A Framework for the Implementation of Lighting Design and Light Cognitive Tools in Kuwait's Design Pedagogy

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ABSTRACT

Lighting is an important design element that affects human health, comfort levels, mood, feelings, and the overall experience in spaces. Academically, light is integrated late in design education. Architecture and interior design schools usually introduce it as a design principle during the second or third year of education. As a result, students perceive it as an additive element in the schematic or design development phases rather than a concept generator from the ideation phase. If we accept that lighting design is essential in the conceptual design phase in order to create better-performing light spaces, then a new lighting design integration is needed in design curricula to encourage students to think about it from the ideation phase, enhance their understanding of lighting design knowledge, and facilitate their cognitive thinking and decision-making processes to eventually produce better performing lighting design projects.

The purpose of this research was to develop a new pedagogical framework for the integration of lighting design knowledge and lighting cognitive tools in design pedagogy to invite students to use it as a concept generator from the early design stages and to aid their cognitive thinking to produce high-quality lighting environments. The framework presents a learning path to introduce lighting design in a sequence from the first year of design education according to three main knowledge domains: the tacit, the procedural, and the explicit. The research contributes to shifting the current approach to lighting design education in Kuwait as an example and in architecture and interior design schools in general.

The researcher used multiple sources of data to develop the framework. First, she reviewed scholarly work and the literature that address lighting design pedagogy, design pedagogical theories, design curricula development models, the lighting design process, and design cognitive tools to create a logical argument for the framework's theoretical structure and to develop its research methods. Second, she analyzed lighting design documents from the United States' developed lighting design programs and Kuwait University to understand the current lighting design pedagogical structure, teaching methods, cognitive design tools, and foundational lighting knowledge. Third, she interviewed current lighting design educators from Kuwait University to understand the current lighting pedagogical model and sequence. Fourth, she interviewed lighting design educators from the United States to obtain new foundational lighting knowledge, creative teaching methods, advanced design cognitive tools, and other suggestions to improve lighting design pedagogy. Fifth, the researcher transferred knowledge from the United States' developed programs to Kuwait University to develop the new framework. Lastly, she presented the preliminary framework to lighting design professionals and educators using a Delphi Method to enhance it further and to rate its implementation possibilities.

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GENERAL AUDIENCE ABSTRACT

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DEDICATION

To my mother, Zainab Dashti, for her constant prayers, unconditional love, and everlasting support throughout my entire life. To my father (RIP), for the strength and dedication, I got from him to never give up on my dreams…

To my husband, Abdulwahab Marafi, for his constant support, love, encouragement, advice, and the power he gave me to keep moving forward towards my ambitions…

To my son Ali and daughter Zainab, my little companions in this difficult journey, for the inspiration, joy, and strength they provided me to complete this degree…

To my sisters, Kawther, Yasmin, and Narjis, for the neverending encouragement, prayers, and support that fueled this achievement …

To my mother-in-law, Fawziya Marafi, for encouraging me to take this wonderful adventure, and for raising a supportive husband.

I appreciate and love all of you
Simply Thank you

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Chapter I

1- Introduction

Light is a natural element that affects our experiences in different spaces. It influences peoples' perception and mood: Dim and warm lighting creates a relaxed environment, whereas bright and cold lighting imposes a more dynamic and energetic atmosphere (Flynn, Segil, & Steffy, 1988). The study of light is critical in design education due to its effects on human health, feelings, mood, behavior, and comfort levels (Brandi, 2006, p. 8; Flynn et al., 1988, pp. 11-18; Winchip, 2005, p. 319).

Despite the critical effects of light, designers take lighting design for granted. They often think about it as an additive element during the schematic design or design development phases instead of perceiving it as a concept generator in the ideation phase. This line of thinking may be due to the designers' past education or the complexity of lighting design knowledge. Lighting design educators usually teach lighting deductively in one or a few classes over the four or five years of design education. They teach it as theory and principles that are then applied to design problems (Gustina, 2011; Poldma, 2009, p. 20; Theodorson, 2006). In addition, most design students focus on their studio projects, devoting little time to other classes such as lighting design courses (Poldma, 2009, p. 21).

