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Modular Design as a Pedagogical Tool in Architectural Studio Education Across Academic Levels

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Abstract

Architectural design studios are learning environments where students develop creative thinking, spatial reasoning, and design skills. Although modular design has been widely discussed as a design strategy, its pedagogical role across architectural education has received limited empirical investigation. Addressing this gap, this study examines how modular design supports creative thinking, spatial organization, and conceptual production across educational stages. The research was conducted during the 2024–2025 spring semester at a public university in Türkiye and involved 53 undergraduate architecture students. A mixed-method design combined structured questionnaire, open-ended responses, student design projects, and rubric-based evaluations. The findings indicate that modular design supports creativity, systematic thinking, and part-to-whole reasoning in the early stages of architectural education, while in later stages it promotes critical awareness of scale, flexibility, and aesthetic coherence. Overall, modular design is a context-sensitive pedagogical approach whose educational contribution evolves according to developmental stage and project complexity.

Keywords: *Modular design**,** architectural studio education, pedagogical tool, design pedagogy, architectural education.*

Mimarlık Tasarım Stüdyosu Eğitiminde Akademik Düzeylere Göre Pedagojik Bir Araç Olarak Modüler Tasarım

Öz

Mimari tasarım stüdyoları, öğrencilerin yaratıcı düşünme, mekânsal akıl yürütme ve tasarım becerilerini geliştirdikleri öğrenme ortamlarıdır. Modüler tasarım, bir tasarım stratejisi olarak yaygın biçimde ele alınmasına karşın, mimarlık eğitimi sürecindeki pedagojik rolü ampirik olarak sınırlı düzeyde incelenmiştir. Bu araştırma boşluğundan hareketle, bu çalışma modüler tasarımın eğitimin farklı aşamalarında yaratıcı düşünme, mekânsal organizasyon ve kavramsal üretime katkısını incelemektedir. Araştırma, 2024–2025 eğitim-öğretim yılı bahar döneminde Türkiye'deki bir devlet üniversitesinde öğrenim gören 53 lisans mimarlık öğrencisi ile gerçekleştirilmiştir. Çalışmada, yapılandırılmış anketler, açık uçlu sorular, öğrenci tasarım projeleri ve rubrik temelli değerlendirmeleri bir araya getiren karma yöntem yaklaşımı kullanılmıştır. Bulgular, modüler tasarımın mimarlık eğitiminin erken aşamalarında yaratıcılığı, sistematik düşünmeyi ve parça-bütün ilişkisini desteklediğini; ileri aşamalarda ise ölçek, esneklik ve estetik bütünlüğe yönelik eleştirel farkındalığı geliştirdiğini göstermektedir. Sonuç olarak modüler tasarımın, eğitsel katkısı öğrencilerin gelişim düzeyi ve proje karmaşıklığına göre değişen, bağlama duyarlı bir pedagojik yaklaşım olduğu belirlenmiştir.

Anahtar kelimeler: *Modüler tasarım, mimarlık stüdyo eğitimi, pedagojik araç, tasarım pedagojisi, mimarlık eğitimi.*

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1. Introduction

Architectural education is not merely a process of transmitting technical knowledge; rather, it constitutes a holistic pedagogical framework aimed at developing students' creative thinking, spatial problem-solving, and conceptual production skills. Architectural design studios form the core of this framework. They provide fundamental learning environments in which students acquire knowledge through experiential engagement with the design process (Schön, 1983; Salama, 2015). The design approaches and methods adopted in studio education directly influence how students perceive, analyze, and produce space; therefore, the quality of studio pedagogy remains one of the central concerns in architectural education (Lawson, 2005). Within this broad pedagogical context, architectural educators employ a variety of design approaches and instructional strategies to support students' design thinking and spatial reasoning. Among the various pedagogical and design approaches adopted in architectural education, modular design has attracted increasing attention because of its potential to support systematic thinking, spatial organization, and structured design exploration. Rather than representing a dominant design paradigm, modular design is increasingly regarded as one of several complementary pedagogical approaches that can support systematic thinking, part-to-whole reasoning, and the development of spatial relationships (Kolarevic, 2003; Oxman, 2008). By enabling units defined within specific dimensions and rules to be assembled through multiple combinations, modular systems introduce a structural logic that shapes design decision-making processes (Akın, 1990).

The pedagogical implications of modular design in architectural education, however, are not uniform and may vary according to students' stage of architectural education and project scale. During the early stages of architectural education, modular systems facilitate students' understanding of fundamental design concepts such as dimensioning, proportion, spatial hierarchy, and overall coherence (Ching, 2015). During the later stages of architectural education, modular design encourages students to engage with increasingly complex design problems by balancing systematic design strategies with creative exploration (Lawson, 2005; Oxman, 2008). This variation suggests that the pedagogical role of modular design evolves in relation to students' increasing studio experience and the growing scale and complexity of design tasks throughout the architectural curriculum. This distinction between the early and later stages of architectural education reflects the progressive structure of architectural studio education, in which students gradually develop design knowledge, studio experience, and critical thinking skills while engaging with increasingly complex design problems. Within the existing literature, modular design has predominantly been examined in relation to production technologies (Kolarevic, 2003) and building systems (Smith, 2010; Burry, 2011). Studies that focus specifically on the pedagogical implications of modular design in architectural studio education—particularly through comparative analyses across the early and later stages of architectural education—remain limited (Salama, 2015). Recent studies in Türkiye have explored architectural studio pedagogy from different perspectives, including studio-based learning, experimental design education, and the integration of construction knowledge into design studios (Yurtgün & Çınar, 2023; Toy & Pulat Gökmen, 2023; Metin, 2023). However, empirical research investigating the pedagogical role of modular design across different stages of architectural education and relating students' perceptions to their design outcomes remains scarce. Moreover, many existing studies rely primarily on perceptual data and rarely integrate tangible design outcomes, such as student projects, into their analytical frameworks.

