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Empirical Study of Spatial Perception in Architectural Education: Assessing Experiential Qualities Through Physical Model Based Inquiry

Cut Sannas Saskia[1*], Agus Budi Purnomo[1], Ardilla Jefri Karista[1], Maria Elizabeth[2]
[1] Department of Architecture, Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia
[2] Independent Researcher

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Abstrak

This study explores the perception of space felt by humans through architectural mockups, to see the influence of architectural elements, especially lighting parameters, brightness, elevation and volumetric proportions, influencing human interpretation of the designed environment. This study was carried out by examining 51 mock-up variations with a room area of 4x4x3.5 meters, the mock-up variations were based on variable settings consisting of three main aspects; position of the ceiling, floor and openings; window opening size; as well as ceiling and floor heights. Based on the findings of this study, it is revealed that perceived brightness, spaciousness and comfort significantly influence spatial evaluation, especially the sense of space to improve the quality of the architectural space experience. Among all variables, comfort emerged as the most influential factor, thus strengthening its role as a core indicator of the success of spatial configuration. This study emphasizes the relevance of physical models not only as a representation tool but as an instrument for measuring the sense of space in architectural works. By basing design analysis on empirical observations, this study uses a mock-up model approach to measure human perception of space, but this study still has limitations compared to evaluating directly on space at the actual scale.

Keywords *: architecture education, cognitive ergonomic, comfort, spatial perception, user centered*

Kontak Penulis
Cut Sannas Saskia
Teknologi Bangunan Fakultas Teknik Sipil dan Perencanaan Universitas Trisakti
Jl. Kyai Tapa No. 1 Kode pos 11440
Tel : (62-21) 5663232 Fax : + (62-21) 5684643
E-mail : cutsannas@trisakti.ac.id

Introduction

This study is an in-depth exploration of the impact of various architectural elements on spatial perception, particularly in the context of architectural model studies. The main focus is to observe students perceptions, evaluations, and responses to their visual experiences on different spatial models. Evaluation of various architectural models aims to obtain different spatial experiences that focus on factors that influence the observer is experience of that space. Through examining elements such as lighting, elevation of space, as well as experiences responses by spatial perception of the built environment can be identified. In this way, the study moves beyond theoretical assumptions and provide an empirical basis for the architectural design process.

Furthermore, this study aims to assess human perception, in this case students, in assessing a space. This assessment is measured statistically, so it can provide an empirical basis for factors in architecture that can influence user perceptions. This study serves as a guide for design decisions, contributing to the design of functionally effective and aesthetically enriching spaces. It is hoped that the study results will advance architectural education by introducing evidence-based teaching methods, informing the development of innovative design practices. Ultimately, the aim is to enhance the user experience through expanding on the correlation of space design and human perception.

Architectural models are a commonly used tool in representing complex spatial designs, as it can help visualize and convey visual and spatial information to the user. The usage of architectural models here aims to help understand how changes in variables, such as lighting, ceiling height, and elevation, may affect the user's perception and how effectively it does so. This in turn should allow for a strong empirical foundation which will support a deeper and evidence-based architectural design practice. The term model in this study is an architectural model with various combinations of spatial model. In the process of building the model, many conceptual problems of the project come to light, new questions are asked about spatial relationships, proportions, perspectives, and even the construction process [1]. Therefore, the model is not only a product that concludes an experience, but is an object that can evoke architectural thinking [2]. An important role in design practice is the model-making process and contemporary studies, because they are interrelated with the architect's creative process. A model's role is to realize a thought and anticipation of constructive reality [3]. Using 3D models may help architects to be more creative and experimental with their design, in contrast to maquettes, since they don't have to worry so much about the technical aspect of their design [4]. Like a sculptor's maquette, an architect's model is simultaneously a search for and a test of ideas [5]. The study model however, is at its core only an exploration of design, not intended to represent a building in its entirety but to portray a single aspect of the design, similar to a sketch or a diagram [6].

The architecture design studio is a complex pedagogical space and constantly evolving practice that aims to train students in a wide range of skills. The complex nature of the studio makes it a challenging topic to approach as a whole and requires a method that can address its multitude of dimensions all at once [7]. Teaching pedagogy based on physical experiences can transmit positive energy in all courses regardless of course content [8]. The development of creative skills in engineering disciplines depends mainly on the ability of students to perceive, build, and analyse accumulated knowledge through training and practical practice [9]. Linking the educational process with the life and educational experiences that architecture students will need to face after completing their architectural education is important [10].