On the other hand, some designers may understand the importance of lighting, but choose to ignore it due to its complexity. Lighting design has both qualitative and quantitative aspects. It requires designers to think about light quantity, light behavior with surfaces, light quality, light color, light direction, and the arrangement of light fixtures for each task within a short timeframe. This process requires effort, time, and money without the aid of computing technology, but with the use of a reliable simulation software, designers can evaluate their lighting designs relatively quickly, with less effort and cost (Holtzman, 2005).

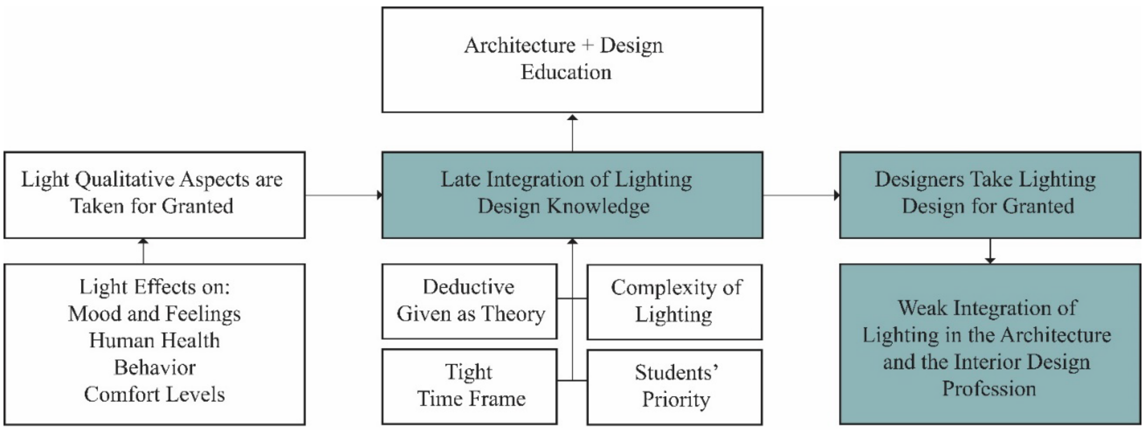


Figure 1-1. Current Status of Lighting Design Knowledge in Architecture and Design Education

In general, architecture, interior design, and other design-related disciplines foster computer technologies to develop and enhance the design process and to better inform its representational explorations. Light simulation tools are digital building performance tools that ease light representation, calculation, analysis, and design decision-making. Light simulation tools are either standalone software, which requires transferring digital models from one program to another, or a simulation plug-in that works within 3D modeling software. Despite the benefits of light simulation tools, designers currently use them for representation and calculation only rather than to inform design decisions. They usually apply these tools to the schematic design or design development phases. This delay in the application is either due to the available tools' traits and performance or the designers' past training and education.

Digital tools do not design but rather provide technical solutions based on the designers' choices (Capra, 1997, p. 38). Thus, designers must understand the concepts of placemaking and design thinking first, then select the most suitable technology to ease and aid the design process. Educators are encouraged to introduce computing technology alongside the corresponding design content so as to ensure an optimal learning environment (Pugliese, 2002). This understanding directs us to light design education and training.