Addressing this gap, the present study investigates the pedagogical role of modular design across different stages of architectural education using a mixed-methods research framework. Quantitative data were collected through a structured questionnaire assessing students' perceptions of modular design, whereas qualitative and project-based evidence was obtained from open-ended questionnaire items, student design projects, and rubric-based project evaluations. Accordingly, the primary objective of this study is to examine how the pedagogical role of modular design evolves across different stages of architectural education by investigating its influence on students' creative thinking, spatial organization, and conceptual production skills.

1.1. Research Question and Contributions of the Study

This study addresses the following research question: How does the pedagogical role of modular design evolve across different stages of architectural education, as reflected in students' creative thinking, spatial organization, and conceptual production skills?. This study contributes to the literature on architectural education in three main ways:

First, it adopts a mixed-methods research framework that integrates quantitative perception data, qualitative student perspectives, and rubric-based evaluations of design products, enabling a comprehensive assessment of modular design beyond perceptual measures alone.

Second, by examining studio applications across different stages of architectural education, the study demonstrates how the pedagogical role of modular design shifts from a structured instructional framework during the early stages of architectural education to a more critical pedagogical tool during the later stages of architectural education.

Third, the findings provide practice-based insights into how modular design can be strategically positioned within architectural studio education, emphasizing its context- and scale-dependent pedagogical potential.

1.2. Theoretical Framework

1.2.1. The concept of modular design and its use in architecture

Modular design is a design approach based on the assembly of units defined within specific dimensions and rules through various combinations. In the architectural context, modularity plays a significant role in both design and implementation processes due to attributes such as ease of production, flexibility, reproducibility, and adaptability (Kolarevic, 2003; Schumacher, 2009). Modular systems enable designers to generate coherent spatial structures by establishing relationships between individual components, while simultaneously introducing a systematic mode of thinking into the design process (Akın, 1990). The modular approach extends beyond the repetition of physical components and can be understood as a conceptual and relational system of organization in which design decisions are governed by explicit rules and interdependencies among components (Burry, 2011). In this respect, modular design offers a structural framework that enhances designers' decision-making abilities and supports the systematic generation of design variations.

With the development of digital design tools and parametric production methods, the concept of modularity has evolved into a more dynamic framework. Contemporary approaches no longer define the module as a fixed or repetitive unit; rather, it is conceptualized as a variable component that can adapt to contextual conditions, design parameters, and performance criteria (Oxman, 2008; Schumacher, 2009). This perspective allows modular design to be implemented flexibly across different scales and architectural contexts. This conceptual evolution has expanded the applicability of modular design across diverse architectural scales and contexts, providing an important theoretical foundation for its pedagogical use in architectural design studios.

1.3. Modular Design and Architectural Education

In architectural education, design studios constitute the primary learning environments in which students transform theoretical knowledge into practice and acquire design experience through active engagement in the design process (Schön, 1983). As the core of architectural education, design studios continue to evolve in response to changing pedagogical and technological demands, requiring more flexible and student-centered learning environments (Masdéu & Fuses, 2017). Their spatial organization and physical setting also embody pedagogical values that influence how learning takes place, a concept described as *built pedagogy* (Monahan, 2002). Beyond serving as instructional settings, design studios also shape studio culture, collaboration, and students' learning experiences through their pedagogical structure and curriculum design (Mariotti & Niblock, 2023). Within this pedagogical context, modular design emerges as a pedagogical tool that supports students' abilities to think from part to whole, comprehend spatial relationships, and develop systematic design decisions (Oxman, 2008). For students in the early stages of architectural education, modular systems facilitate

the concretization of fundamental design concepts such as scale, proportion, repetition, and hierarchy (Ching, 2015; Duzenli et al., 2019). By enabling students to experience the design process within a controllable framework, the modular approach provides a guiding structure in the face of uncertainty (Salama, 2015). In this respect, modular design is regarded as an effective method that supports learning processes during the early stages of architectural education. Accordingly, modular design functions as a form of pedagogical scaffolding during the early stages of architectural education, providing students with a structured environment in which foundational design competencies can be gradually developed.

During the later stages of architectural education, modular design assumes a more critical pedagogical role. As students' design experience increases, greater emphasis is placed on originality, context, and aesthetic coherence, and the constraints imposed by modular systems become a subject of critical discussion (Lawson, 2005; Burry, 2011). This condition indicates that modular design produces a dual pedagogical effect—both supporting and challenging creativity. From this perspective, modular design in architectural education is understood not merely as a formal production method, but as a comprehensive framework that fosters systematic thinking, decision-making, and pedagogical guidance (Pala Azsöz & Kaprol 2022; DeKay & Tornieri, 2023; Milovanovic & Gero, 2020).

One of the primary contributions of modular design to architectural education is its capacity to enhance students' systematic thinking skills. Modular systems transform the design process from a sequence of arbitrary decisions into a deliberate structure guided by defined rules and relationships, thereby supporting students in justifying their design decisions and constructing spatial organization in a more controlled and coherent manner (Lawson, 2005; Burry, 2011). From a pedagogical perspective, the constraints introduced by the modular approach are not regarded as limiting factors for creativity; rather, they are understood as components of a learning environment that encourages problem-solving, alternative generation, and critical thinking (Salama, 2015; Taneri & Dogan, 2021). Working with modular systems in the design studio contributes to learning through trial and error and enables students to develop a critical distance toward their own design processes.

Within the literature, the pedagogical effects of modular design in architectural education are predominantly addressed at a perceptual level, while studies that systematically evaluate concrete design outputs—such as student projects—remain limited (Burry, 2011). Addressing this gap, the present study examines the pedagogical effects of modular design through a combined assessment of quantitative perceptual data, qualitative student reflections, and rubric-based project analyses. In addition, recent studies increasingly associate modular design with digital and parametric design tools, linking it to hybrid pedagogical models that support algorithmic thinking and systematic decision-making within the design process (Davis, 2013; Alassaf, 2025; Vazquez, 2024). Within this context, the present study positions modular design as a pedagogical mediator between rule-based systematic thinking and exploratory design processes, rather than as a purely computational or technologically driven approach.

