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# Teaching Aperture Design in Architecture: A Pedagogical Approach to Illumination, Structure, and Space

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**Abstract:** This study investigates the pedagogical approach focusing on the integration of iterative learning, interdisciplinary collaboration, and hands-on prototyping by a project of aperture design within a studio-based architecture course. Therefore, the purpose of this study is to identify the potential of these approaches in improving students' comprehension of the interdependence between apertures and essential aspects of architecture like light and space. The researchers employ a qualitative case-study approach with feedback and collaboration within and across disciplines and four phases of conceptual designing and full-scale mock up construction. The primary objective was to assess how these teaching methods enhance students' comprehension and conception of the relationship between apertures and key architectural elements such as light, structure, and spatial experience.

Undergraduate students of 5th semester architecture at National College of Arts Rawalpindi initiated a systematic, four-stage, conceptual design of openings (doors, windows, skylights etc.) which underwent critique sessions and feedback from fellow students majoring in Fine Arts and Visual Communication subjects. The last step was the creation of life size mock-ups facilitating an understanding by students of how to design and actually build their solutions. The difference in this approach was to try and close the conceptual-practical divide where the students could apply theoretical knowledge to the practical works while getting feedback from their peers and instructors.

The results verify significant enhancement of the student learning in a number of areas, including light control and management, material application, and the balance between beauty and utility of a space. Integrating feedback from other disciplines was also central to broadening the students' design views of a space and aperture design ideas. The repeated application of the design-bid-review-construct cycle encouraged abstract thinking and the assessment of designs depending on performance.

A major contribution of this study is the application of the experiential learning models in architecture and finding that, hands-on design tasks with support from interdisciplinary faculty can meaningfully boost the students' technical lore and conception knowledge. In view of that, future studies could build on these findings and adopt the use of digital technology and assess the experience and impact of such pedagogy at a senior level during the undergraduate study of architecture and interior design.

**Keywords:** Architectural pedagogy, Prototypes, Explorative research, Light and architecture

## 1. Introduction

In architectural education one of the most pressing issues is the problem of the discrepancy between the theoretical curriculum and practice. For example, although the distortions of an aperture and distortions of light could be explained to students using traditional teaching techniques, the complexity of how such factors work together in the execution of an architectural design is not well captured in the conventional models of learning. Hence, students often have difficulties in achieving optimal solutions that concern the aesthetic aspect of objects and their purpose. This separation of theory and practice hampers their capacity to fully understand how apertures not only define the space and the experience but also characterise architectural space.

This is essential since aperture layout is one of the main yet simple component of architectural design, which defines the light supply scheme, possibilities of manipulating the inner space concept, and allows influencing the resultant mood within the building. Mostly students do not get a chance to try themselves in how certain aperture influences the light and the material used in the architecture that is pivotal for proper design of architectural spaces. Second of all, interdisciplinary input is mostly lacking, which results in students' limited view of what they are capable of designing. It is for this reason that it becomes pertinent to close these gaps in order to prepare the students to the real world challenges they are likely to face in their professional practice.

While there is a vast amount of work done on the theoretical side of the aperture design, there is limited literature on the practical aspects of teaching this concept by implementing the use of the experiential learning model. The absence of research-based papers regarding the impact of iterative feedback processes, cross-disciplinary collaborations, and life-scale prototype offs on students' understanding of aperture design is a research gap. This research proposal seeks to address that gap by exploring how these teaching techniques may be used to enhance the learning of aperture design to architecture students in a practical manner, with focused emphasis on the studio session.

The research involves architectural students in a systematic, sequential, multiple staged design activities carried out within architectural studios. The challenges that students have to address with respect to light, structure and spatial dynamics are to be embodied in apertures that students will need to design. During this process, they also get inter-discipline input from Fine Arts and Visual Communication students as well as feedbacks from the peers and instructors in the iterative manner. It fosters a prototypical feedback environment where the students will refine their aperture designs step by step and will be driven to think outside the box about their designs.

The main goal of this research is to assess the efficiency of studio-based learning environment in enhancing students' knowledge of aperture design. The assumption here is that undertaking an iterative design process, getting feedback from students from other disciplines, and creating life-scale models will lead to the students gaining a richer and embodied learning about how apertures mediate architectural space. Furthermore, it is the intention of this study to evidence how these forms of experiential learning can promote critical thinking, creative, and problem-solving aptitudes, which are invaluable to architectural training and profession.

To achieve these objectives, the study is guided by the following research questions: How does the feedback provided in the course of this iterative design process help students develop better understanding of how to reconcile utilitarian and formal demands involved in the act of aperture design? How does interdisciplinary collaboration contribute to enlargement of students' perspectives on materiality and space interactions in architecture? And lastly, how does hands-on usage of the tools help the students to apply their theoretical learning into coming up with functional prototypes?

Through addressing the issue of the specific approach to the learning-teaching process and the outcomes of this approach, this paper sets out to bring its input to the discussion concerning the pedagogy of architecture and architecture students, with the emphasis on the applied and the design studio as the principal ways to develop critical thinking and creative problem-solving skills.

## 2.Literature Review: Theoretical Framework for Aperture Design in Architectural Pedagogy

### Aperture Design as a Pedagogical Tool in Architecture

Aperture design is a core component of architectural practice and determines how light impacts architectural spaces as well as the form, performance, and character of structures. Lechner (2014) in his view opines that while discussing about the apertures it is vital to understand that apertures are essential for light control in building since they admit natural light as well as modulate the thermal comfort. Apertures are not only objects with specific functions, but also become visual accents, affect the perception of the room by the user and contribute to the formation of the architectural image. This supports the idea that apertures serve not just a functional purpose but also significantly affect the user's perception of space. By modulating light and thermal conditions, apertures contribute to the overall ambiance and comfort of architectural environments, allowing architects to create more inviting and sustainable spaces. Therefore, teaching aperture design in architectural education is important since it opens understanding of this relationship between light, structure and space.

As known, in architectural education teaching aperture design enables directly considering these basic architectural concepts with students. In the next section, the author draws from Pallasmaa (2009) to emphasize that the control of light in relation to apertures plays a critical role in the development of students' understanding of the qualities of the light that can be felt and hence in the creation of spaces that are friendly and hence the need to consider students' ability to design such friendly spaces. However, despite the teaching of aperture design in architectural education, one finds a gap in the literature as to how this concept can be taught in a manner that can easily be translated into practice. According to Frampton (2020), the design fundamentals must be imparted through a process of osmosis, but student engaging learning models rarely allow them to physically investigate how apertures affect, or form part of, the architectural layout.

