that support spatial reasoning during design development.

Research in design cognition suggests that spatial thinking enables designers to perceive architectural form as an organized system of relationships rather than as isolated visual elements. According to Kosslyn and Thompson [8], spatial cognition involves the mental organization of spatial relations, including orientation, distance, scale, and transformation. Within architectural learning environments, these cognitive processes support the interpretation of plans, sections, elevations, and volumetric relationships that collectively structure architectural space. Ware [9] similarly emphasizes that the interpretation of spatial relations constitutes a central component of visual reasoning in design thinking.

In architectural education, the development of spatial thinking becomes particularly critical during the early stages of design learning. First-year students are required to interpret architectural precedents, understand spatial structures, and manipulate formal relationships through drawings and models. However, several studies in design education indicate that novice designers frequently struggle to interpret spatial configurations in a systematic manner. Lawson [10] explains that inexperienced students often focus on visible formal features rather than on the relational logic that organizes architectural compositions. Similar observations have been reported in more recent research on design studio learning, which identifies spatial interpretation as one of the primary challenges in early architectural education [4], [11].

Consequently, spatial thinking should be understood in architectural education as a structured cognitive competence that enables students to interpret spatial relations, manipulate architectural configurations, and generate coherent design alternatives.

Developing this competence requires pedagogical strategies capable of externalizing spatial relationships and making them cognitively accessible during the design process.

2.2 Components of Spatial Thinking in Architectural Design Learning

Within architectural cognition research, spatial thinking is typically described as a composite ability composed of several interrelated cognitive skills. These include spatial visualization, spatial orientation, spatial perception, and mental transformation. Rather than operating independently, these abilities function together as part of a broader visual–spatial reasoning system that supports design analysis and generative thinking. As illustrated in Figure 1, these components do not operate in isolation but are integrated within a unified visual–spatial reasoning system that organizes spatial principles, elements, and relationships to support design application.

Spatial visualization refers to the ability to imagine spatial configurations and mentally manipulate them across different representational formats. This ability enables architecture students to translate two-dimensional drawings into three-dimensional mental representations and to anticipate how spatial configurations may change through design modifications. Spatial orientation, by contrast, relates to the understanding of positional relationships between objects within space and the ability to interpret directional relations between architectural elements. Kosslyn and Thompson [8] note that these abilities play a central role in spatial reasoning tasks involving mental imagery and spatial transformation.

Empirical studies in architectural education further demonstrate the importance of these abilities for design learning. For example, recent research examining spatial ability among architecture students shows that spatial visualization and mental rotation significantly influence students' capacity to interpret architectural drawings and manipulate spatial configurations during design tasks [12].

Similarly, Türkmenoğlu Berkan *et al.*, [6] demonstrate that structured educational activities such as drawing exercises, representation techniques, and spatial modeling significantly enhance students' spatial perception and visualization abilities. In early design studios, however, students frequently encounter difficulties when attempting to reorganize spatial relations within architectural configurations. These difficulties do not necessarily arise from the inability to reproduce architectural forms but rather from the inability to reinterpret the relational structure that organizes them. As a result, design outcomes may vary visually while still reproducing the same spatial configuration. This challenge highlights the importance of educational approaches that explicitly support the development of spatial reasoning in architectural learning environments.

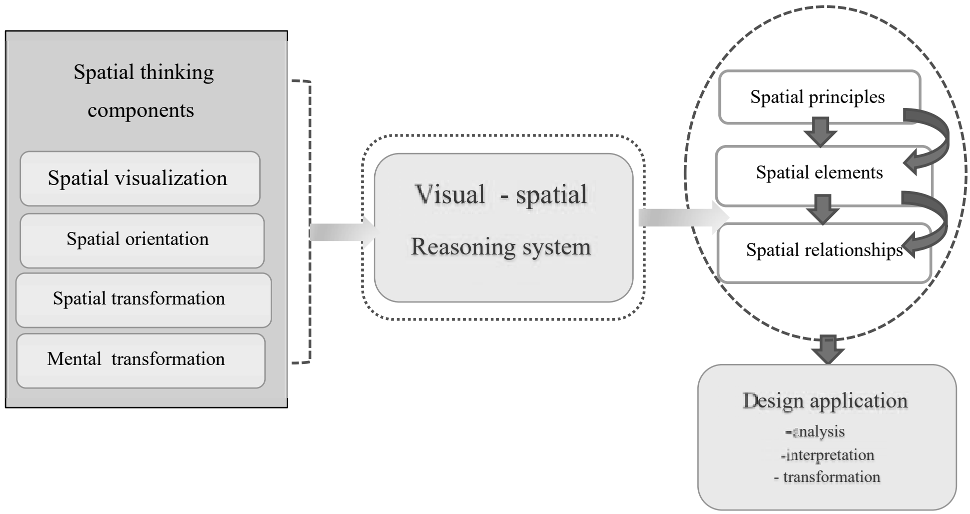


Figure 1. Conceptual model of spatial thinking components as an integrated visual-cognitive system supporting architectural design reasoning. Source: Author.

2.3 Mind Mapping as a Visual–Cognitive Tool in Architectural Education

Mind maps have increasingly been adopted in educational contexts as visual tools capable of organizing complex information through relational representation. Unlike linear note-taking structures, mind maps arrange concepts, ideas, and relationships around a central node, allowing knowledge to be represented within a spatial network of interconnected elements. This visual organization supports comprehension, memory, and conceptual reasoning by externalizing relationships that may otherwise remain implicit in verbal explanation.

Within architectural education, this characteristic makes mind mapping particularly relevant. Architectural design problems involve multiple interconnected layers including spatial organization, functional relationships, circulation patterns, structural logic, and contextual conditions. Mind maps can therefore assist students in structuring these complex relationships within a visually organized analytical framework. Salama [13] emphasizes that visual structuring tools play a significant role in design education by supporting analytical reasoning and knowledge organization within studio learning environments.

Research on visual thinking tools similarly suggests that diagrammatic frameworks help designers organize design information and explore relationships between design variables. Eppler [2] explains that visual knowledge structures such as mind maps enhance analytical reasoning by making conceptual relationships visible. When architectural elements and their relationships are visually represented, students are better able to interpret the internal structure of design problems and identify connections between spatial components.