2. Material and Method

This study employs a mixed-methods research framework to investigate the effects of the modular design approach on students' design processes and spatial production practices in architectural education. The methodological framework integrates quantitative survey data, qualitative student perspectives, and rubric-based evaluations of student design projects, which are examined collectively and holistically. This approach enables an assessment of the pedagogical impacts of modular design not only at a perceptual level, but also through the design process itself and tangible project outcomes. To provide a clearer overview of the research process, the overall research framework, data collection procedures, and analytical stages are summarized in Table 1.

Table 1. Overview of the mixed-method research design, data collection procedures, and analytical stages

Phase	Data Source	Instrument	Timing	Analysis
Quantitative	Student perceptions	Structured questionnaire (Likert-scale)	After completion of the design project	Descriptive statistics, Spearman correlation
Qualitative	Student reflections	Open-ended questionnaire items	After completion of the design project	Thematic analysis
Design Products	Student projects	Rubric-based evaluation	After completion of the design project	Comparative rubric assessment

2.1. Research Design and Participants

The study was conducted during the 2024–2025 spring semester within architectural design studio courses offered by the Department of Architecture at a public university. The research population consisted of undergraduate students who developed design projects using a modular design approach during this period. Participants were selected on a voluntary basis, and only students who completed the survey questionnaire in full were included in the research sample. In total, 53 students participated in the study.

The sample included first- and third-year students who directly engaged in modular design–based studio projects, as well as second- and fourth-year students who were repeating the course. This variation was considered advantageous, as it enabled the inclusion of students with different levels of prior studio experience. For the purposes of this study, first- and second-year students were considered to represent the early stages of architectural education, whereas third- and fourth-year students were considered to represent the later stages of architectural education. This categorization reflects the progressive structure of architectural studio education, in which students gradually develop design knowledge, studio experience, and the ability to address increasingly complex design problems. For analytical purposes, participants were therefore grouped into these two educational stages throughout the statistical and qualitative analyses.

The relationship between the theoretical dimensions guiding the study, the corresponding data sources, participants, and analytical procedures is summarized in Table 2.

Table 2. Research design framework

Research objective	**Research dimension**	**Data source**	**Participants**	**Analysis**
Examine the pedagogical role of modular design across educational stages	Creativity	Questionnaire, open-ended responses, student projects	53 students	Descriptive statistics, thematic analysis, rubric evaluation
	Spatial organization	Questionnaire, student projects	53 students	Kruskal–Wallis, rubric evaluation
	Conceptual production / design decision-making	Open-ended responses, student projects	53 students	Thematic analysis, rubric evaluation

The distribution of participants across the stages of architectural education is presented in Figure 1.

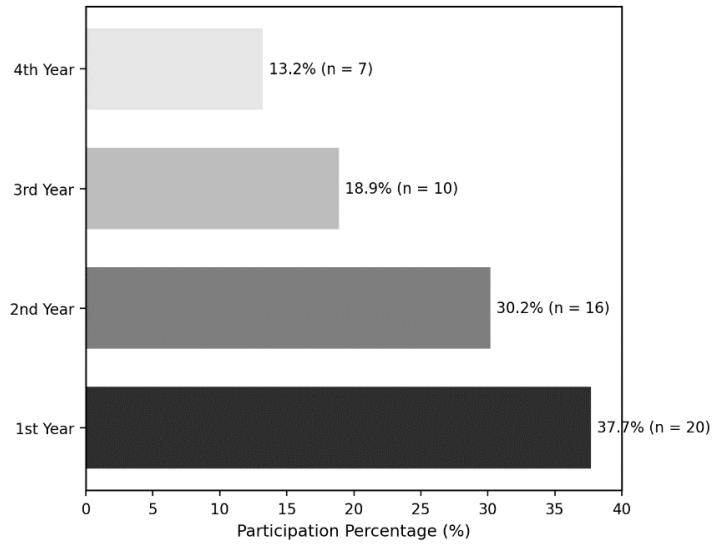

Figure 1. Distribution of participants across the stages of architectural education.

As shown in Figure 1, the sample consisted of 20 first-year students (37.7%), 16 second-year students (30.2%), 10 third-year students (18.9%), and 7 fourth-year students (13.2%).

The research process was carried out within the scope of the design studio course. Participants were informed about the purpose and scope of the study, and all data were collected in accordance with ethical principles, with participant anonymity fully ensured. Ethical approval for this study was obtained from the Social and Human Sciences Research Ethics Committee of Trakya University Rectorate (Decision No: E-29563864-050.99-948929; Session No: 2025/11; Decision Date: 13 November 2025).

2.2. Data Collection Instruments

The survey questionnaire, which constituted the first data source of the study, consisted of four sections. The first section included demographic information related to participants' stage of architectural education and educational background.

The second section comprised five-point Likert-scale items designed to assess students' perceptions of the effects of modular design on four analytical dimensions derived from the theoretical framework: creativity, spatial diversity, functionality, and aesthetic coherence. Representative items included statements such as *"Modular design facilitates the generation of alternative design solutions," "Modular systems contribute to the production of functional spaces,"* and *"Modular design supports aesthetically coherent spatial compositions."*

The four analytical dimensions adopted in this study were derived through a synthesis of the architectural design quality and architectural design education literature rather than from a single existing measurement scale. Architectural design is widely recognized as a multidimensional process that should be evaluated through complementary conceptual, spatial, functional, and formal criteria in architectural design education (Schön, 1983; Lawson, 2005; Salama, 2015; Eilouti, 2020). Accordingly, creativity was included to evaluate originality and the generation of alternative design ideas; spatial diversity to assess the organization and variety of spatial configurations; functionality to examine the degree to which design solutions respond to user and programmatic requirements; and aesthetic coherence to evaluate the visual and compositional consistency of the architectural proposal. Together, these four dimensions provide a comprehensive framework for examining the pedagogical effects of modular design within architectural studio education. The selection of these dimensions was also guided by their direct relevance to the learning objectives of architectural design studios and their applicability to both perceptual and project-based evaluation.