Spatial perception is a central topic in architectural studies, particularly when associated with the use of models as a medium for design exploration. Architectural models not only function as physical representations of design ideas but also serve as tools for understanding, experiencing, and evaluating spatial qualities before they are realized in full scale.

[9] emphasize the importance of spatial perception in the built environment, focusing on how architectural elements influence user experience in terms of comfort, orientation, and visual perception. Their study highlights that lighting, color, material, and spatial proportions play crucial roles in shaping perception. Furthermore, this study underscores the significance of multisensory approach, including visual, tactile, and affective experiences that each plays a role in the evaluation of spatial quality. In the context of models, this becomes highly relevant, as models simulate visual and spatial qualities in a limited scale. Understanding these elements is crucial to ensure how the perceptions generated through models can align with design intentions.

Methods

Using models, this study is conducted to identify key aspects that underpin students' assessments. Each model variation was evaluated systematically, considering factors such as the positioning of the ceiling, floor, and openings; the dimensions of window openings; and the heights of the ceiling and floor.

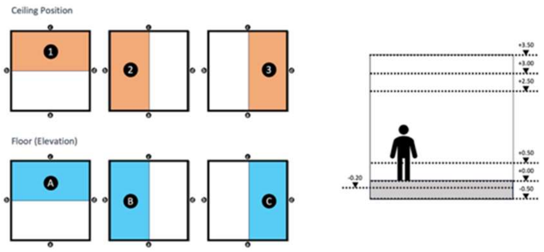

Figure 1. Ceiling position and floor height

Fifty one model variations, with a room dimension of 4x4x3.5 meters, were designed, with variations based on the configuration of three primary parameters: the positioning of the ceiling, floor, and openings; the dimensions of window openings; and the heights of the ceiling and floor.

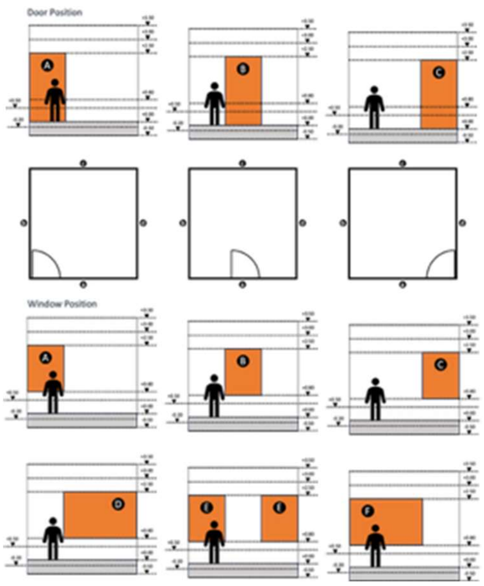

Figure 2. Opening Position

The assessment methodology employs a systematic approach that considers user perceptions of the spatial experiences generated by each configuration. Students, as primary respondents, are tasked with evaluating the provided study models. The analysis of these evaluations aims to uncover factors that shape the spatial experiences as perceived by the students. Adopting a quantitative study method, this study investigates the perceptions of model variations within the context of architectural studies.

The data set comprises 51 distinct model variations which are then assessed by 51 students, enrolled in the Architectural Design Studio 1 course. A distinctive feature of this study lies in the open-ended responses elicited from students, where the rationale for their selection of each model are then recorded in survey format. These responses are then translated into codes, which are analyzed using the SPSS statistical software. This method not only facilitates the examination of predefined variables, it also enables the identification of emergent factors that arise from students' responses.

Open-ended responses allow students to freely articulate the underlying reasons behind their preferences for each model variation. These responses are subsequently analyzed using SPSS statistical software. The analysis then identified correlations between students' evaluations of model variations and the investigated variables. The SPSS results are to test the hypotheses regarding the significance of differences in students' perceptions across various parameters. Responses are systematically coded, and the frequency of occurrence for each identified variable are then quantified. These key variables, emerged from the students' answers, include lighting, perceptions of brightness and darkness, perceptions of spaciousness or confinement, elevation, and sense of comfort.