Studies examining the use of mind mapping in design methodology further highlight its potential role in supporting design thinking processes. For example, demonstrates that mind mapping can assist designers in decomposing complex design problems and organizing conceptual relationships during early design exploration. By arranging design variables within a relational visual structure, mind maps support the interpretation of architectural information and facilitate the generation of structured design ideas.

2.4 The Role of Mind Mapping in Developing Spatial Thinking

The relationship between mind mapping and spatial thinking lies primarily in the ability of guided visual frameworks to externalize spatial relations and support their cognitive manipulation. Spatial thinking in architecture requires the ability to identify spatial relationships, interpret spatial hierarchies, and reorganize spatial configurations during design development. Mind maps can facilitate this process by representing spatial relationships within a structured relational diagram. As illustrated in Figure 2, guided mind mapping mediates the transition from spatial perception to controlled spatial transformation.

When students analyze architectural precedents or design tasks using guided mind maps, they are encouraged to move beyond simple visual observation toward relational interpretation. Architectural elements become connected within a network of spatial relations that may include adjacency, enclosure, hierarchy, orientation, and proportional organization. Through this process, students develop a more integrated mental model of architectural space that supports spatial reasoning during design development.

Recent research in architectural education indicates that structured visual tools can enhance students' capacity to organize spatial and compositional information. Diagrammatic representations have been shown to support analytical reasoning in design studios by enabling students to visualize relationships between design elements [3], [4]. In this context, mind maps function as relational diagrams that help students interpret and reorganize spatial information within design tasks.

Furthermore, guided mind maps can support the transition from spatial interpretation to spatial manipulation. When relationships between architectural elements are explicitly represented, students are able to explore alternative spatial configurations by modifying these relationships. Such operations may involve reorganizing spatial hierarchies, altering functional relationships, or redefining circulation structures within architectural compositions. Through this mechanism, spatial thinking becomes an active process of interpretation and transformation rather than passive observation.

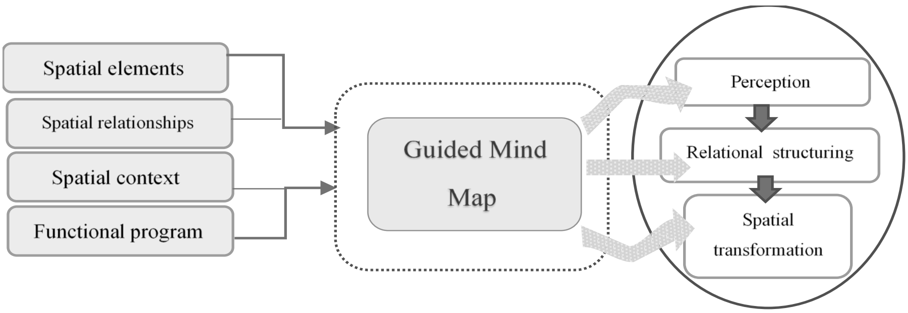


Figure 2. Cognitive mechanism of guided mind mapping in developing spatial thinking through perception, relational structuring, and spatial transformation. Source: Author.

2.5 Integrating Mind Mapping with Spatial Thinking in First-Year Design Studios

Within first-year architectural design studios, students are required to simultaneously develop skills in interpreting architectural representations and generating design proposals. This dual demand often creates cognitive overload, limiting students' ability to manage spatial information and to understand how spatial relationships inform design decisions. Consequently, early design learning environments require pedagogical frameworks capable of structuring spatial reasoning processes and supporting the organization of complex design information [4].

Guided mind mapping offers a structured visual–cognitive framework that can support this process. When applied as an analytical tool rather than as an open-ended brainstorming technique, mind maps enable students to identify architectural elements, recognize relationships among spatial components, and organize information within coherent relational structures. Such structured representations facilitate the construction of spatial mental models that underpin design reasoning and decision-making [2].

Furthermore, guided mind mapping contributes to the development of multiple dimensions of spatial thinking. The visual organization of elements and relationships enhances spatial visualization and supports the interpretation of spatial configurations. At the same time, the relational structure of the map allows students to reorganize spatial information, explore alternative configurations, and engage in controlled transformation processes during design tasks [3].

Despite these theoretical advantages, empirical research examining the cognitive impact of guided mind mapping on spatial thinking in architectural education remains limited. While recent studies have explored diagrammatic reasoning, spatial ability development, and visual cognition in design learning, fewer investigations have specifically addressed the role of structured mind mapping in supporting spatial thinking within early design studios [6]. This gap is particularly evident in Iraqi architectural education, where limited empirical work has examined the pedagogical effectiveness of visual–cognitive tools in studio-based learning environments.

Accordingly, the present study aims to address this gap by investigating the effectiveness of guided mind mapping as a structured visual–cognitive framework for developing spatial thinking among first-year architecture students in Iraqi design studios.

3. Methodology

3.1 Research Design

The study adopted a quasi-experimental research design to examine the effectiveness of guided mind mapping in developing spatial thinking among first-year architecture students in Iraqi architectural design studios .This design compares two groups of students: an experimental group exposed to a structured mind-mapping training program and a control group taught through the conventional architectural design studio approach.A pre-test and post-test structure was implemented to evaluate changes in spatial thinking abilities before and after the intervention. Quasi-experimental approaches are widely used in architectural education research because they enable the evaluation of pedagogical interventions within authentic studio environments [14], [10].

3.2 participants

The research population consisted of first-year students enrolled in the Department of Architectural Engineering at the University of Technology in Baghdad, Iraq. This educational stage represents the foundational phase of architectural training, during which students begin to develop essential competencies in visual perception, spatial reasoning, and architectural form composition. At this level, students are introduced to fundamental design principles, visual analysis, and the basic processes of architectural thinking, making it an appropriate context for examining the development of spatial thinking abilities within architectural design education.

The total sample included 260 students collected across two academic years. The first cohort consisted of 225 students from the academic year 2022–2023, while the second cohort included 35 students from the academic year 2024–2025.

Because all participants were first-year students enrolled in the same architectural program and learning environment, the sample can be considered relatively homogeneous in terms of educational background and studio learning conditions.