The third section included open-ended questions aimed at eliciting students' individual experiences and perceptions of modular design. Rather than measuring predefined constructs, these questions were designed to encourage participants to reflect on their design experiences, enabling themes related to creativity, spatial organization, and design decision-making to emerge inductively through the content analysis. Students were invited to reflect on issues such as how modular design influenced their design process, which aspects of the approach they considered most beneficial, and what limitations they experienced while working with modular systems.

The fourth section focused on comparative evaluations of students' project development processes before and after engaging with the modular design approach.

The second data source consisted of design outputs produced by students during the studio process. At the first-year level, students developed projects within studio themes related to public open spaces and temporary structures, whereas third-year students focused on studio themes addressing historical contexts and industrial design approaches. These projects were evaluated in terms of modular system configuration, spatial organization, and conceptual coherence, thereby providing qualitative, design-based data that supported and complemented the survey findings.

2.3. Data Analysis

Quantitative data were analyzed using statistical analysis software. Participants' perception levels regarding modular design were initially examined through descriptive statistics. Non-parametric statistical tests were preferred due to the ordinal nature of Likert-scale data and the relatively small sample size (Field, 2018). To investigate relationships between variables, appropriate correlation analyses were conducted, and group comparisons were performed to examine whether students' perceptions differed across the stages of architectural education. The Kruskal–Wallis test was used to examine differences among students from the four years of the architecture program, and following significant results, post-hoc pairwise comparisons were conducted using Mann–Whitney U tests. Bonferroni correction was applied to control for multiple comparisons, and the adjusted significance level was set at $p < 0.0083$ (Field, 2018).

The quantitative findings were organized according to the four predefined analytical dimensions introduced in the data collection instrument: creativity, spatial diversity, functionality, and aesthetic coherence. These dimensions served as the framework for presenting and interpreting the quantitative findings rather than representing themes generated through qualitative analysis.

Qualitative data were analyzed using inductive content analysis following the procedures described by Elo & Kyngäs (2008). Responses to the open-ended questions were examined through open coding, during which meaningful expressions were identified and assigned initial codes. Conceptually similar codes were then grouped into broader categories and refined into themes through an iterative comparison process. The coding process was guided by thematic consistency. Student design projects were analyzed using a rubric-based evaluation framework following established principles of rubric-based assessment (Brookhart, 2013). The rubric operationalized the three analytical dimensions defined in the theoretical framework. Creativity was assessed through originality and innovation, spatial organization through functionality and spatial coherence, and design decision-making through the effective application of modular systems and formal coherence. These project analyses were interpreted in conjunction with quantitative and qualitative findings, thereby enabling an assessment of the pedagogical effects of the modular design approach through tangible design outputs.

The Likert-scale items were designed to capture students' perceptions of different aspects of the modular design approach rather than to measure a single latent construct; therefore, internal consistency coefficients such as Cronbach's alpha were not calculated. Rubric-based evaluations were conducted using predefined criteria aligned with studio learning objectives and discussed within the studio teaching framework to ensure consistency.

3. Findings

The findings are presented in relation to the research question and are organized around the three pedagogical dimensions examined in this study: creativity, spatial organization, and design decision-making. Quantitative, qualitative, and rubric-based evidence are presented in a complementary manner to provide a comprehensive interpretation of each dimension.

3.1 Participant Characteristics

This subsection summarizes the characteristics of the study participants to provide the contextual background for the subsequent quantitative, qualitative, and rubric-based analyses. The study included 53 undergraduate architecture students from all four years of the architecture program. The distribution of participants by year of study has already been presented in Figure 1. First-year students constituted 37.7% of the sample, followed by second-year (30.2%), third-year (18.9%), and fourth-year students (13.2%). For analytical purposes, these participants were subsequently grouped into the early and later stages of architectural education.

3.2. Findings Related to Creativity

This subsection presents quantitative findings on creativity together with qualitative and project-based evidence relevant to this dimension. The quantitative findings are presented according to the four analytical dimensions assessed through the Likert-scale questionnaire: creativity, spatial diversity, functionality, and aesthetic coherence. Figure 2 summarizes students' overall evaluations of the modular design approach, while the corresponding percentage distributions for each questionnaire item are reported in the text.

Overall, students reported positive perceptions of the modular design approach across all four analytical dimensions. The highest evaluations were associated with spatial diversity and the production of functional and aesthetically coherent spaces. Positive evaluations were also observed for creativity and original spatial production, although responses to these dimensions showed relatively greater variation among participants.

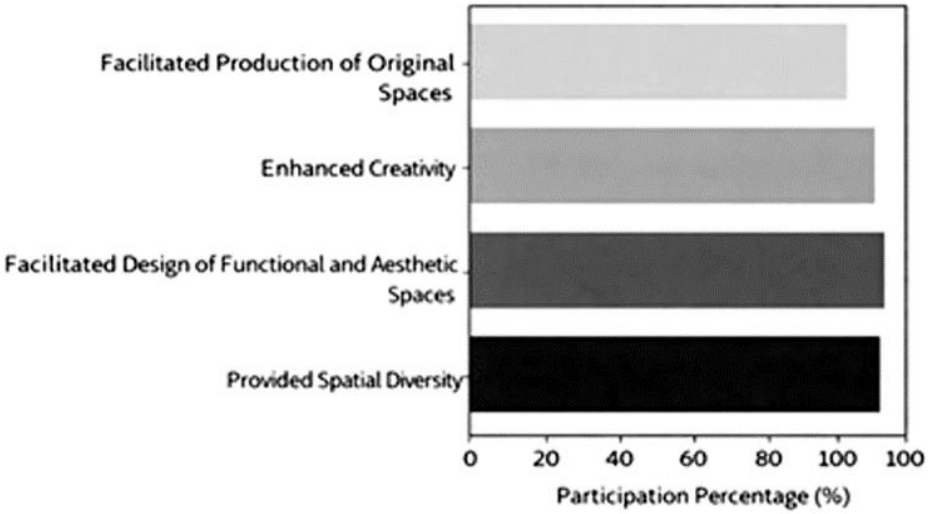

Figure 2. Students' evaluations of the modular design approach across the four predefined analytical dimensions (%)

Overall, the quantitative findings indicate that students perceived modular design positively across the four analytical dimensions considered in this study. More detailed analyses examining the relationships among these dimensions and differences between the early and later stages of architectural education are presented in the following sections.