Table 1. Operational variables

Variable Name	Data Collection Method	Data Unit	Data Source
Lighting	Student observations through model evaluations; recorded from open-ended responses regarding light quality (good/poor)	Frequency of mentions in responses; category: good/poor	Student responses (open-ended survey)
Brightness -Darkness	Student observations regarding the perception of brightness or darkness of the space; recorded from open-ended responses	Frequency of mentions; category: bright/dark	Student responses (open-ended survey)
Spaciousness-Compactness	Student perception of spatial openness or compactness; recorded from open-ended responses	Frequency of mentions; category: spacious/ compact	Student responses (open-ended survey)
Elevation	Student observations on variations in floor and ceiling elevation; recorded from open-ended responses	Frequency of mentions; elevation variation category (e.g., low/medium/ high)	Student responses (open-ended survey)
Comfort	Students' subjective perception of spatial comfort; recorded from open-ended responses	Frequency of mentions; category: comfortable/ uncomfortable	Student responses (open-ended survey)

Lighting refers to the perceived light adequacy of the space. Students observe how effective or insufficient the openings in the model are. Several factors influence this perception, including the position and size of openings, as well as the ceiling height and elevation, all of which significantly affected the perceived lighting quality. On the other hand, the brightness and darkness aspect reflects students' interpretations of the visual variations produced by said lighting conditions. How much contrast is present between the light and shadow are present in the models. Evaluations of differences in the position and size of openings, along with room height, revealed how these changes influenced these perceptions of contrast. The spaciousness and confinement variable represents students' perceptions of the room size as conveyed by each model variation. Although the physical dimensions of the spaces remained constant across all models, variations in ceiling height and elevation generated distinct visual impressions related to spatial openness or constraint. Regarding elevation, the study examined variations in vertical configuration achieved by adjusting floor and ceiling heights. A total of 51 elevation variations were considered, and the analysis of student responses emphasized the critical role of elevation in shaping the distinct spatial character of each configuration. Comfort is a subjective variable assessed by students across the model alternatives. This observation encompassed responses to variations in openings, room height, and the overall spatial atmosphere produced, all of which contributed to the students' sense of comfort within the model environments.

Discussion

Lighting plays a crucial role in shaping students' spatial perception within the examined models. Statistical analysis reveals that overall lighting conditions do not exhibit a significant effect ($p > 0.05$); however, specific lighting attributes, such as brightness levels, demonstrate a more pronounced impact. Lighting conditions in an architectural space strongly influence how that space is perceived and experienced. Recent studies show that strategic lighting design can shape occupants' mood, comfort, and spatial impressions. For example, manipulating the color of light has measurable psychological effects: different lighting colors produce significant changes in observers' mood states and impressions of the space (e.g. red ambient light can alternately induce calm or irritation) [11]. Recent study explored how varying daylight illuminance levels impact architectural experiences in a virtual office environment. The study found that changes in daylight levels significantly influenced occupants' perceptions of the space, affecting factors such as visual comfort and ambiance. This underscores the importance of considering daylight variability in architectural design to enhance user experience [12].

Table 2. Influence of spatial factors on perception score

Model		Coefficients[a]				
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1,465	1,410		-1,039	0,304
	Lighting	-0,149	0,131	-0,139	-1,139	0,261
	Spaciousness	0,188	0,062	0,525	3,038	0,004
	Compactness	0,180	0,061	0,487	2,923	0,005
	Brightness	0,370	0,112	0,406	3,293	0,002
	Darkness	0,226	0,130	0,211	1,743	0,088
	Elevation	0,066	0,113	0,063	0,589	0,559
	Comfort	0,317	0,081	0,426	3,928	0,000

a. Dependent Variable: Score

Students' assessments are significantly impacted by the variable "Brightness" ($p = 0.002$, $\beta = 0.406$), this suggests that areas with enough lighting are seen more favorably. On the other hand, despite having a positive correlation with the dependent variable, the variable "Darkness" does not reach statistical significance ($p = 0.088$). This finding implies that although adequate lighting improves spatial awareness, inadequate lighting does not always result in unfavorable assessments. According to study in environmental psychology, inhabitants' total visual comfort and pleasure with a space are greatly influenced by the way sunshine and shadow interact [13].

Previous study suggests that psychological elements like contrast, continuity, and coherence affect how individuals perceive space in addition to physical dimensions. The results of this study demonstrate that while the experiment's physical space dimensions stayed the same, students' subjective assessments of how spacious the room was altered based on visual cues, proportions, and spatial articulation. These findings highlight how crucial it is to incorporate perceptual psychology into architectural education in order to provide students a better knowledge of how user experience is influenced by spatial arrangements.