In terms of demographic characteristics, participants belonged to the typical university entry age range in Iraq, approximately 18–20 years, which corresponds to the standard age of first-year undergraduate architecture students. Age variation within the sample was therefore minimal and was not treated as an independent analytical variable in the study. Similarly, gender distribution was not considered a determining analytical factor, since the design tasks employed in the study evaluate spatial reasoning and visual–cognitive processes that are not dependent on gender differences.

Following the quasi-experimental research design adopted in this study, the sample was divided into two groups. The experimental group (n = 133) received the proposed instructional intervention based on guided mind mapping through a structured training program that included theoretical explanations and a sequence of design exercises aimed at developing spatial thinking abilities. In contrast, the control group (n = 127) followed the conventional architectural design studio instruction without exposure to the mind-mapping intervention, providing a baseline condition for comparison.

This group distribution provides a suitable methodological structure for the quasi-experimental research design, allowing statistical comparison between the two groups in order to evaluate the effectiveness of the guided mind-mapping approach in supporting the development of spatial thinking in architectural design education. The structure of the sample and its division into experimental and control groups is illustrated in Figure 3.

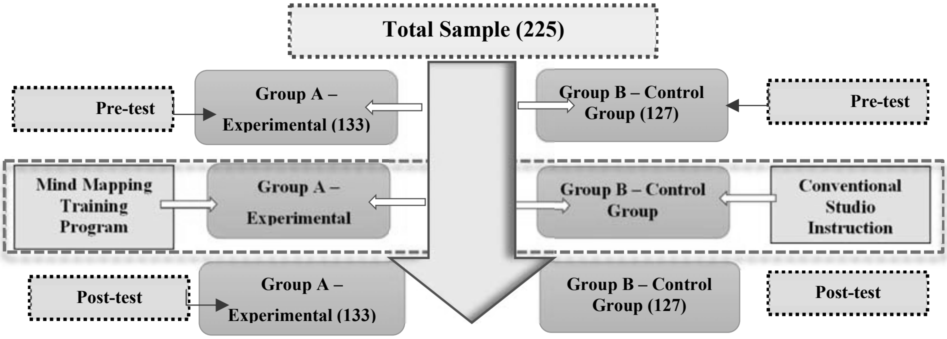


Figure 3. Distribution of experimental and control groups according to the experimental research procedure. Source: Author.

3.3 Research Variables

The present study examines the effect of guided mind mapping as an instructional intervention aimed at supporting the development of spatial thinking within the architectural design studio. In accordance with the quasi-experimental research design, two primary variables were identified: the independent variable representing the instructional intervention and the dependent variable representing students' spatial thinking performance.

To clarify the relationships between the independent and dependent variables and the role of guided mind mapping within the design learning process, a conceptual framework was developed, as illustrated in Figure4 .

The independent variable consists of the guided mind-mapping training program introduced within the architectural design studio. The program was implemented through a structured sequence of theoretical explanations and design exercises intended to organize spatial information visually and to support the interpretation of spatial relationships during architectural design tasks. Through this intervention, mind maps were employed as visual–cognitive tools that assist students in identifying spatial elements, structuring spatial relations, and organizing architectural information within a coherent analytical framework.

The dependent variable represents the level of spatial thinking demonstrated by students during architectural design tasks. Spatial thinking in architectural education involves the ability to interpret spatial relationships, organize functional and circulation systems, and manipulate spatial configurations during the development of architectural form. In the context of the present study, spatial thinking was assessed through the analysis of students’ design outputs produced during the house design exercise, which required students to translate spatial relationships into coherent architectural configurations.

Evaluation of spatial thinking performance was based on a set of observable indicators reflected in students’ design representations. These indicators included the clarity of spatial organization, the effectiveness of zoning and circulation structures, the coherence of spatial relationships between architectural elements, and the ability to generate consistent architectural form based on spatial logic. Such indicators provide measurable evidence of students’ ability to analyze, structure, and manipulate spatial information during the architectural design process.

Through this variable structure, the study examines the extent to which guided mind mapping contributes to improving students’ spatial reasoning abilities in architectural design learning environments.

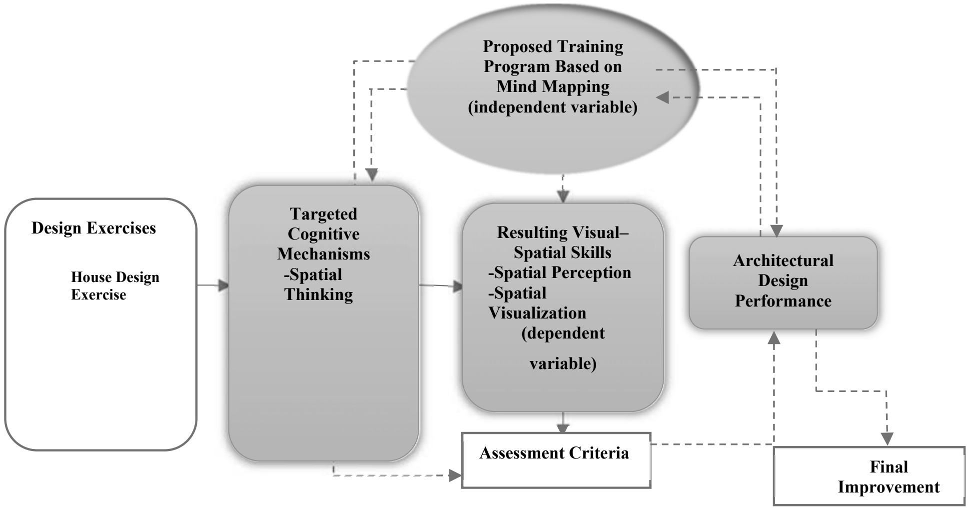


Figure 4. Conceptual framework of the training program for developing visual thinking based on mind mapping. Source: Author.

3.4 Design Tasks

The cognitive processes under investigation were examined through two complementary architectural design tasks based on the house design project, which represents a fundamental exercise in early architectural education. Unlike precedent-based analytical tasks, the selected design tasks required students to generate architectural form through the interpretation and organization of spatial relationships within a defined design scenario.

The house design project was structured to address both contemporary and traditional architectural approaches, allowing students to engage with distinct spatial logics and compositional systems. This dual framework provided a broader basis for examining the development of spatial thinking through the manipulation of spatial organization, functional zoning, and architectural form.