3.3. Findings Related to Spatial Organization

Relationships among variables relevant to spatial organization were examined through correlation analysis. Spearman correlation analysis was performed to examine the relationships among the four perception dimensions assessed in the questionnaire (Table 3). Several statistically significant positive correlations were identified. The strongest correlations were observed between creativity and originality ($r = .50$, $p < .01$), originality and aesthetic coherence ($r = .50$, $p < .01$), and creativity and aesthetic coherence ($r = .45$, $p < .01$).

By contrast, functionality showed comparatively weaker associations with the other perception dimensions, particularly with creativity ($r = .18$). Overall, the correlation analysis indicates that students' perceptions of creativity, originality, and aesthetic coherence were more closely related than their perceptions of functionality.

Table 3. Spearman correlation analysis results for variables related to modular design perceptions

Variables	Creativity	Functionality	Originality	Aesthetic
Creativity	1.00			
Functionality	.18	1.00		
Originality	.50**	.49**	1.00	
Aesthetic	.45**	.38*	.50**	1.00

p* < .05, **p < .01*

Differences in these perception dimensions between the early and later stages of architectural education are presented in the following section.

3.4. Findings Related to Design Decision-Making

Differences between the early and later stages of architectural education were examined to better understand variations in students' design decision-making. The Kruskal–Wallis test was performed to examine whether students' perceptions of modular design differed across the stages of architectural education (Table 4).A statistically significant difference was identified only for the dimension of functional and aesthetically coherent spaces ($H = 9.00$, $p = .02$). No statistically significant differences were found for the dimensions of creativity, spatial diversity, or original spatial production.

Post-hoc pairwise comparisons using the Mann–Whitney U test with Bonferroni correction indicated that the significant difference was observed between first-year and third-year students ($p = .007$), whereas no other pairwise comparisons reached statistical significance.

In addition, the Mann–Whitney U test examining workshop participation revealed no statistically significant differences across any of the perception dimensions (Table 5).

Table 4. Kruskal–Wallis test results for perceptions of modular design across *stages of architectural education*

Conceptual Dimension	H Value	*P Value*
Enhancement of Creativity	3.49	0.32
Spatial Diversity	2.87	0.41
Original Spatial Production	0.31	0.96
Functional and Aesthetically Coherent Spaces	9.00	0.02*

**p* < .05*

Table 5. Mann–Whitney U test results comparing perceptions by workshop participation

Conceptual Dimension	U	*p* Value	Effect Size (r)
Creativity	211.50	.39	–.18
Functionality	206.50	.47	–.15
Spatial Diversity	223.00	.25	–.24
Originality	163.50	.66	.09

**p* < .05*

3.5. Qualitative Findings

The qualitative findings presented in this section provide complementary evidence supporting the three pedagogical dimensions investigated in this study—creativity, spatial organization, and design decision-making. The themes derived from students' reflections are interpreted in relation to the quantitative findings to provide a deeper understanding of the pedagogical role of modular design across different stages of architectural education. Following the open coding process, conceptually similar codes were grouped into broader themes representing recurring patterns in students' perceptions of modular design. The identified themes describe students' perceptions of the contributions of modular design to spatial production and creativity. The definitions of these themes are presented in Table 6, while their distributions across the stages of architectural education are presented in Tables 7 and 8.

Table 6. Definitions of themes related to modular design

Theme Name	Description
Diversity and Flexibility	Ability to generate different spatial scenarios
Speed and Practicality	Acceleration of the design process and ease of implementation
Functionality and Planning	Facilitation of functional solutions and systematic planning
Creativity and Originality	Development of original solutions and creative ideas
Guidance / Instructional Role	Facilitation of the learning process and provision of design guidance
Formal Coherence and Proportion	Designing formally consistent and well-proportioned structures
Critical Perspective / Constraints	Limiting effects observed in certain cases
Sustainability and Transformability	Contribution to sustainability through adaptable and transformable structures

The qualitative analysis indicates that students most frequently associated modular design with diversity and flexibility, followed by its guidance and instructional role. In contrast, sustainability and transformability were mentioned comparatively less frequently. The distribution of these themes across the stages of architectural education is presented in Table 7, while themes specifically related to creativity are presented in Table 8.

Table 7. Distribution of themes related to spatial production across different stages of architectural education

Theme Name	1st year	2nd Year	3rd Year	4th Year	Total
Diversity and Flexibility	10	3	6	6	25
Speed and Practicality	2	0	3	7	12
Functionality and Planning	0	0	2	8	10
Creativity and Originality	5	0	4	2	11
Guidance / Instructional Role	11	0	0	0	11
Formal Coherence and Proportion	0	0	3	0	3
Critical Perspective / Constraints	0	1	0	2	3

Table 8. Distribution of themes related to creativity across different stages of architectural education

Theme Name	1st year	2nd Year	3rd Year	4th Year	Total
Diversity and Flexibility	5	2	4	3	14
Speed and Practicality	1	1	1	1	4
Functionality and Planning	0	1	2	2	5
Creativity and Originality	6	0	5	5	16
Guidance / Instructional Role	0	0	0	0	0
Formal Coherence and Proportion	0	0	0	0	0
Critical Perspective / Constraints	0	0	0	0	0
Sustainability and Transformability	2	0	1	3	6

Representative quotations from students at different stages of architectural education are presented below to illustrate the recurring themes identified through the content analysis.

"The modular system helped me understand scale and spatial order more clearly and made the design process easier to control." *(1st-year student)*

"The modular system helped me understand spatial organization, but at later stages it limited my formal freedom." *(3rd-year student)*

"During the later stages of architectural education, modular design provided a strong structural framework, but it also revealed limitations in terms of flexibility and aesthetic coherence ." *(4th-year student)*

The qualitative findings suggest noticeable differences across the stages of architectural education. Students in the early stages primarily described modular design as a guiding instructional framework that facilitated the understanding of scale, spatial organization, and part-to-whole relationships. In contrast, students in the later stages more frequently emphasized issues related to flexibility, originality, and aesthetic coherence, reflecting a more critical evaluation of modular systems as project complexity increased.