This research extends from these concepts by offering a studio-based learning model which includes iterative design cycles, interdisciplinary critique, and full-scale prototyping. It also does so in an effort to solve an architectural education problem that isolates the theoretical discussion of aperture design from practical implementation.

### Constructivist Learning and Iterative Design Processes

One of the main components of the discussed theoretical framework of the proposed pedagogy is based on constructivism learning theory. Both Piaget (1973) and Vygotsky (1978) opined that constructivism entails the learning process where students construct knowledge as they interact with the environment. With regard to architectural education, this means that the students grasp knowledge in a best way if they are not only spectators of the design process but active members of it. According to Salama (2016), studio-based context is quite suitable for such enagement as it allows students to test, fail and learn through design and redesign processes. This iterative process helps students not only learn through mistakes but also encourages creative problem-solving, which is essential for developing resilient design skills that can adapt to real-world architectural challenges.

It has also shown how the design process which is so crucial in architectural education strongly resonates with Schön's (2017) iterative theory of reflection-in-action. Schön says that the design studio is a prophetic dialogue with the materials through endless spirals of designing, criticizing the design and redressing the designing. This process of iteration makes the students more equipped in critical thinking and it also provides them information as to how to evaluate their designs in light of given realities such as constraints and standards for performance.

Specifically, the aperture can only be understood and evolved iteratively such that it becomes sensitive to light and the space in which it is placed. A central concept of mechanical design is the ability to build and experiment with aperture designs, which students rarely are given the opportunity to do in traditional architecture programs. In the same manner, Webster (2008) explores that adopting the iterative design paradigm can assist educators in fostering their students' better critical judgement of architectural concepts given that they are exposed to the outcomes of executing conceptual ideas and designs.

The pedagogical approach described in the present study is based on constructivism paradigm of learning, according to which students construct their knowledge through interaction with the environment that provides ideas and stimuli. This is supported by Kolb's (1984) experiential learning theory whereby students enlightened by their practise and its consequence. Compared to other aspects of aperture design, this approach enables the students not only to envision light, space, and materiality but also to manipulate and experiment with their concepts while building full-scale prototypes at life scale. This is also in support of Schön's (2017) theory of reflective practice where students are able to think continually using "reflection-in-practice" and "reflection-on-practice" to analyze their decisions made during the design process and improve on them. By integrating these theoretical approaches into the study, the work fosters further appreciation of architectural concepts attained through cycles of embodied practice as well as critical reflection and feedback loops from peers and tutors that complement the theoretical knowledge students need to address concrete design problems.

Experiential Learning Through Prototyping

Among the major weaknesses highlighted in literature with regard to architectural education, is general exclusion of physical, hands on learning models. As cited by Kolb (1984), experiential learning is the kind of learning that the students experience as they engage in an activity and reflect on the consequences. With regards to aperture, through life scale prototyping the students get an opportunity to see how the design works in real life situations hence getting valuable feedback required in the fine tuning of the designs.

In line with this, Addington and Schodek (2012) observe that this is in tandem with the assertion by some scholars, which holds that the pedagogy of using physical prototypes in architecture allows the students actualize theoretical concepts into tangible materiality. By modeling these, students can explain it practically as relating the aperture to the distribution of light and materials of space and also the feeling of space. Such a learning method can prove very effective in the kinds of knowledge that involve aperture design since the learner has an actual material that is different from the virtual feel that comes with a computer simulation.

The teaching strategy employed in this study integrates formative learning with an emphasis on prototyping and testing of the students' designs as part of authentic practice. Besides enhancing training of the students' technicalities in designs, it also provides them with the ability to think about the ramifications of the designs they create. Sennett (2008) has rightly observed in this context that although this kind of learning by making does aid in breaking down the architecture ideas, it also assists students to reflect upon the object building process.

Thus, according to the literature review, it is possible to state that aperture design should be integrated much more coherently in the system of architectural education. This research, therefore, has to fill the gap as provided by the constructivist learning theories where the iterative design processes, interdisciplinary collaboration and learn through prototyping are involved. From the scholarly findings the outlined pedagogical framework is the foundation for a comprehensive scheme that will allow the students foster critical thinking, creativity and more importantly problem-solving skills both in learning and the actual practical practice of architecture.

**Interdisciplinary Collaboration and Broadening Design Thinking**

The last and one more key tenent of this teaching/learning framework is interdisciplinarity as it helps the students develop critical thinking concerning architectural design & expands their vision concerning built envirnoments & its impact on the multiplicity of inhabitants. The study by Lawson (2006) just described points to the value of interdisciplinary collaboration, especially in design education in which one works in different perspectives – to the enhancement of creativity. Although interdisciplinary collaboration can enhance the understanding of the experience of spaces in architectural education it can focus on the elements of light and materiality.

Other creative disciplines' input can enhance students' aperture design perspective as it would make them think about the functional concepts alongside with such visual and tactile effects. According to Salama, (2016) interdisciplinary interaction challenges the students to go deeper than the practical constrains of architectural designs, or the feelings and psychological effects that it may instigate. This broader perspective is important in making well rounded architect to design spaces that are not only functional but also have a meaning to the users.

Interdisciplinary collaboration which has been described above also approaches the realities of professional practice of an architect who cooperates with a number of other specialists from different fields including engineers, artists and those who deal with the environment. As Oxman pointed out in the year 2006, the only way to prepare students for this kind of collaborative environment is to ensure that they embrace Design thinking for complex problems so that they can be able to solve such problems holistically. Through the integration of feedback from the other disciplines into the teaching of aperture design, this research seeks to use methods that will prepare students to develop appropriate critical and creative thinking as they work on their designs.

**3.Methodology: Teaching and Learning Approach**

This research employs a studio-based learning approach where students engage in architectural design projects, passing through the four D's: This means to identify the objectives, define the strategic initiatives, build value-based propositions and engage in realizing them. These stages comprise of the framework of the studio based methodology. In the Discover phase, the students will be exposed to the concepts of aperture in an introduction to architectural design lectures and case studies of architects such as Le Corbusier and Louis Kahn where students will learn on how apertures affect light and space. In this phase, the students gather information on the site location and environment and come up with drawing templates which will prompt the design process from the material stand point of view. This usually involves using peer feedback and critical comments from the instructor Further clarification of these concepts is done in the Define phase. Here, students are forced to justify measurable and tangible design goal and objectives especially concerning the amount of natural light allowed in the rooms while at the same time respecting the architectural and aesthetic aspects of the building. During the Develop phase, it is important that there should be an integration of effort of different experts from various fields. Students from Fine Arts and Visual Communication give their contributions on the sensory and aesthetic considerations of aperture design, which makes the architecture students to come up with the effect and feeling impacts apart from the functional aspect. Last, the Deliver phase involves making full-scale models of student apertures from construction cardboard so that the ideas can be tested with practical applications. The most effective part for them is the hands-on prototyping of apertures that show

how they control the light and space; with feedback, they are able to adjust the designs.