Students' spatial awareness was not significantly impacted by the "Elevation" variable ($p = 0.559$, $\beta =$

0.063). Elevation changes could create a more dynamic spatial experience, according to students' qualitative feedback, even though their quantitative influence was relatively small. This result is consistent with earlier studies that demonstrate how well-lit spaces improve visibility, openness, and user involvement, all of which contribute to a more satisfying spatial experience. Some of the spatial phobias might be triggered by six different factors. Space cramming is one of the main factors contributing to the uneasy feeling, among other things [14]. These claims indicate that the foundation for creating a comfortable space can be found in the use of lower elements, which are situated below the viewer's point of view and away from the primary viewing directions. This also applies to elements that can be incorporated into the area of the space's boundary planes (floors, walls, and ceilings), which allow for the opening of the space from the inside while simplifying its form [15].

The psychological reactions of occupants are significantly impacted by vertical spatial differences, such as ceiling height and vertical volume. Studies in environmental psychology and neuroarchitecture has shown that a space's ceiling height can affect people's feelings and mental states. For instance, a 2023 virtual reality study on the interiors of art galleries showed that while higher ceilings were associated with more feelings of joy and positive affect, low ceilings tended to elicit negative emotions (participants reported higher levels of fear and anger in a tight, low-ceilinged gallery) [16].High ceilings also subtly altered behavior; for instance, people maintained more distance from others and had more upward gazes in a tall space, indicating an expansive, open sensation [17]. These empirical insights validate long-held architectural intuition that vertical spaciousness contributes to psychological comfort. Whether in scale models or full-scale rooms, the vertical dimension (height of the ceiling or depth of a void) is an important variable to consider. A generous vertical space can impart feelings of freedom and openness, whereas a compressed vertical space may induce claustrophobic or suppressive sensations.
Perception of spatial breadth, represented by the variables "Spacious" and "Narrow," emerged as a key factor in spatial assessment. Both variables demonstrated strong statistical significance (Spacious: $p = 0.004$, $\beta = 0.525$; Narrow: $p = 0.005$, $\beta = 0.487$), confirming that students are highly responsive to the volumetric proportions of space. This reinforces fundamental design principles emphasized in architectural education. Similar observations have been reported in previous studies, where minor vertical changes, such as differences in ceiling or floor height can influence spatial cognition even when not explicitly recognized in structured evaluations. Perceived spaciousness or sense of spaciousness is one of the most significant spatial aspects and affective qualities of the built environment that may influence one's perception of space [18].

These results indicate that although elevation is not a primary factor in students' evaluation mechanisms, it still functions as a secondary element that subtly shapes their engagement with space. This underscores the need for further study on implicit cognitive responses to elevation changes, particularly within the context of architectural education and immersive spatial simulations.

Among all the analyzed variables, Comfortable emerged as the most statistically significant determinant ($p < 0.001$, $\beta = 0.426$). This finding suggests that comfort serves as the principal criterion in students' spatial evaluations. Spatial comfort is a holistic subjective evaluation that encompasses visual, physical, and psychological factors in an environment. In architectural contexts, comfort refers not only to ergonomic or thermal conditions but also to an overall sense of ease, pleasantness, and "fit" within a space. The configuration of a space plays a significant role in fostering spatial comfort, particularly when its structural regularity and internal layout are taken into account. Recent literature attempts to define this concept: spatial comfort has been described as the feeling of coziness and contentment that results from the combined effect of a space's physical configuration, visual qualities, and even tactile attributes [19].

The strong correlation between perceived comfort and students' assessments indicates that, regardless of variations in lighting, spaciousness, and elevation, the overall sense of comfort significantly influences how a space is judged.