Representative examples of first-year studio projects are presented in Figure 3 to illustrate how the qualitative themes identified through the content analysis were reflected in students' design outcomes.

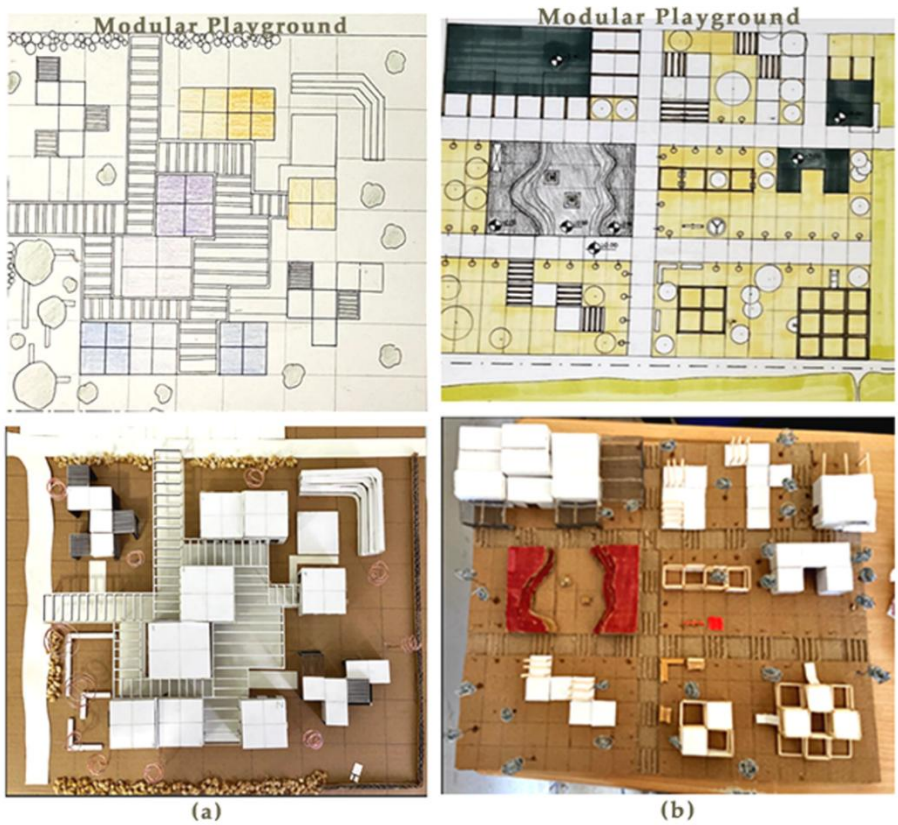

Figure 3. Representative first-year studio projects illustrating the application of modular design in playground design: (a) Project 1 and (b) Project 2, each including the plan drawing and corresponding physical model. (Compiled by the author from student projects produced in the first-year architectural design studio course.)

Representative examples of third-year studio projects are presented in Figure 4 to illustrate how modular design was applied during the later stages of architectural education.

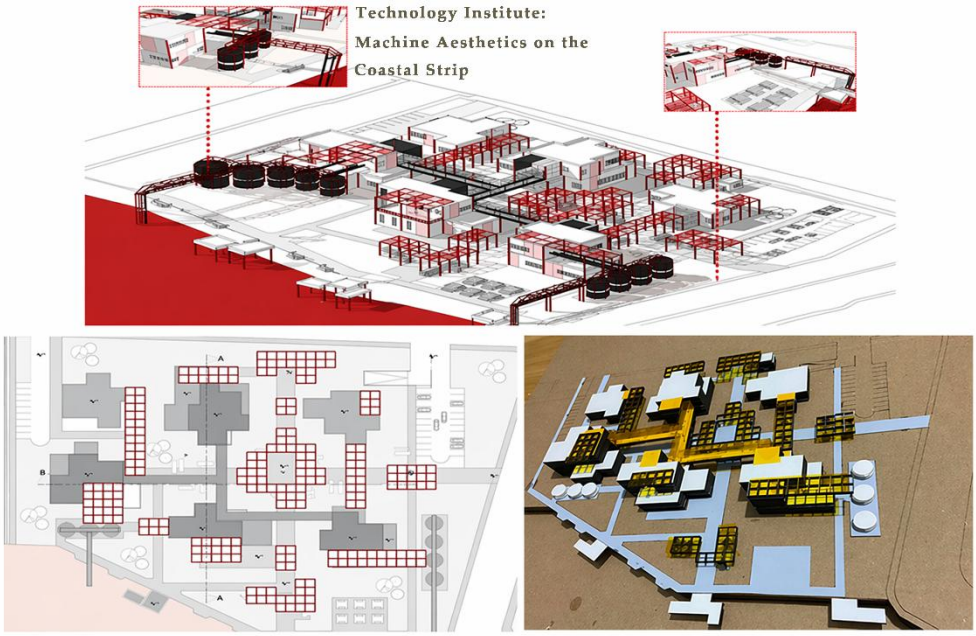

Figure 4. Representative third-year studio projects illustrating the application of modular design in architectural design. (Compiled by the author from student projects produced in the third-year architectural design studio course.)

Representative examples of fourth-year studio projects are presented in Figure 5 to illustrate the application of modular design in more complex architectural design projects.