It is based on the constructivist learning theory that state that learning is an active process of the learner in the process of constructing knowledge through interaction with the environment (Piaget, 1973). Thus, it is backed by Schön (2017) and his theory of reflective practice and, according to which, students develop, enact, and then critique their designs systematically. This is learning model which makes it easier for students to associate theory learned in the class with practice, especially in relation to light manipulation and spatial dynamics.

### 3.1 Research Design

The study employs qualitative case-study research approach that enabled identification of how the students built the designs iteratively using feedback and prototypes. This approach corresponds to Yin's (2018) case study methodology because its purpose is to study a modern day event in its natural setting. This case also has an iterative feedback loop for academic purposes that is inherent in the architectural education process.

The study was done in a period of six weeks at the National College of Arts (NCA) Rawalpindi, with students in the architecture department of the 5th semester. This particular academic context offered the design tools and environment required for prototyping aperture design.

### 3.2. Studio-Based Learning

The studio environment encouraged active learning through four structured phases: The studio environment encouraged active learning through four structured phases:

- Phase 1: Theoretical Foundation: Aperture design concepts were taught using lecture methods as well as case study of some architects like Kahn and Le Corbusier. The first design exercises included drawing and building simple forms of apertures so students could teach about the effects of light on space.
- Phase 2: Iterative Design and Critique: Adopting maquettes and models, students advanced on their designs; weekly feedback was provided by the peers and the instructors. This made sure that further development preserved technical as well as aesthetic aspects by concentrating on the light use and material.
- Phase 3: Interdisciplinary Collaboration: Students responded to feedback sessions with students from Fine Arts and Visual Communication to get an understanding of the feel and the sensuous attributes of their designs. Most importantly, this cross disciplinary approach helped students to look over functional requirements successfully.
- Phase 4: Life-Scale Prototyping: Only selected designs were produced at life scale As earlier noted, students had an opportunity to test their apertures on life scale prototyping. This phase allowed students to gain understanding of firsthand experience of their decisions in regards to light distribution or material interaction or the dynamics of the space.

### 3.3. Student Evaluation

Student progress was assessed through qualitative and quantitative methods, focusing on: Student progress was assessed through qualitative and quantitative methods, focusing on:

- Design Complexity: Lighting, material, and structural commodities students' competence to assimilate.
- Material Use: How various materials work in relation to light and space?
- Light Control: Apertures and Their Effect on the Natural Light Management.

An assigned rubric offered quantifiable feedback for each phase to compare the progress in design and technical features.

### 3.4. Data Collection

The assessment of work created by student groups as well as preliminary sketches and models and full-scale mock-ups was organised in a systematic manner. Prior to data collection, students were informed about the research objectives, and consent was obtained.

Participation was voluntary, and students were assured that withdrawing would not affect their academic standing. Personal identifiers were removed to maintain student anonymity throughout the study. Sketching was done by students and the sketches were reviewed to see how well the students could represent the concepts for aperture design into solutions with functionalities and form. In each sketch, a set of criteria was applied dependent on light control, material interaction, and spatial dynamics that have been discussed in the context of the project's learning objectives. The assessment of the prototypes in terms of light manipulation as well as the spatial experience was done by both looking at the prototypes and touching them. These aspects were assigned by the instructors so as to quantify students' performance in other sub-aspects like; design complexity, light distribution, on use of the material, and functionality and formalism. Data was gathered in multiple forms, including observational notes, student reflections, and physical design artifacts (models, sketches, and prototypes). These diverse data sources provided a comprehensive view of the students' design processes and outcomes

The student reflections were again qualitatively coded where the occurrence of common themes in the responses are named and categorized. First, all the students' reflections were taken and read through to ensure that none of them were missed. First emerged codes stemmed from repeated ideas or terms associated with learning experience such as 'integration of feedbacks,' 'light manipulations,' 'material experiments,' and 'interdisciplinary inputs.' Subsequently, these codes were aggregated under overarching theme areas corresponding to the study's research objectives. For instance, reflections that pertained changes in design approach following feedback from Fine Arts students were under the category of; Interdisciplinary Influence of Design Thinking. Likewise, the following reflections were grouped under the theme "Experiential Learning and Hands-On Prototyping": reflections that focus on changes in thinking regarding aperture design while engaging in prototyping activities. This coding process served to structure the qualitative data into patterns which gave some insights on change in students' conception of aperture over the course of the project. Themes were taken and further examined with regards to the impact that iterative feedback and interdisciplinary collaboration in groups had on students' capacity to apply theoretical concepts in actual design problems.

Limitations: The small sample size limits the study's generalizability. Furthermore, the interdisciplinary feedback was confined to a specific group of students from Fine Arts and Visual Communication, and future research could include broader disciplinary inputs. The qualitative nature of the data also means findings are rich in detail but not quantitatively generalizable.

## 4.The Design Project

This section outlines the overall project process, from the initial study phase through to the development of the final design. The following subsection provides details of the initial study and conceptualization phase.

### Overview of the Design Project: Objectives, Constraints, and Context

Through illumination, tectonics, and spatial habitation, the design project examined apertures in architectural spaces. The main goals were: Investigate how apertures can improve natural light distribution, structural and material configurations, and spatial perception. Site characteristics and materials limitations forced students to design with actual constraints. The setting was learning studios in which individuals worked jointly and offered constructive criticism to fellow students.

### Project Process and Methodology

### Initial Study and Conceptualization

The first phase of the design process comprised conducting a literature review for aperture design, which outlined the necessary theoretical concepts. The students started with concepts on light control and spatial modulation, and materiality in context with Lechner (2014) & Pallasmaa (2009). This tactile interaction deepens students' understanding of materiality,