The design tasks were organized as follows:

1. **Modern House Design Task:**

   Students were required to develop a contemporary residential design grounded in the principles of modern architecture. The task emphasized spatial openness, functional clarity, and the integration between interior and exterior spaces. Particular attention was given to the organization of circulation systems, volumetric composition, and the articulation of architectural elements such as openings, structural systems, and façade treatments, reflecting the core principles of modern architectural design.

2. **Traditional House Design Task:**

   Students were required to design a residential unit based on the spatial and organizational principles of the traditional Baghdadi house. The task focused on spatial hierarchy, privacy gradients, and the organization of spaces around a central courtyard. Emphasis was placed on culturally embedded spatial relationships, including transitions between public, semi-private, and private domains, as well as environmental responses such as shading, enclosure, and inward-oriented spatial configurations characteristic of traditional Baghdadi architecture.

The implementation of both design tasks was conducted over a period of four weeks, with two studio sessions per week, ensuring a structured and continuous engagement with the design process. Within this timeframe, students progressed through a sequence of design stages including concept formation, generation of alternatives, evaluation, development, and final presentation, as illustrated in the architectural design process framework. This structured approach ensured that spatial thinking was examined not only as a conceptual cognitive ability but also as an applied design process manifested through students' architectural outputs across both modern and traditional design contexts.

This dual design framework, contrasting modern architectural principles with the spatial logic of the traditional Baghdadi house, provides a critical pedagogical context for examining how spatial thinking develops across different organizational systems. While modern architecture emphasizes openness, continuity, and functional efficiency, the traditional Baghdadi house relies on hierarchy, enclosure, and inward spatial organization. This contrast enables a deeper understanding of how students interpret, organize, and transform spatial relationships under varying architectural paradigms.

3.5 Guided Mind-Mapping Intervention

The training program adopted guided mind mapping as a structured visual–cognitive framework for supporting the development of spatial thinking within architectural design tasks. Rather than functioning as a free-form ideation technique, mind mapping was implemented as an analytical and generative tool that regulates how spatial relationships are interpreted, organized, and transformed during the design process.

Prior to the design exercises, students were introduced to the fundamental principles of architectural design thinking, with particular emphasis on the relationship between spatial organization, function, form, and environmental context. In the modern house design task, the pedagogical introduction focused on the spatial and formal logic of modern architecture, including openness, continuity, and the integration of interior and exterior spaces. In contrast, the traditional house design task introduced the spatial structure of the Baghdadi house, emphasizing hierarchy, privacy gradients, and inward-oriented spatial organization.

Within the framework of diagram-based design reasoning, visual representations play a central role in structuring how architectural form is analyzed and manipulated. Oxman [15] explains that diagrammatic thinking enables the decomposition and recompositing of architectural systems through controlled operations, while Salama [13] highlights the role of structured visual frameworks in supporting systematic reasoning in architectural education. Eppler [2] further emphasizes that visual knowledge-structuring tools enhance analytical thinking by making relationships between design elements explicitly visible.

Building on this perspective, guided mind maps were employed to externalize spatial relationships and organize design information within a relational framework. Students were required to identify spatial functions, circulation systems, and environmental factors, and to represent these components within structured mapping diagrams. This process supported the interpretation of spatial configurations and enabled students to recognize how architectural relationships are formed and interconnected.

Through this structured representation, mind maps facilitated the transition from spatial interpretation to design generation. Students used the mapped relationships to guide the development of design alternatives through controlled transformation operations such as reorganization, addition, subtraction, and spatial reconfiguration. Recent studies in architectural education indicate that such visual structuring tools can support the organization of spatial relationships and enhance design reasoning in studio environments [3], while Hettithanthri [4] demonstrates their effectiveness in strengthening relational interpretation in early design education.

Within this intervention, guided mind mapping functioned as a cognitive scaffold that supported the systematic development of spatial thinking by linking analytical interpretation with generative architectural design processes.

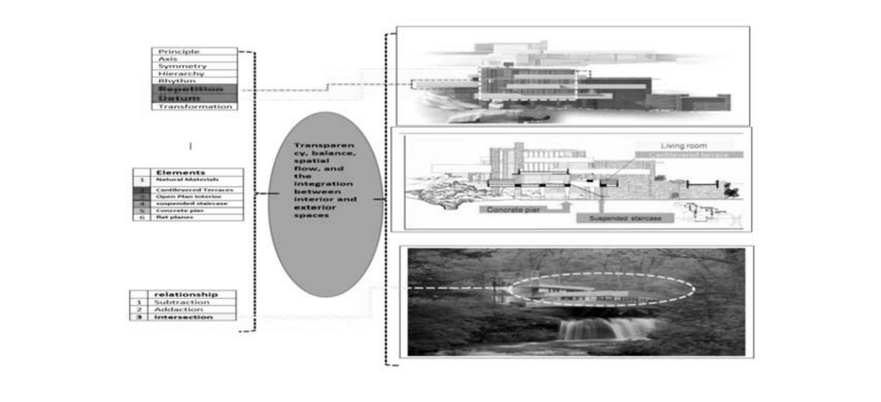
3.6 Instructional Structure and Role of Studio Mentors

The guided mind-mapping intervention was implemented within the architectural design studio as a structured educational program supervised by studio instructors. The house design task was conducted over a period of four weeks, allowing students to progressively develop spatial thinking through structured analytical and design processes. Each week was organized into two complementary sessions. One theoretical lecture, lasting two hours, introduced the conceptual foundations of spatial thinking, along with the architectural principles underlying both modern and traditional residential design. Within these sessions, guided mind mapping was presented as a visual–cognitive framework for organizing design knowledge and structuring spatial relationships. To support this process, students were introduced to analytical mind-mapping models derived from canonical architectural examples. As illustrated in Figures 5 and 6, guided mind maps were developed for the analysis of Fallingwater House as a representative model of modern architecture and the Baghdadi courtyard house as an example of traditional architecture. These diagrams explicitly mapped architectural form and function, including spatial organization, functional zoning, circulation systems, and the relationships between built form and context.