Table 3. Summary of key spatial variables

Topic	Description	Academic Perspective
Lighting	Refers to students' assessments of the lighting conditions in each model (effective or insufficient). Variations in the position and size of openings, ceiling height, and elevation significantly affect perceived lighting quality within the models.	Statistical analysis shows that optimal lighting (high brightness) improves positive perceptions of space (p = 0.002). From a cognitive ergonomics perspective, adequate visual stimulation reduces users' cognitive load. Conversely, low-intensity darkness does not necessarily lead to negative evaluations (p = 0.088), suggesting that poorly lit spaces are not automatically perceived negatively. This aligns with perception literature emphasizing the role of psychological factors in spatial interpretation.
Brightness–Darkness	Reflects students' interpretations of the room's brightness or dimness. Variations in openings and ceiling height affect the perception of light intensity and shadow within the architectural models.	Study data shows Brightness significantly affects evaluations (p = 0.002), while Darkness does not (p = 0.088). From a cognitive ergonomics viewpoint, light intensity serves as a key visual cue: well-lit spaces facilitate orientation and enrich information processing. On the other hand, low-intensity darkness introduces visual uncertainty but does not necessarily provoke negative judgments.
Spaciousness–Compactness	Refers to students' perceptions of spatial openness or compactness. Even though room dimensions stayed constant, ceiling height and elevation variations created distinct visual impressions of openness or constraint.	Results show perceptions of spaciousness and narrowness are highly significant (p = 0.004 and p = 0.005), confirming students' sensitivity to volumetric proportions. From a cognitive ergonomics lens, volumetric proportions serve as primary cues in mental spatial mapping; for example, different ceiling heights can trigger approach or withdrawal responses. Small vertical changes can alter spatial perception, reinforcing the need for empirical, experimental approaches in architecture education.
Elevation	Refers to variations in vertical configurations (floor and ceiling heights), with 51 elevation variations tested. Student feedback emphasized elevation's role in shaping spatial character.	Quantitatively, Elevation showed no significant effect (p = 0.559), suggesting it's not an explicit evaluation criterion. However, qualitative feedback noted that elevation variations added visual dynamism. From a cognitive ergonomics perspective, elevation acts as a secondary factor implicitly shaping user interaction with space.
Comfort	Reflects students' subjective perceptions of comfort across model variations, including responses to openings, room height, and overall spatial atmosphere.	Comfort emerged as the most statistically significant factor (p < 0.001), indicating it is the main criterion in spatial evaluations. From a cognitive ergonomics standpoint, comfort is multidimensional (visual, thermal, acoustic, psychological). Lighting quality and room atmosphere play dominant roles in shaping comfort perception.

In architecture, comfort is a multidimensional concept encompassing thermal, visual, acoustic, and psychological aspects. The term comfort in a general sense stands for the feeling of being comfortable or the state of physical and psychological wellbeing [20].

The findings of this study indicate that students intuitively prioritize comfort when evaluating spatial configurations. Therefore, future pedagogical approaches should emphasize not only the technical aspects of spatial design but also the experiential and ergonomic factors that contribute to user well-being. These findings have significant implications for architectural education and spatial design practice. First, the importance of lighting and spatial volume highlights the necessity of including perception and cognitive psychology into the architecture curriculum. Students can acquire a better comprehension of spatial experience that goes beyond traditional design concepts by utilizing experimental models and empirical testing. Second, an interdisciplinary approach to architectural design is essential, as evidenced by the close relationship between comfort and spatial evaluation. Ensuring user comfort should be a primary priority throughout the design process, even though technical precision and proportionality are still crucial. This result is consistent with the human-centered design trend, which emphasizes both functional and aesthetic elements while giving priority to the user experience.

Conclusion

This study highlights the major role of lighting, brightness, spatial proportions, elevation, and comfort in shaping spatial perception within architectural model studies. Quantifiable evidence as gathered from students' evaluations shows the nuanced impacts of said architectural elements. This emphasizes the need to integrate perceptual psychology and cognitive ergonomics into architectural education. The importance of perception and psychological factors in architectural education is evident in which lighting, spatial expanse, and comfort significantly influence students' spatial evaluations, highlighting the necessity of a user centered approach in design pedagogy.

The effects in which different elements have on spatial perception varies. While lighting did not universally affect spatial perception, attributes such as brightness proved to be significant, aligning with prior study in the psychological dimensions of visual comfort. Similarly, perceived spaciousness appears to be highly responsive to variations in volumetric proportions, reinforcing traditional architectural principles concerning openness and enclosure. Elevation, although quantitatively less impactful, was qualitatively recognized as enhancing spatial dynamism and depth. This suggests a more subtle yet meaningful implication for spatial cognition and architectural design practice. On the other hand, comfort proves to be the most influential determinant, reiterating that architectural spaces must prioritize holistic, user centric considerations beyond aesthetic and functional attributes.

Integrating empirical study methods into the architectural curriculum will enable educators to equip students with analytical skills to create spaces that are functional, aesthetically pleasing, and also comfortable as it focuses on the user experience. Empirical study methods are essential for connecting theoretical design ideas with actual user perceptions. A data-driven method helps improve design quality, allowing it to better meet the needs and preferences of users. Although important insights into students' spatial perception were obtained, specific limitations should be recognized. The controlled experimental setup might not entirely capture the intricacies of spatial experiences in actual environments. Additionally, depending only on statistical significance as an indicator of effect might miss the qualitative subtleties of spatial awareness. Longitudinal studies that monitor shifts in students' perceptions over time would provide a deeper insight into how architectural education influences spatial cognition

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