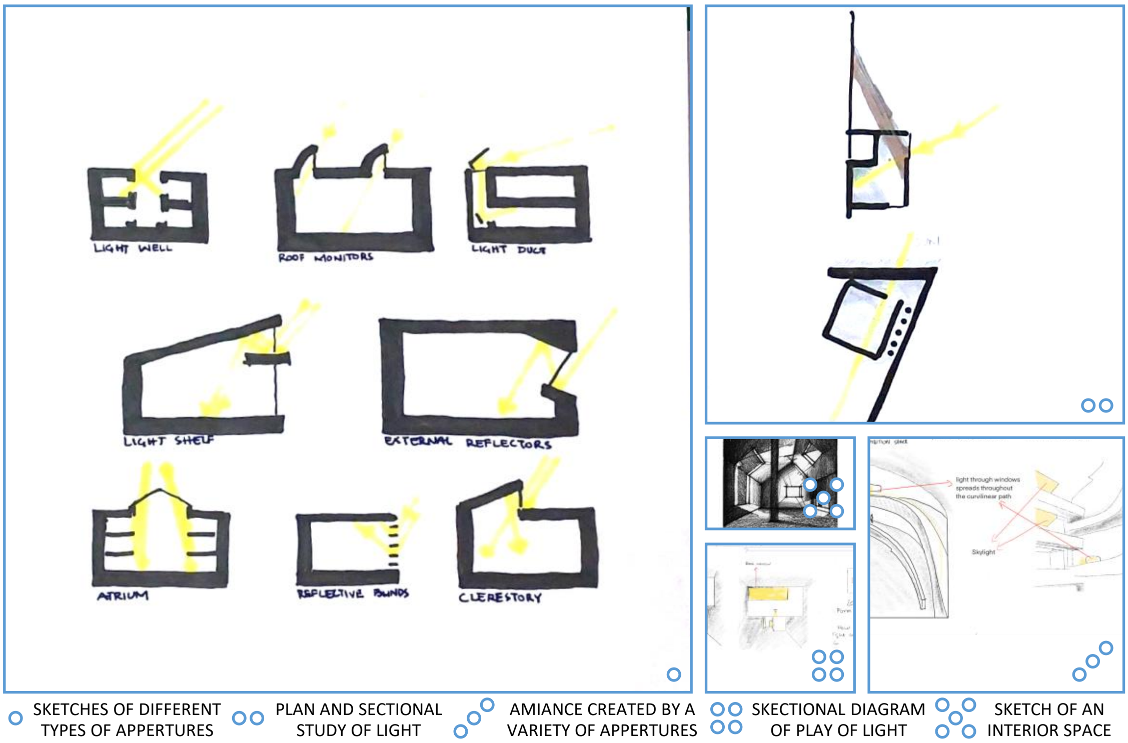


*Figure 1: Initial study of appertures by students (source: author generated)*

allowing them to critically assess how materials and light interact to create dynamic spatial experiences. It moves the learning process from the abstract to the tangible, enhancing comprehension of architectural concepts.This gave the necessary background knowledge for determining the effects of the aperture inregards to the form and function of architecture spaces. Based on these theoretical findings, students were challenged to advance their first ideas of the design shown in figure 1. Spearheaded by the constructivist learning model (Piaget, 1973), students were engaged in the co construction of knowledge through drawing and computer modellling. Said designs evolved in response to the theoretical concepts, where jut as intended students would translate such concepts as light distribution and interaction between material and work. The approach used was from Schön in the aspect of the reflective practice where students always went back and reflected and modified their conceptual designs on the feedback given.

It then explained how the focus of the research was identified by comparing the architects who have worked on aperture designs or used them in their constructions which included Corb, Scarpa, Loos, Kahn, Chareau Holl, Siza, Aalto, Ando and Le Corbusier. For this they read about their works regarding the application of apertures to regulate light, the partition space, and structural hierarchy (Curtis, 1996; Frampton, 2020). This phase also involved the utilization of maquettes and sectional models to think about spatial organization and aperture performances in several conditions.

**Collaborative Analysis and Ambiance Discussion**

After the conceptualization stage, the design process enters the feedback iteration stage, which corresponds to the method outlined above. They undertook weekly critique sessions where each of the students showed the progress of his/her designs to the fellow students as well as the instructors. Such sessions were aligned to Schön's (2017) notion of reflection in and on practice, where the students were forced to analyse the critiques they received and come up with informed decisions on how to enhance their aperture designs.

This element together with feedback from Fine Arts and Visual Communication students was important in this phase as it offered the students a more rounded view of design from the artistic and the practical viewpoint. Debating the implications of this feedback process was crucial to embedding changes into their designs; the analysis prying students from purely executing ideas and making them reflect on the artistic impact of apertures reflecting the modality of space; as found by Salama (2016) advocating for interdisciplinary practice in design education.

Later in the investigation, the students photographed the maquettes and the sectional models in order to capture the spatial character as in figure 2. These images were followed by interprofessional group-based lectures with students of Fine arts, Textile and visual communication students. These discussions provided diverse views on the spatial atmosphere, haptic/tactile aspects, and aesthetic, along with architectural research with views from other art forms of arts (P. 52 Salama, 2016). This section outlines the overall project process, from the initial study phase through to the development of the final design. The following subsection provides details of the initial study and conceptualization phase.

**Data Collection and Life-Scale Prototyping**

In the final stage, students constructed life-scale prototypes of their selected aperture designs shown in figure 3. The hands-on nature of this phase is strongly linked to the experiential learning model (Kolb, 1984), where students learn by doing and reflecting on the tangible outcomes of their work. The prototyping allowed students to test the functional and aesthetic aspects of their designs in a real-world