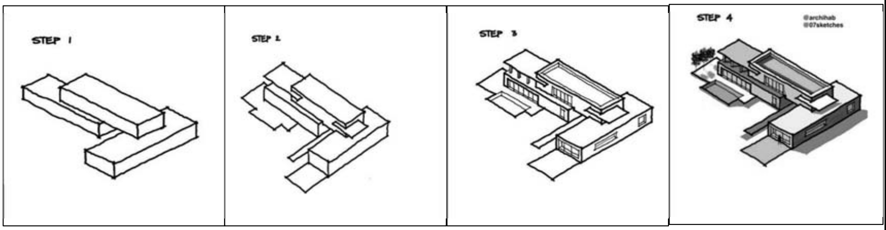
The second session was conducted within the architectural design studio and extended over six hours. During these sessions, students applied the guided mind-mapping framework to their own house design projects. The process involved structuring spatial relationships, organizing functional systems, and translating conceptual ideas into coherent spatial configurations, supported by continuous feedback and supervision.

Throughout the implementation period, studio instructors functioned as mentors facilitating the analytical process rather than directing design outcomes. Their role focused on guiding students in interpreting spatial relationships, structuring their design reasoning, and ensuring that transformation processes remained grounded in clearly identified architectural principles. This instructional structure ensured methodological consistency while fostering independent and cognitively structured design thinking.

Case study Analysis- **Falling House Analysis**



Concept diagram



Functional and Area/Space Program

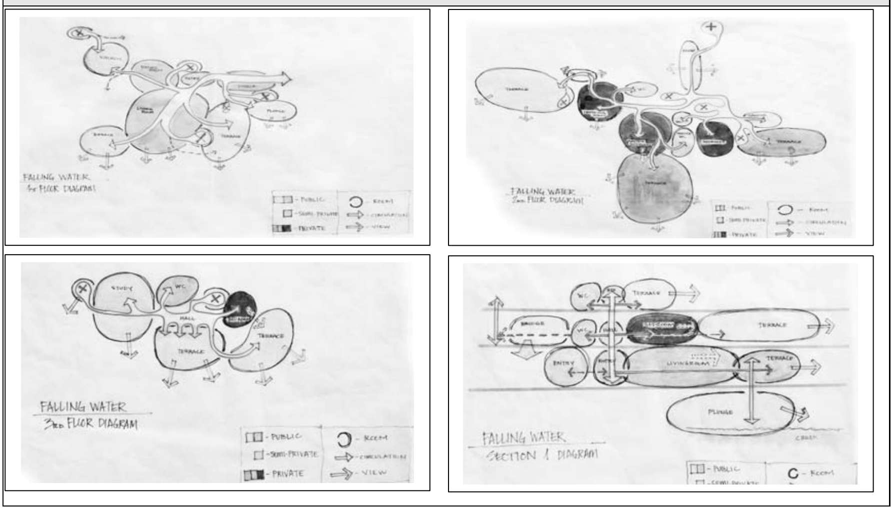


Figure 5. Guided mind-mapping framework form falling house (modern house design). Source: Author.

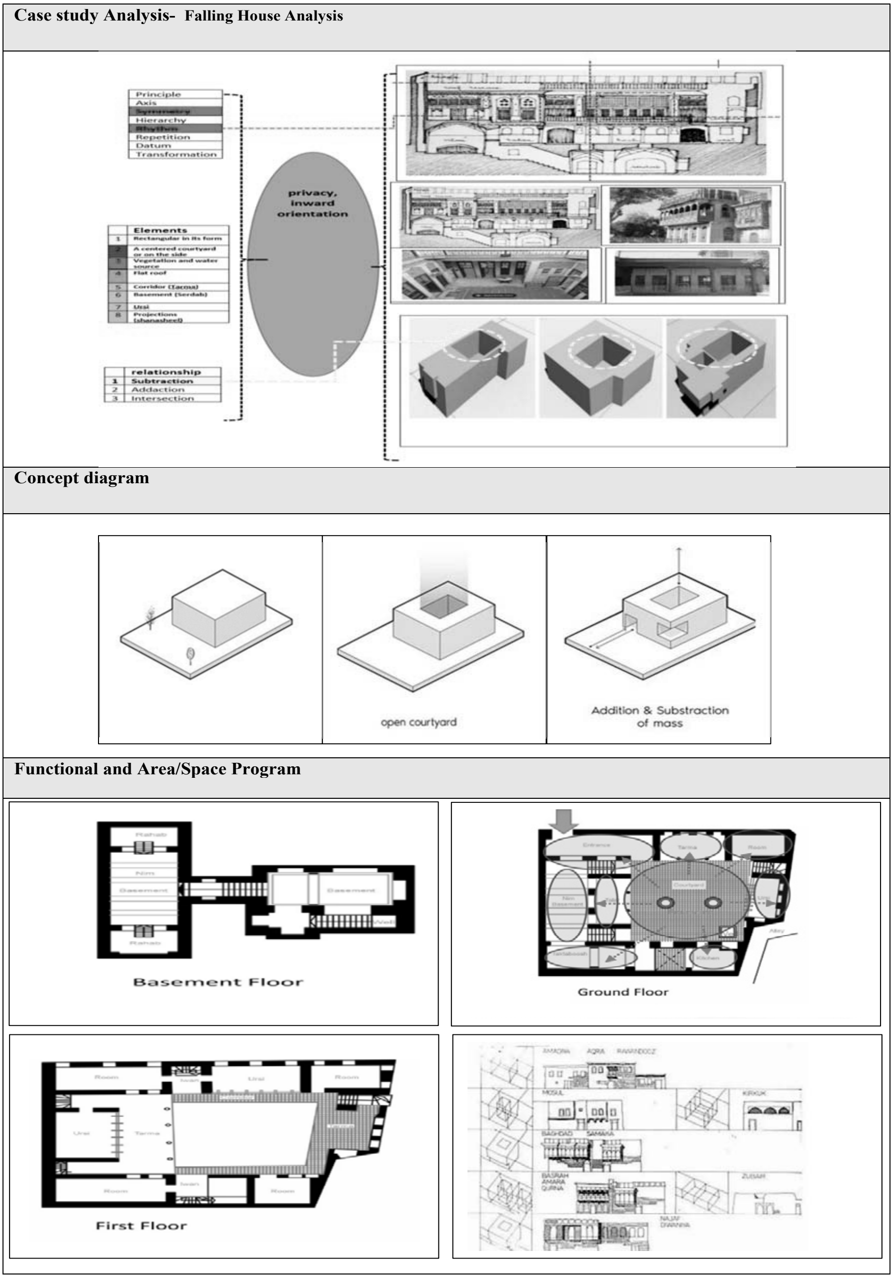


Figure 6. Guided mind-mapping framework for Baghdadi house (traditional house design). Source: Author.