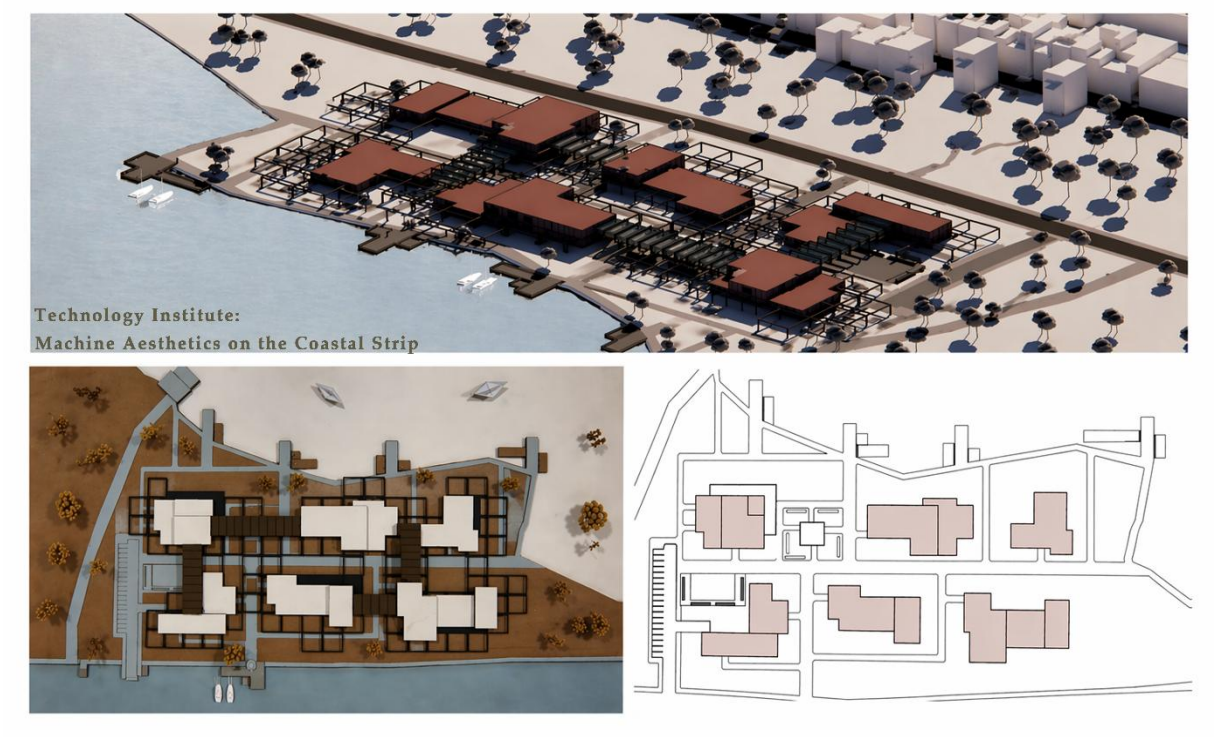

Figure 5. Representative fourth-year studio projects illustrating the application of modular design in architectural design. (Compiled by the author from student projects produced in the fourth-year architectural design studio course.)

3.6. Rubric-Based Project Evaluation

The rubric-based evaluation of student design projects provides project-based evidence supporting the findings related to creativity, spatial organization, and design decision-making. These evaluations complement the quantitative and qualitative results by demonstrating how students' perceptions were reflected in their tangible design outcomes across the stages of architectural education.

Representative rubric-based evaluations of selected student projects are presented in Table 9. Across the stages of architectural education, the evaluations document differences in creativity, functionality, formal coherence, and the use of modular systems.

Table 9. Rubric-based evaluation results of selected student projects

Project Level	Creativity	Functionality	Use of Modularity	Formal Coherence	Evaluation
1st Year	High	High	Very High	High	The modular system was effectively used as a structural framework supporting spatial organization and the learning process.
2nd year	High	Very High	Very High	High	The modular system structured the design process by reducing uncertainty and contributed to the coherent development of functional and spatial decisions.
3rd Year	Very High	Very High	High	High	The modular approach was integrated with the conceptual framework, achieving a balanced relationship between creativity and systematic structuring.
4th Year	High	Very High	High	High	It was observed that the formal and conceptual limitations of the modular system became more apparent, particularly generating a critical discussion in terms of originality and aesthetic coherence.

Taken together, the quantitative findings, qualitative analyses, and rubric-based project evaluations demonstrate a consistent pattern regarding the pedagogical role of modular design. While the quantitative analyses identified differences in students' perceptions across the stages of architectural education, the qualitative findings provided explanatory insights into these differences, and the rubric-based evaluations illustrated how these differences were reflected in students' design outcomes. The convergence of these complementary data sources strengthens the overall interpretation of the findings.

4. Discussion

The findings of this study demonstrate that the pedagogical role of modular design is not static but evolves throughout architectural education. Rather than functioning as a single instructional strategy, modular design supports different learning processes as students progress through successive stages of studio education. The integration of quantitative findings, qualitative student perspectives, and rubric-based project evaluations indicates that modular systems contribute not only to spatial organization and conceptual development but also to the formation of increasingly critical design thinking. These findings suggest that the educational value of modular design is closely associated with students' developmental stage rather than representing a universally applicable pedagogical approach.

The findings suggest that modular design plays a particularly important pedagogical role during the early stages of architectural education by providing a structured framework that enables students to develop fundamental design competencies. Rather than restricting creativity, modular systems appeared to reduce uncertainty during the design process. At the same time, they supported students' understanding of scale, proportion, spatial hierarchy, and part-to-whole relationships. These observations are consistent with Schön's (1983) concept of reflective studio learning, in which structured design experiences facilitate the gradual development of design thinking. Similarly, Goldschmidt (1991) emphasizes that structured design activities support the development of design reasoning by enabling novice designers to reflect on, evaluate, and progressively refine their ideas throughout the design process. Within this context, modularity can be interpreted as a pedagogical scaffold that assists students in developing systematic design reasoning before engaging with increasingly complex architectural problems.

As students progressed through architectural education, the pedagogical function of modular design shifted from instructional guidance toward critical design inquiry. Rather than focusing primarily on spatial organization, students increasingly questioned issues related to originality, flexibility, production logic, connection details, and aesthetic coherence. This shift suggests that greater studio experience enables students to evaluate modular systems more critically while simultaneously recognizing both their pedagogical potential and their inherent limitations. These findings support arguments by Habraken (2000) and Lawson (2005), who describe design constraints not merely as limitations but as conditions capable of stimulating creative exploration and critical decision-making.