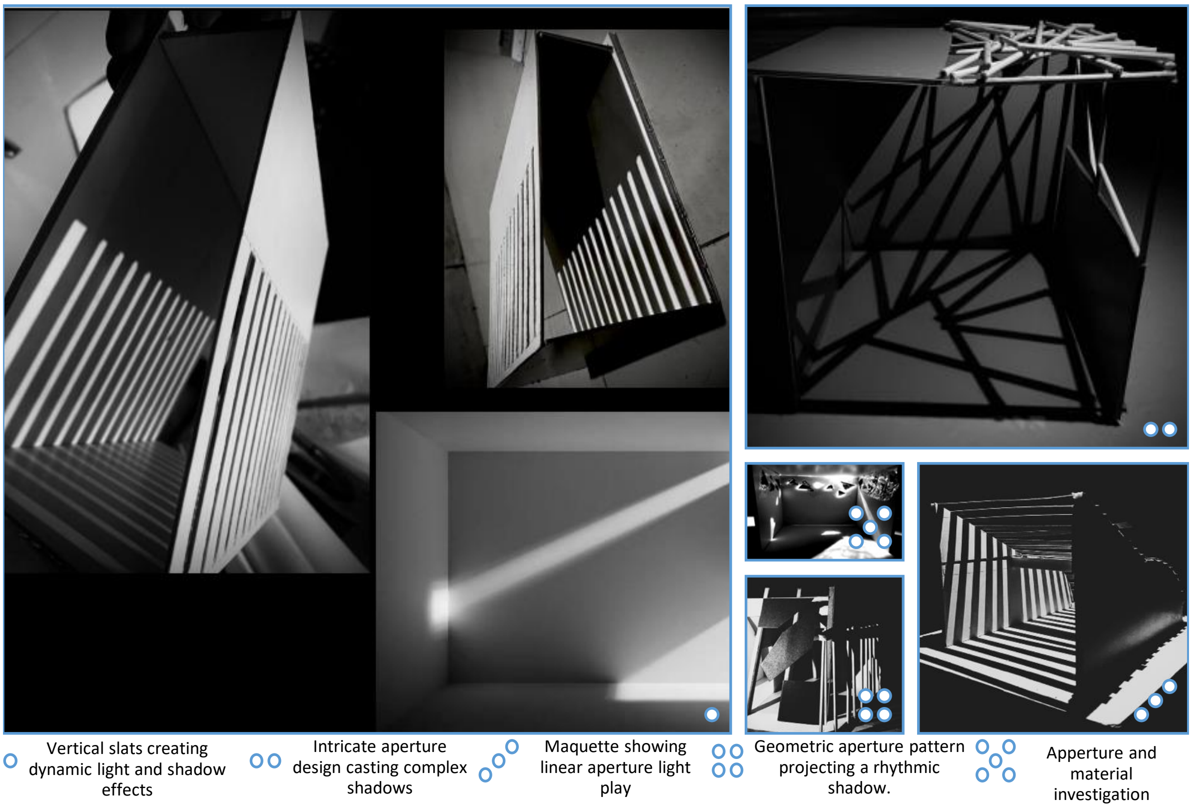


***Figure 2:*** *Study Models to study light and its ambiance in space*

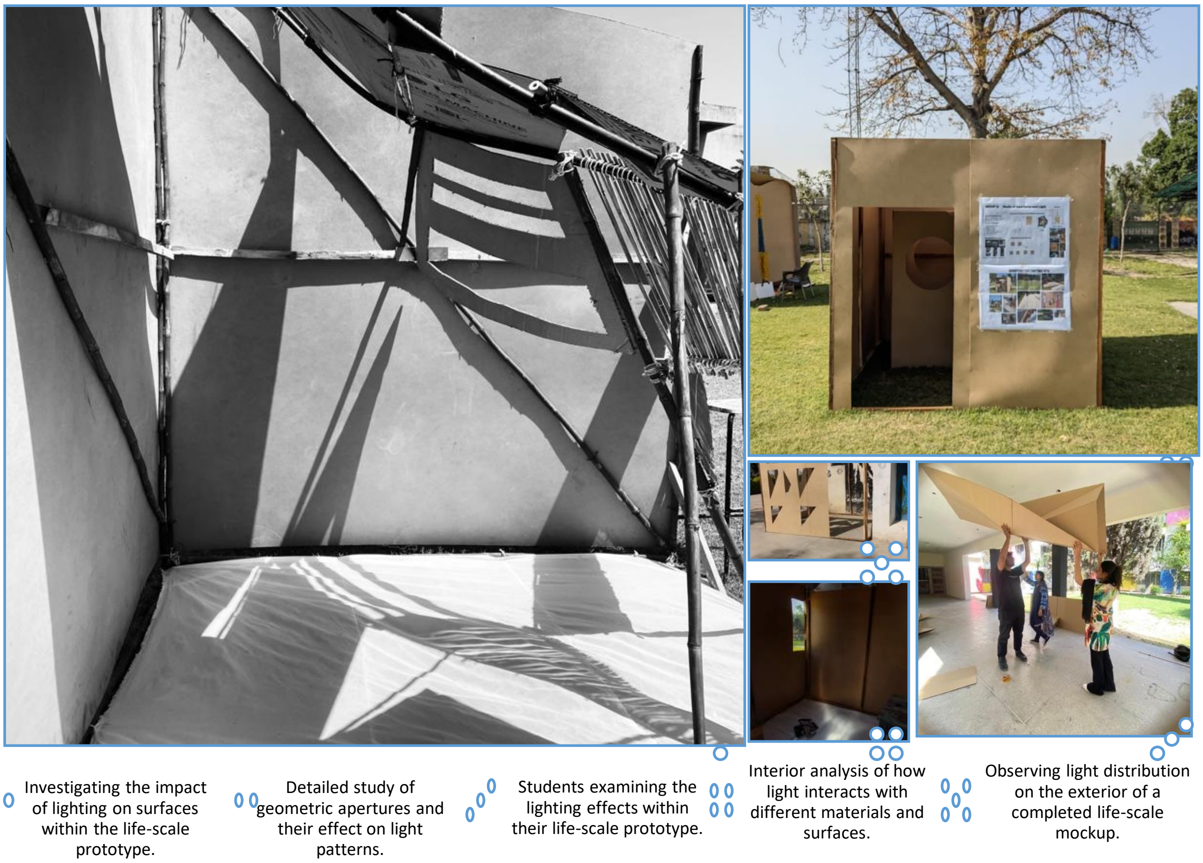


***Figure 3:*** *Process of making Life scale models and studying impact on space*

setting, providing immediate feedback on how their apertures controlled light, interacted with materials, and shaped the spatial environment.

The life-scale models were evaluated based on how well they achieved the design goals established during the conceptualization phase, particularly in terms of light manipulation, spatial experience, and material application. The focus was on ensuring that the theoretical principles discussed during the initial stages were successfully translated into practical design solutions.

Considering these insights from the interdisciplinary discussions, they developed life-scale mockups of their designs. With these prototypes, the students were able to develop real-life concepts of space, light, and materiality rather than purely theoretical constructs. The detailed investigations of each life-scale space involved observations about lighting and how it affected various surfaces and materials within the zones (Addington & Schodek, 2012).

**Final Analysis and Documentation**

Throughout the design process, students were encouraged to reflect on their learning and design evolution. Student reflections were collected at various stages, providing qualitative data on how their understanding of aperture design changed over time. This reflective process is central to the constructivist and reflective practice models, where learning is driven by self-evaluation and continuous improvement.

By engaging in this iterative and experiential process, students demonstrated a deeper understanding of how apertures impact architectural spaces, moving beyond theoretical knowledge to practical, real-world applications. The last process entailed closely assessing the constructed life-scale prototypes concerning the tectonic work, light survey, and space feel shown in figure 4. These aperture designs stretched natural light from determining the distribution to the structural disposition and the setting of the students' spaces. Consequently, these record offerings of documented buildings were beneficial in understanding the actual use and implementation of design and the theoretical frameworks supporting them (Pallasmaa, 2024).

### Prototype Analysis

The prototype analysis involved evaluating the life-scale spaces based on the following criteria:

1. Illumination: The possibility of regulating lighting conditions with the help of aperture placement and configuration.
2. Tectonics: Compatibility of structural elements with apertures to form compact and integrated forms.
3. Materials: The decision-making process regarding the selection of these materials and the effects of their use on light and the experiences of space.
4. Spatial Habitation: The production of purposeful and stimulating environments that enable people to interact and physically navigate.