3.7 Analytical Structure of the Guided Mapping Framework

The guided mind-mapping framework for the house design project was structured as a sequential cognitive–design system integrating both pre-design analysis and design development activities. This structure reflects the pedagogical organization of the studio process, in which spatial thinking is progressively constructed through interconnected analytical and generative stages. Recent studies in architectural pedagogy emphasize that structured visual–cognitive frameworks can enhance the organization of design knowledge and support the development of relational reasoning in early design education [5].

The framework was organized into two primary phases:

(1) Pre-design analytical phase

The initial phase focused on structuring students' understanding of the design problem through systematic decomposition of contextual and spatial information. This phase included four main analytical components: problem identification, site analysis, case study analysis, and functional–spatial programming. These components enabled students to interpret architectural information as a relational system rather than as isolated data points.

Within this phase, guided mind maps functioned as analytical tools that externalized relationships between spatial elements and contextual factors. Students translated site data and programmatic requirements into relational diagrams, allowing them to understand architecture as an integrated spatial system rather than a collection of isolated components. This approach aligns with recent findings indicating that diagrammatic and mapping tools support the structuring of complex spatial information and improve analytical clarity in design studios [4].

(2) Design development phase

Building upon the analytical foundation, the second phase focused on the generation and transformation of architectural form through structured design operations. This phase included concept formation, generation of design alternatives, comparative evaluation, development of the selected alternative, and final presentation.

Within this phase, guided mind mapping operated as a cognitive mediator linking analytical knowledge to design action. The mapping structure integrated three core components—form, function, and site relationships—into a unified relational system that guided design decisions. Such integration reflects contemporary perspectives in design cognition, which emphasize the role of structured visual frameworks in supporting the transition from analysis to synthesis through controlled transformation processes [3].

As illustrated in Figure 7, the conceptual scenario was structured through guided mind mapping to represent the design logic of both modern and traditional housing models. This representation integrates site context, form generation, functional organization, and spatial relationships into a unified visual–cognitive framework, enabling students to compare and reinterpret different architectural paradigms within a structured design process. Similar approaches have been shown to enhance students' ability to construct coherent design strategies and navigate between multiple spatial systems in architectural education [16].

Figure 7. Conceptual scenario of house design based on guided mind mapping (Modern house – Jadiriya riverside vs. Baghdadi house – Kadhimiya traditional), illustrating form–function–site relationships. Source: Author.

The transition between the two phases represents the shift from spatial perception to spatial reasoning and design synthesis. In this process, spatial relationships identified during the analytical phase were transformed into generative design rules, enabling controlled operations such as spatial reorganization, addition, and modification [15].

Furthermore, the integration of modern and traditional housing paradigms within the same framework allowed students to compare different spatial logics. While modern house design emphasized openness and functional continuity, the Baghdadi house focused on spatial hierarchy, privacy gradients, and courtyard-centered organization. This duality strengthened students' ability to interpret and reconstruct spatial systems across different architectural contexts.

Consequently, guided mind mapping did not function merely as a visualization tool, but as a structured cognitive framework that organized the entire design process—from problem definition to final architectural synthesis—supporting the development of coherent and contextually grounded design outcomes [15], [2], [1].

3.8 Assessment Rubrics

Student design outputs were evaluated using a structured descriptive–quantitative rubric to ensure consistency and comparability across both the modern and traditional house design tasks[17]. The assessment framework was aligned with the cognitive objectives of the study, focusing on the development of spatial thinking through three interrelated dimensions: `architectural analysis, visual representation, and architectural form synthesis.

The first dimension, architectural analysis, assessed students' ability to interpret the design context through site analysis, precedent studies, and functional program definition. This included the identification of spatial elements, environmental conditions, and functional relationships, enabling students to construct an integrated understanding of architectural systems.

The second dimension, visual representation, evaluated the translation of spatial and functional understanding into graphical outputs, including diagrams, plans, sections, elevations, and three-dimensional models. Particular attention was given to the use of diagrammatic tools, such as guided mind maps, to organize spatial and functional relationships.

The third dimension, architectural form synthesis, assessed the students' ability to integrate spatial and functional relationships into coherent architectural configurations. Emphasis was placed on the relationship between form and function, the organization of interior–exterior connections, and the development of a consistent architectural language reflecting either modern or traditional design approaches.

As illustrated in Table (1), architectural analysis and architectural form synthesis were each assigned a weight of 35%, reflecting their central role in structuring and integrating both spatial and functional relationships. Visual representation was assigned a weight of 30%, capturing its role in externalizing and communicating design thinking.

Table 1: Assessment weights aligned with intervention effect

Main dimension	Sub-dimension	Weight (%)
Architectural analysis	Site analysis	35
	Analysis of comparable precedents	
	Functional program analysis and spatial relationships	
Mental Transformation	Analysis of AI-generated examples	30
	Preliminary drawings, sections, elevations	
	3D models and diagrammatic representation	
Visual Synthesis	Integration of interior–exterior relationships	35
	Form–function integration and spatial organization	
	Application of compositional principles (modern / traditional)	
Total		100

3.9 Statistical Analysis

Paired-samples t-tests were conducted to examine pretest–posttest differences within each group in relation to spatial thinking development in the house design exercise. Independent-samples t-tests were then employed to compare posttest performance between the experimental and control groups. Statistical significance was evaluated at an alpha level of ($\alpha = 0.05$.)The analysis focused on measuring changes in students' ability to organize spatial relationships and generate coherent spatial configurations.

3.10 Reliability and Effect Size

To ensure the consistency of performance assessment in the house design exercise, the scoring rubrics were evaluated for inter-rater reliability. Two independent architectural design instructors, trained in the use of the architectural analysis, visual representation, and architectural form synthesis rubrics, assessed a randomly selected subset of student projects. The level of agreement between raters was examined using Cohen's kappa coefficient, which indicated a high degree of consistency in scoring across both the modern and traditional house design tasks. This result supports the reliability of the rubrics in capturing students' spatial thinking performance.