One of the most noteworthy findings of this study concerns the apparently contradictory relationship between modular design and creativity. Students simultaneously perceived modular systems as supporting the generation of alternative design solutions while also recognizing that standardized dimensional systems may constrain formal freedom. Rather than representing a contradiction, this tension appears to constitute an important pedagogical characteristic of modular design. Learning to negotiate between freedom and constraint encourages students to justify design decisions, evaluate alternatives, and develop critical awareness throughout the design process. This interpretation is consistent with previous studies suggesting that creative constraints can stimulate rather than inhibit design thinking (Lawson, 2005; Goldschmidt, 1991). The relatively weak relationship observed between creativity and functionality also suggests that students may initially associate modular design more strongly with formal exploration than with functional performance, highlighting the importance of balancing creativity and functionality within architectural studio pedagogy.

A distinctive contribution of this study lies in the integration of quantitative analyses, qualitative student perspectives, and rubric-based evaluations of design outcomes within a single mixed-method

framework. The convergence of these complementary data sources provided a more comprehensive understanding of the pedagogical role of modular design than would have been possible through a single method alone. While the quantitative findings identified general patterns in students' perceptions, the qualitative analyses explained the reasoning underlying these perceptions, and the rubric-based evaluations demonstrated how they were reflected in students' design products. This triangulated approach enhances the robustness of the findings and illustrates the value of mixed-method approaches in architectural education research.

Overall, the findings indicate that the educational value of modular design depends on how it is positioned within the architectural curriculum. Rather than adopting a uniform instructional strategy across all studio levels, modular design appears to be most effective when its pedagogical objectives are aligned with students' developmental stage and the complexity of the design task. Accordingly, modular systems may function as structured learning frameworks during the early stages of architectural education and as tools for critical reflection and conceptual exploration during the later stages of architectural education. This stage-sensitive understanding extends current discussions on architectural studio pedagogy by demonstrating that the educational contribution of modular design evolves together with students' design experience. Unlike studies that examine modular design primarily as a design strategy or construction method, the present study demonstrates that its pedagogical function is dynamic and evolves throughout architectural education. This interpretation is also consistent with contemporary understandings of modularity, in which modular systems are increasingly regarded as adaptive and performance-based components rather than fixed repetitive units (Oxman, 2008). These findings contribute to ongoing discussions on architectural studio pedagogy by demonstrating that the educational role of modular design is dynamic, context-dependent, and evolves together with students' design experience.

5. Conclusion

This study examined how the pedagogical value of modular design changes across different stages of architectural education by integrating quantitative survey findings, qualitative student perspectives, and rubric-based evaluations of student design projects. The findings demonstrate that modular design does not represent a single pedagogical strategy; rather, its educational contribution evolves in parallel with students' cognitive and design development.

Taken together, the findings suggest that the educational value of modular design depends on its alignment with students' developmental stage. Rather than serving a uniform instructional purpose throughout the curriculum, modular design functions as a flexible pedagogical framework whose educational contribution evolves alongside students' growing design experience and increasing project complexity.

The principal contribution of this study lies in demonstrating that the pedagogical role of modular design is dynamic rather than static. By integrating perception-based survey findings, qualitative student perspectives, and rubric-based evaluations of design outcomes, the study provides a comprehensive understanding of how students' perceptions are reflected in their design processes and architectural products. This methodological integration extends existing research by illustrating the value of combining multiple forms of evidence when investigating learning processes within architectural design studios.

The findings also have practical implications for architectural studio education. Rather than applying modular design uniformly throughout the curriculum, architectural educators may consider adapting modular design activities according to students’ developmental stage and the complexity of studio projects. During the early stages of architectural education, modular systems can be employed as instructional frameworks that support the acquisition of fundamental design principles and systematic design thinking. During the later stages of architectural education, modular design may serve as a critical design strategy that encourages students to question conventional solutions, explore alternative spatial configurations, and develop a greater awareness of production processes, flexibility, and aesthetic coherence. Such a stage-sensitive implementation may contribute to more effective

studio learning environments by aligning pedagogical strategies with students' developmental progression throughout architectural education.

Despite these contributions, several limitations should be acknowledged. The study was conducted within the architectural design studios of a single public university and involved a relatively limited sample of undergraduate architecture students. Consequently, the findings should be interpreted within the educational context in which the research was undertaken and should not be generalized without caution. Furthermore, because the questionnaire was intentionally designed to examine multiple pedagogical dimensions rather than a single latent construct, internal consistency measures such as Cronbach's alpha were not applicable. Nevertheless, the multidimensional structure of the questionnaire and the absence of a formally validated measurement scale may limit direct comparisons with studies employing standardized psychometric instruments. The study also focused on students' perceptions and studio outcomes within a single educational setting and therefore did not consider institutional differences, alternative studio models, or cross-cultural educational contexts.

Future research may extend this work by examining modular design pedagogy across different educational institutions, cultural contexts, and interdisciplinary studio environments. Longitudinal studies and investigations integrating emerging digital design technologies, including parametric design, digital fabrication, and AI-supported design processes, may further contribute to understanding how modular design supports architectural learning in rapidly evolving educational settings.

In conclusion, this study demonstrates that modular design should be understood not simply as a design method but as a context-sensitive pedagogical approach whose educational contribution evolves throughout architectural education. By responding to students' changing learning needs, modular design supports the progressive development of spatial reasoning, creative thinking, and critical design awareness. These findings contribute to the growing body of research on architectural studio pedagogy while offering practical guidance for the development of more responsive, stage-sensitive, and pedagogically informed studio curricula.

Acknowledgements and Information Note

This study was conducted in accordance with national and international research and publication ethics. Ethical approval was obtained from the Social and Human Sciences Research Ethics Committee of Trakya University Rectorate (Decision No: E-29563864-050.99-948929; Session No: 2025/11; Decision Date: 13 November 2025).

Participation in the study was voluntary, and informed consent was obtained from all participants. All data were anonymized, and no personal or identifiable information was collected or disclosed.

Author Contribution and Conflict of Interest Declaration

The article was written by a single author. There is no conflict of interest.

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