## 5. Findings

The project revealed several key findings:

1. Illumination: Good aperture design offers many options for enhancing daylighting without creating a glazing or overheating effect. This light distribution and intensity can be observed in the various solutions students came up with in their prototypes.
2. Tectonics: The arrangement of apertures and structural members was critical in establishing structures, and articulating highlighted different structural systems of frames and shells when working on their aperture concepts.
3. Materials: The use of particular materials and their treatment determined the play of light on space. Light reflected on the shiny surfaces made the place bright, while the smooth surfaces produced softer lighting. In the actual design process, students tested different materials such as glass, wood, and metal to get the expected lighting.
4. Spatial Habitation: The apertures were exceptionally significant in defining the spatial characteristics of the work. Apertures

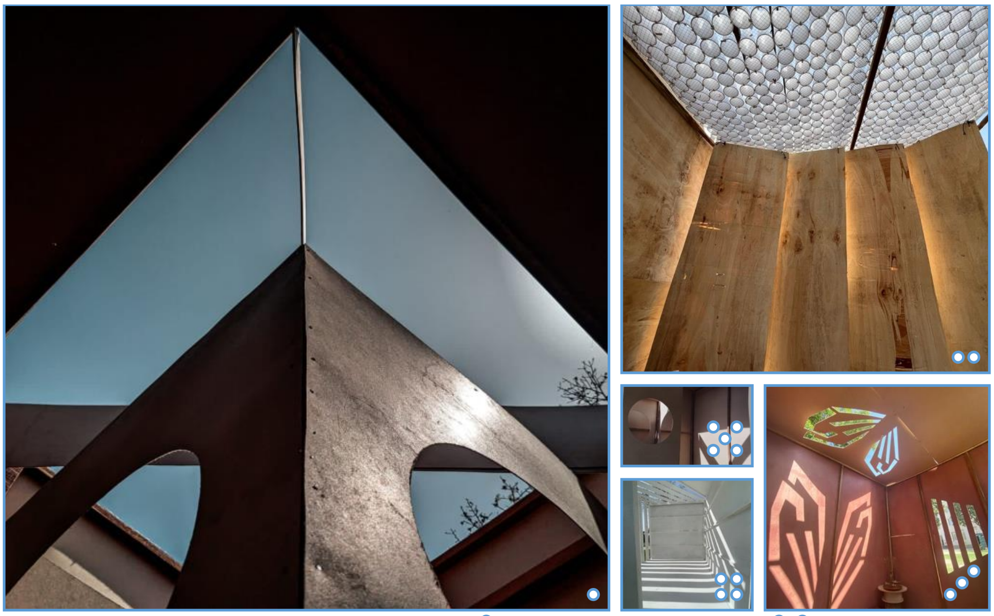


***Figure 4:*** *Life scale models and light ambiance*

impact the user's view, air, and light to help them understand how to use the space.

## 6. Results

This section provides the reflection on key learning outcomes of the studio-based design project, highlighting the students' developmental progress over the course of the project as a result of feedback, integration, and practical models. It is structured into three major learning outcomes which underscore the enhancements of students' design skills and their appreciation of aperture configuration within architectural practice.

### 6.1. Learning Outcome 1: Progression in Understanding Spatial Dynamics and Light Distribution

Analysis of students' sketches and oral presentations revealed a logical evolution of ideas that presented how apertures control space and light interactions. During initial stages of the project a number of students proposed very simple, superficial forms, that were quite weak in terms of the differentiation of light and space. But with consecutive critiques and changes in their design, students slowly started getting the idea of light interaction and came up with better aperture designs to solve such problems as glares, light diffusion, and the level of intensity. Finally, as students remained building on the feedback given, they began exploring the aperture size, aperture position and form as a way of improving the spatial journey. This progression is in line with literature on architectural education where studies indicate that design-challenge based and cyclical learning enhances the students' elaborated understanding of architecture (Goldschmidt, 2014; Salama, 2016).

### 6.2. Learning Outcome 2: Impact of Interdisciplinary Feedback on Design Processes

These feedback sessions were very useful since they titled across disciplines and helped to enhance students' designs. This was particularly valuable as in their critique architecture students were able to draw on insights from Fine Arts and Visual Communication students to consider the aesthetic and haptic character of apertures. Such feedback made the architecture students to consider more than just the generic parts of their designs and how positions of aperture influence users.

According to the questionnaires; Students indicated that such inter-disciplinary interaction enriched the course by expanding what design thinking entails, that is, the ability to incorporate artistic and sensory dimensions to a design. This is in congrisstenc with other studies that have pointed out the need to embrace interdisciplinarity as a means of enhancing creativity and innovation within architectural education (Frampton, 2020; Salama, 2016).

### 6.3. Learning Outcome 3: Hands-On Prototyping and Its Connection to Theory.

The hands on prototyping phase provided students with the best opportunity to understand the implications of aperture designs that they have chosen. This method of using life-scale prototypes gave students concrete feel on how aperture and space work with light and materials. A lot of students said that in this phase they gained a much better understanding of the theoretical aspects of architecture because it only made them witness how theories work in real life.

The decision to build the designs physically enabled the students to physically validate aperture position, material choice, and light positioning. This teaching strategy rubs with Schön's (2017) model of reflective practice when learning takes place when a person is testing and developing his plans and work.

### 6.4. Quantifying Student Progress

Qualitative data were collected as well while the progress of a student was monitored through a recorded quantitative assessment based on rubrics. The rubric measured student performance in key areas such as: The rubric measured student performance in key areas such as:

***Table 1:*** *Quantitative Progress in Student Design Performance*

| Criterion | Initial Phase | Mid-Phase | Final Phase | Explanation of Progress |
|---|---|---|---|---|
| **Conceptual Understanding of Apertures** | 1/5 | 2/5 | 5/5 | Initially, students had a basic understanding of apertures focused on functional aspects. Through critiques, they grasped how apertures shape spatial experience, improving significantly by the final phase. |
| **Spatial Quality and Light Distribution** | 0/5 | 2/5 | 5/5 | Early designs lacked effective light control, often resulting in uneven light distribution. By the final phase, students optimized aperture size, placement, and form to achieve balanced light environments. |
| **Material Interaction with Light** | 1/5 | 2/5 | 4/5 | Initially, students chose materials without considering light interaction. Over time, they experimented with reflective, translucent, and opaque materials to enhance the light's effect on space. |
| **Design Iteration and Refinement** | 1/5 | 3/5 | 5/5 | Early designs showed minimal refinement, with students not revisiting their ideas. By the final phase, students had iterated multiple times, showing significant improvement in attention to detail. |
| **Engagement with Critique and Feedback** | 0/5 | 1/5 | 4/5 | Initially, students were hesitant to integrate feedback. Through the mid and final phases, they became more proactive, incorporating feedback constructively to enhance their designs. |
| **Integration of Aesthetic and Functional Aspects** | 0/5 | 2/5 | 4/5 | In the beginning, designs either prioritized aesthetics or functionality. By the final phase, students successfully balanced both, creating designs that were both functional and visually compelling. |
| **Collaboration and Interdisciplinary Learning** | 0/5 | 1.5/5 | 5/5 | Early collaboration with other disciplines was minimal. By the final phase, students fully integrated interdisciplinary feedback, enriching their designs with artistic and experiential insights. |

• Design Complexity: Capability to design complex and workable aperture structures.
• Light Manipulation: Ability to manage the light distribution, intensity, and glare and placement of aperture.
• Material Selection: An appreciation of how materials affect light and space interaction and the resultant atmosphere.