Beyond statistical significance, effect size measures were calculated to determine the magnitude of the intervention's impact on spatial thinking development. Cohen's d was computed for pretest–posttest differences within each group, as well as for posttest comparisons between the experimental and control groups. The experimental group demonstrated large effect sizes in the house design task, indicating that guided mind mapping produced not only statistically significant but also practically meaningful improvements in students' ability to organize spatial relationships and generate coherent spatial configurations.

In contrast, the control group showed only small to moderate effect sizes, reflecting limited improvement primarily associated with cumulative learning rather than structured cognitive support. These findings reinforce the effectiveness of guided mind mapping as a cognitive–pedagogical framework for enhancing spatial thinking in early architectural design education.

4. Findings

4.1 Task: House Design (Spatial Thinking)

The paired-samples t-test results (Table 2) indicate a differentiated pattern between the control and experimental groups in their ability to organize spatial relationships and construct coherent spatial configurations within the house design task. This task directly reflects spatial thinking as it requires the integration of functional zoning, circulation systems, and spatial hierarchy into a unified architectural form.

Table 2. Results for House Design

Group	Test	Sample size	Mean	Standard Deviation	Paired-samples t-test value	Significance level
Control	**Pretest**	**127**	**20.634**	**10.922**	**1.745**	**0.089**
Control	**Posttest**	**127**	**48.46**	**15.35**		
Experimental	**Pretest**	**133**	**21.18**	**11.252**	**13.022**	**0.000**
Experimental	**Posttest**	**133**	**75.363**	**14.545**		

Within the control group, the mean score increased from) 25.942(in the pretest to)43.69(in the posttest; however, this change did not reach statistical significance (Sig. = 0.089) (Table 2). As illustrated in Figure 8, although the control group demonstrated a noticeable increase in mean performance, the relatively high standard deviation suggests that this improvement remained inconsistent and did not reflect a systematic development in spatial reasoning.

In contrast, the experimental group demonstrated a substantial and statistically significant improvement, with the mean score increasing from)26.761(in the pretest to)89.445(in the posttest (Sig. = 0.000) (Table 2). This pronounced shift is clearly visualized in Figure 8, where both the magnitude of the mean increase and the controlled dispersion pattern indicate a strong enhancement in students' ability to structure spatial relationships and generate coherent spatial configurations.

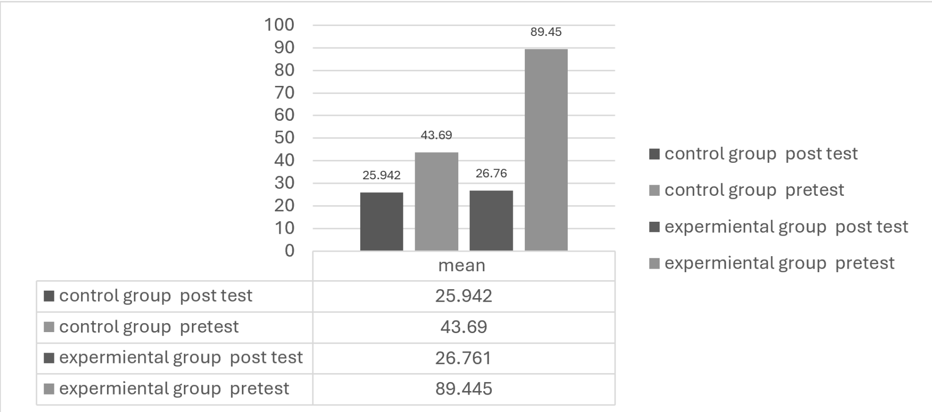


Figure 8. Pretest and posttest mean scores and standard deviations for house design task. Source: Author

The independent-samples t-test conducted on posttest scores (Table 3) did not indicate a statistically significant difference between the two groups (Sig. = 0.068), as shown in Figure 9. However, the experimental group achieved a considerably higher mean score compared to the control group, indicating a stronger level of spatial organization and design coherence.

From a design cognition perspective, the limited improvement observed in the control group reflects a reliance on intuitive or experience-based design decisions without a structured framework for organizing spatial relationships. In contrast, the experimental group exhibited a qualitatively different pattern of learning. The guided mind-mapping training enabled students to explicitly structure spatial relationships, organize functional systems, and translate conceptual intentions into coherent spatial configurations.

Consequently, students in the experimental group demonstrated clearer spatial sequencing, stronger functional zoning, and more consistent integration between concept and spatial form. These findings confirm that guided mind mapping effectively supports spatial thinking as a structured cognitive process, facilitating the transformation of abstract design ideas into coherent architectural solutions.

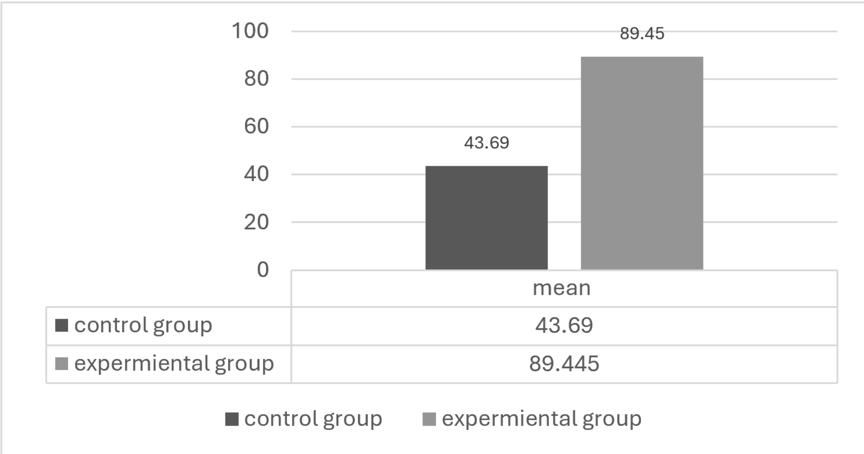


Figure 9. Posttest mean scores and standard deviations for the Villa Savoye task. Source : Author

4.2 Evidence for the Effect of Guided Mind Mapping on Spatial Thinking in House Design

The posttest results of the house design task reveal a clear and consistent pattern of improvement in the experimental group compared to the control group. As illustrated in Figure 10, students who were trained using guided mind maps achieved significantly higher mean scores (89.445) than those in the control group (43.69). This consistent performance difference indicates that the observed learning gains are not incidental but reflect the systematic impact of the guided mind-mapping intervention on spatial thinking.