The table shows clear improvements in each category as students progressed through the design phases. For instance, the average score in Spatial Quality and Light Distribution increased from 0/5 in the initial phase to 5/5 in the final prototype phase, reflecting the enhanced understanding gained through feedback and hands-on experimentation.

### 6.5. Feedback and Student Reflections

Students also participated in post-project surveys, where they provided reflections on the learning process. Survey results indicated that 85% of students felt that the hands-on prototyping phase was the most valuable aspect of the project, as it allowed them to apply theoretical knowledge in a real-world context. Additionally, 70% of students reported that interdisciplinary feedback sessions significantly enhanced their design thinking.

The feedback highlights the importance of practical, hands-on learning and the value of collaborative, interdisciplinary engagement in shaping students' architectural designs.

6.6. Summary of results:

***Table 2:*** *Student Feedback on Learning Process*

| **Survey Indicator** | **Percentage of Students Agreeing** |
|---|---|
| **Hands-On Prototyping Enhanced Understanding** | 85% |
| **Interdisciplinary Feedback Broadened Design Thinking** | 80% |
| **Iterative Design Process Improved Final Outcome** | 90% |
| **Integration of Aesthetic and Functional Aspects** | 75% |
| **Peer Feedback Contributed to Design Refinement** | 78% |
| **Collaboration Increased Confidence in Design Choices** | 72% |
| **Improved Ability to Articulate Design Intentions** | 82% |
| **Reflections on Real-World Applications of Designs** | 70% |
| **Project Encouraged Critical Thinking and Problem Solving** | 88% |
| **Gained Deeper Understanding of Material-Light Interaction** | 79% |
| **The Project Improved My Spatial Awareness** | 85% |
| **Feedback Sessions Helped Refine Conceptual Thinking** | 83% |

The integration of qualitative and quantitative data show that the studio-based, iterative learning approach enhances the students' design skills and their understanding of aperture design. The inclusion of interdisciplinary feedbacks and the use of the life-scale prototypes helped the participants to understand the characteristics of light, material and space in an integrated manner and within real life contexts as opposed to reliance on the theoretical knowledge.

**7. Discussion: Pedagogical Implications**

In this project, the integration of studio-based instructional techniques effectively supported key areas of learning in architectural education, based on constructivist as well as experiential learning theories. This discussion demonstrates how the iterative design process, inter-disciplinary collaboration, and hands-on prototyping benefited the students' cognitive processes and design skills based on literature from both educational and architectural fields.

**7.1. Constructivist Learning**

The teaching approach in this project fully supports the tenets of constructivism learning theories which has been formulated by Piaget (1973) where learning is an active process in which learners engage construct their own knowledge through constructive experiences as opposed to receptive learning where learners are mere recipients of teachers' knowledge. Because of the setting used in the studio, the students were able to interact with the physical as well as the theoretical aspect of aperture design. Through the process of making a maquette, constructive criticism, as well as developing life-scale prototypes, the real-life practice was certainly achieved by all students.

This is in line with the view of other scholars who agree that architecture students grasp concepts better when they are in possession of practical exercises that involve solving design issues (Salama 2016). These findings reinforce the argument that hands-on approaches foster deeper engagement with architectural problems, aligning with the iterative, feedback-driven methodology employed in this study, where students were able to bridge theoretical and practical design skills.In the subsequent phases of the project, the students were able to build additional layers of how apertures affect light, structure and space, in accordance with Kolb's experiential learning theory (1984). They are in line with earlier research about constructivism, especially in studio-based learning, that argues that the development of intellectual skills and designs occurs in a cycle of action-reflection where students experiment with ideas, observe that they fail, and modify or discard them (Schön, 2017).

The ability to build some prototypes on campus meant that students were able to relate architectural theory to spatial construct. This method supports Dewey's (1938) idea of the educational experience should be anchored in learners' transactions to construct knowledge from the environment. In the same vein, Biggs and Tang's (2011) proposed theory found that in active learning contexts such as in the present case where students are provided with design tasks and allowed to self-organise, it helps to strengthen their capacity to integrate knowledge.

**7.2. Iterative Learning and Design Thinking**

The concept of learning in this teaching approach is the process of iteration which mirrors the principles of design thinking as well as reflective practice proposed by Schön (2017). In regard to this, the project benefitted the students by enabling them to undertake the following processes characteristic of architectural programs: designing, critique, and redesigning.

Literature on use of learning cycle in architectural education has overtime affirmed that more so when learning involves iteration, that is, where more than one attempt is made and the end result is better because of critical improvements made in between; students develop more robust ways of solving problems and the capacity to manipulate more variables in design (Salama & Wilkinson, 2007). The fact that the designs were being reviewed weekly offered students the chance to introduce, modify and adapt their original ideas as they did counter designs from the challengers thus emulating real world architectural practice as postulated by Cuff (1991). Furthermore, the use of the feedback constructively during the final designs indicates that the student's work reflects the design thinking processes that more or less go through such cycles of testing and improving an initial idea over a designing process (Cross 2011). This cyclical refinement not only improved the technical precision of students' designs but also fostered creative risk-taking, a critical aspect of developing innovative architectural solutions.

The iterative process also benefited the development of metacognition within the course because students learned to reflect on the design progress and on their learning process as well. Fisher & Scriven (1997) suggest that processes involved in thinking about thinking or doing meta cognition is imperative for building independent learners for life. In this project, the aspect of metacognition was well displayed as students learned how to identify critical issues likely to arise in the designing process and also probably apply criticism appropriately.