From a design cognition perspective, guided mind maps functioned as an organizational cognitive mediator that facilitated the transition from conceptual intention to spatial configuration. By externalizing spatial relationships, functional structures, and hierarchical organization, the mapping process enabled students to regulate their design thinking, structure spatial analysis, and apply controlled transformations in the development of architectural form.

This structured cognitive support enhanced students' ability to integrate functional zoning, circulation systems, and spatial hierarchy into coherent spatial compositions. As a result, the experimental group demonstrated not only higher quantitative performance but also a qualitatively more advanced level of spatial organization, reflected in clearer spatial sequences, stronger functional coherence, and more consistent alignment between concept and spatial form.

Accordingly, the pattern illustrated in Figure 10 confirms that guided mind mapping strengthens spatial thinking as an underlying cognitive process in early architectural design education. Rather than merely improving final design outcomes, the intervention supports the regulation of design reasoning processes, enabling students to systematically organize and transform spatial relationships into coherent architectural solutions.

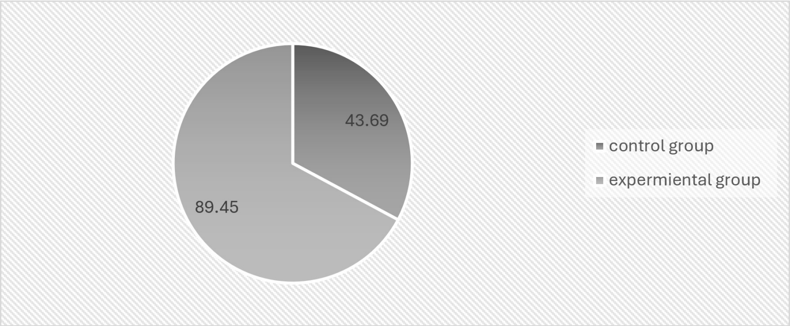


Figure 10. Posttest mean scores for the control and experimental groups for house design tasks. Source : Author

5. Discussion

The findings of the present study indicate that guided mind mapping functions as an effective visual–cognitive mechanism for enhancing spatial thinking within early architectural design education. The observed improvement in the experimental group reflects a shift from intuitive and fragmented spatial understanding toward structured spatial reasoning supported by explicit relational organization. These findings are particularly relevant in the context of contemporary architectural challenges, where increasing design complexity requires structured cognitive frameworks to support design reasoning and decision-making[18].

From a cognitive perspective, the guided mapping framework contributed to improving students' ability to interpret architectural space as an organized system of relationships rather than a collection of isolated elements. Students demonstrated an increased capacity to identify spatial hierarchies, organize functional zones, and structure circulation patterns within coherent spatial configurations. This transformation suggests that spatial understanding was no longer limited to visual recognition but extended to relational interpretation, a process emphasized in recent research on spatial cognition in design education [12].

The results further suggest that externalizing spatial relationships through guided mind maps facilitated the transition from spatial perception to spatial manipulation. By representing elements, relationships, and governing principles within a structured visual framework, students were able to explore alternative spatial configurations and reorganize design components more systematically. This process reflects the role of diagrammatic thinking in enabling controlled transformation and generative reasoning, as highlighted in contemporary studies on visual–cognitive tools in design learning [4].

In contrast, the limited improvement observed in conventional studio settings indicates that exposure to design tasks alone is insufficient for developing spatial reasoning skills. Without structured cognitive support, students tend to rely on surface-level imitation and struggle to reorganize spatial relationships within design problems. This finding aligns with recent research suggesting that novice designers often face difficulties in transitioning from perceptual observation to relational reasoning when explicit analytical frameworks are not provided [3].

Although both groups demonstrated improvement in spatial performance, the qualitative characteristics of the experimental group's outputs reveal a more advanced level of spatial organization. Design solutions exhibited clearer spatial sequencing, stronger functional integration, and greater consistency between conceptual intention and spatial configuration. This indicates that guided mind mapping influenced not only performance outcomes but also the internal structure of spatial reasoning processes.

From a design cognition standpoint, these findings support the interpretation that spatial thinking develops through the integration of perception, representation, and transformation within structured cognitive frameworks. Guided mind maps functioned as mediating tools that organized this integration by making spatial relationships explicit and operable, as emphasized in recent studies on knowledge visualization and cognitive structuring [19]. Such mechanisms are consistent with recent perspectives emphasizing the role of visual–cognitive scaffolding in supporting systematic design reasoning [16].

Educationally, the study highlights the importance of incorporating structured visual tools within early architectural design studios. Spatial thinking should be addressed as a core cognitive skill that requires explicit pedagogical support rather than being treated as an implicit outcome of design practice. The guided mapping approach provides a structured methodology for supporting students in organizing spatial knowledge and developing coherent design solutions [5].

Nevertheless, the findings should be considered within the scope of the study. The investigation was conducted within a specific educational context and focused on first-year students, which may limit the generalizability of the results. Future research may extend this approach to different educational levels and design contexts in order to further explore the broader applicability of guided mind mapping in architectural education.

Overall, the findings suggest that guided mind mapping strengthens the cognitive infrastructure underlying spatial thinking by enabling students to interpret, organize, and transform spatial relationships within a structured design process. This contribution extends beyond performance improvement, supporting a deeper transformation in design cognition during early stages of architectural education.

6. Conclusions

The findings indicate that guided mind mapping can function as an effective visual–cognitive framework for supporting the development of spatial thinking in early architectural design education. Structuring spatial information through explicit relational representation enhances students' ability to organize, interpret, and transform architectural space within coherent design systems.

These results highlight the potential of guided visual frameworks to systematically support the development of spatial reasoning, moving beyond implicit learning approaches commonly associated with conventional studio practice. The integration of structured cognitive tools within early design education can therefore contribute to improving the quality and coherence of architectural design outcomes.

Although the findings are context-specific, they suggest that guided mind mapping represents a transferable approach for strengthening spatial thinking across architectural learning environments. Further research may explore its application within diverse educational contexts and through the integration of digital and three-dimensional design tools.

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