**7.3. Interdisciplinary Collaboration**

Multidisciplinary integration has also shown to improve the learning process through introducing architecture learners to different paradigms of thinking that they probably would not encounter regularly (Frampton, 2020). Applied in architectural education, this approach stimulates search for novelty as the students work with other paradigms and approaches (Salama, 2016). For example, architecture works together with students from the Faculty of Fine Arts and Visual Communication: as a result, the architecture students are forced to look beyond simple technical issues linked with light, material, and space and expand their vision looking for new opportunities. Besides, this exposure improves their design skills as well as fits in the changing model of education that embraces diplomas from different disciplines at once (Lawson, 2006).

One of the most affecting examples of such outcome was when an architecture student, who first experienced certain difficulties in configuring aperture which should allow simultaneously to deliver enough light and to be beautiful at the same time, read the critical yet constructive feedback of a peer from Visual Communication course. The detour pointed out the emotional and sensory impact of light triggering a redesign of the architecture student's to embrace a more complex modulation of diffuse light. The student admitted, "I did not realize that light can elicit a very powerful emotional response until I got feedback from the Visual Communication student, it changed how I was using the aperture completely. " This example shows how one form of cross disciplinary feedback can impact the students by challenging their design thinking processes to the extent of embracing more of sensory and emotions to the functional aspects of the design.

Such interactions not only amplify the students' designs but also extend their thinking on the impact of aperture on the users; a phenomenon typically masked in normal architectural learning Oxman (2006) concluded that students of architecture are positively impacted by this integration as it fosters structural learning that enables the architecture to solve design issues with diverse forms of knowledge. This collaboration introduces a holistic view of design, allowing students to incorporate perspectives beyond architecture, such as visual arts and engineering. This broader viewpoint enhances the creativity and functionality of their solutions, better preparing them for the interdisciplinary nature of professional practiceWhile this is evident in our study, where interdisciplinary collaboration enhanced creativity, future research could further explore how integrating environmental engineering or urban planning perspectives might enrich students' architectural solutions to modern-day challenges. Chickering and Gamson (1987) also add that when students engage in academic activities by sharing their own views and ideas and by involving in the evaluation of their peers' views and ideas, the process of academic learning takes place.

The implications of this study underscore the training potential of interdisciplinary work in broadening participants' perspectives of design. Through showing that experiential, feedback based learning models can address these issues this work has implications for architectural education more generally. It is suggested that architectural education should include interdisciplinary critique sessions, along with prototype design as a way of improving students' technical competence and depth of architectural thinking for addressing actual architectural issues. These findings imply that comparable approaches of architectural education might be of benefits applied in different architectural education settings to improve the creativity and practical knowledge of future architects.

**7. 4. Experiential Learning Through Prototyping**

The last stage of life-scale prototyping was useful for the completion of the gap between the theoretical knowledge and the experience. Through their constructions, students apprehended how apertures worked within real situations, corroborating or disproving their hypothesis as per the distribution of lights and the qualities of the material and area they involved within their designs. This approach is inline with Kolb's (1984) experiential learning model whereby knowledge is acquired through practice and then fortified by reflection.

In architecture, the use of physical prototyping is very vital in the teaching process because it helps convey to the students how their ideas in their minds will be manifested into physical objects. The most important feature of the presented work was the opportunity of building aperture designs, testing them, and using the results which directly illustrate the given theory. Previous studies on design education highlight the benefits of the haptic essence of interacting with the materials and construction methods to master spatial organization and user experience (Pallasmaa 2009). This aligns with our findings, where students demonstrated a deeper understanding of how light interacts with materials during hands-on prototyping, suggesting that tactile learning accelerates comprehension of complex spatial dynamics.

In addition, the physical models served the form of feedback that is tangible where the build environment point out success and failure of design decisions made by students and some aspects of failure prompt students to reconsider their approach due to realities of the built world (Brown, 2009). This relates to the concept of 'making', one of the teaching paradigms where learners construct, with construction and material experimentation forming an important part of design learning (Sennett, 2008)

**8. Conclusion**

This paper has outlined the systematic teaching methodology of aperture design in an architectural studio as well as the success of hands-on or iterative approach to teaching. Through design critique, cross-disciplinary work, and life-size prototyping, the pedagogical strategy provided them with ways of contributing to the enriched understanding of architectural thinking and notions of light, structure and space.

The iterative design process helped the students practice a more detailed analysis of their works, driven by both the feedback from their colleagues as well as the instructors. This approach encouraged critical thinking and let the students solve design problems in the way that is close to how architects work daily, in dynamics. Pervasive reflections and revisions helped improve the students' design thinking, pushing them to come up with richer, more nuanced, and better functional and formal solutions.

In addition, the addition of the interdisciplinary review sessions added an additional dimension to students' learning experiences. Students obtained insights about materiality and spatial perspective from Fine Arts and Visual Communication department, which introduced the aesthetics of thinking into the design process with vitality and sensitivity. While this social aspect contributed positively to the creative aspect of the students' work, it also helped them to appreciate how to manage many stakeholders they will encounter in their professional practice in the future.

Finally, it is especially noteworthy that the last phase, or the life-scale prototyping phase, was particularly beneficial for the theory to practice transition. Students could then construct architectural design and its constituents and deliberately examine how the apertures addressed with light and space in real life which was changed intentionally by the students due to the results. For the students this direct experience in the built environment was an opportunity to enhance the translation skills where practical experience was brought about as the concepts were taught. In sum, this pedagogical model applied and effectively cultivated students' ability to solve problems in architecting. Overall, through the conjoining of iterative learning through application and student discussion together with multidisciplinary and tangible prototyping, it stressed the theory by supplementing a strong, thorough, and holistic design thinking as well as problem-solving foundation. It is suggested that the similar paradigms could be of significant value for future architectural pedagogy where students would graduate prepared to address both the conceptual and the practical dimensions of the design process.

**Acknowledgment of Research Limitations**

This study was conducted in an academic environment and with a limited number of students as subject prototypes, thus the results are not generalizable to a much larger population of students. There was little use of digital media and tools in the designing and product prototyping, though the research work involved hands-on, actual process. Regarding the limitations of the study, the future research could involve a higher number of participants and incorporate advanced digital applications in the design and analysis part to create a wider range of designs.

**Directions for Further Research in Architectural Education**

1. Digital Tools: Essential features need to emerge through the next stages of this study: parametric design, as well as augmented and virtual reality need to be examined as means to provide students with immersive design experiences.
2. Interdisciplinary Collaboration: Understanding the impact of cross-sdisciplinary collaborations particularly with engineering and environmental science discplines on design thinking.
3. Iterative Learning: The effectiveness could be observed post the students' graduation and longitudinal learning could be done to examine the cumulative effects of iterative learning on the students' designs.
4. Material Experimentation: New investigation for the use of sustainable and smart materials in teaching-design may promote green architectural practices.

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