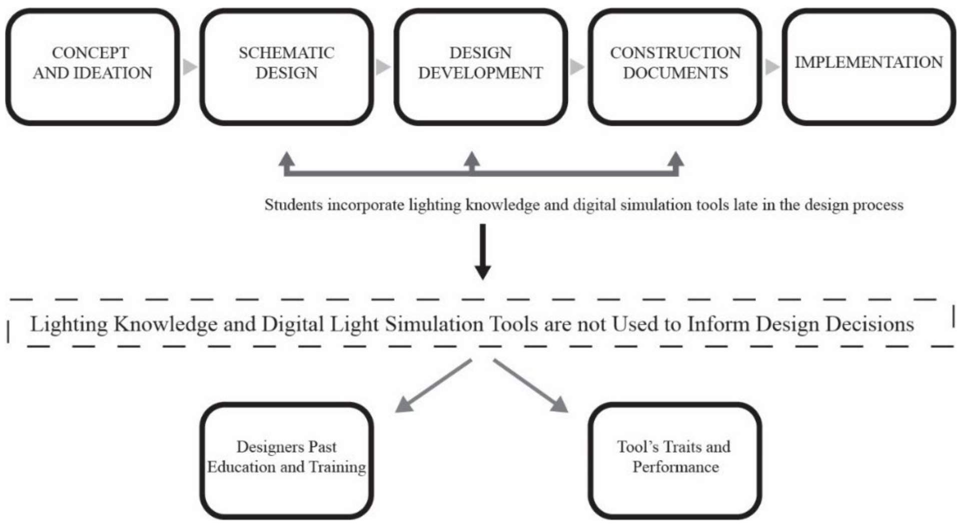


Figure 1-2. Current Integration of Lighting Design Knowledge and Digital Tools in the Design Process

Gabriel (an advocate of the lighting profession and education) argues that a strong academic educational base establishes a strong profession. As such, "We can't continue to be satisfied with people coming out of architecture, interior, and theater schools with only a tiny bit of lighting experience" (Danoff, 2014, p. 12). Likewise, Milham specifies that, "lighting education is not in a good place… fewer schools have faculty that are qualified to teach lighting" (Rosen, 2014, p. 21). Architecture and design schools have a significant impact on students and professional designers (Danoff, 2014); most designers adopt their school's way of thinking and techniques in their professional careers. (Dewey, 2014; Siminovitch, 2010). Some educational programs adopt new tools and technologies to create a more effective interdisciplinary learning environment, whereas others emphasize a more traditional process. Mishara, Koehler, and Henriksen (2010) support the former approach. They argue that an interdisciplinary approach integrating technology into the learning process encourages a more creative learning environment. It helps students solve complex problems and apply their academic knowledge in their professional careers (Mishra, Koehler, & Henriksen, 2010, pp. 2-7). This argument supports the Bauhaus and the constructivist pedagogical theories.

The Bauhaus embraces manufacturing techniques and technology in its design education to create an interdisciplinary and experiential design curriculum (Alqabandy, 2012). It encourages a student-centered design educational model which emphasizes self-learning and problem-solving methods over apprenticeship (Aloshan, 2016; Alqabandy, 2012). The constructivist philosophy also integrates technology and practical knowledge with design aesthetics. It aims to develop the designers' way of thinking and skills by providing them with both technical and artistic skills. Thus, it immerses the artist in the surrounding society rather than separating art from practice (Alqabandy, 2012).

The Beaux-Arts pedagogical approach, on the other hand, emphasizes draftsmanship and composition over other design aspects. It encourages students to create artistic architectural forms instead of practical ones (Hamlin & Cret, 1908). It also emphasizes textbook theories, steering students toward entering juried design competitions rather than preparing them for their practical careers (Cret, 1941). Thus, the Beaux-Arts favors a teacher-centered educational approach in which the final design product is more important than the design process and design thinking. The teacher-centered approach depends on teachers' feedback and critique. It presents students with problem-based learning, but leaves little room for students to think critically and learn experientially.

While the Beaux-Arts influenced early architectural education in the United States, the Bauhaus philosophy developed it. Design institutions that follow the Bauhaus curriculum aim to create a more efficient learning environment and better prepare students for their demanding professional careers. Though some design programs do recognize the importance of lighting design and technology, the majority does not address light as a critical design component. One could argue that lighting educators question how to teach lighting design properly precisely because it has both quantitative and qualitative aspects.

As a result, design education is in need of a new pedagogical framework that better integrates lighting design knowledge and light cognitive tools. The purpose of this qualitative research is to improve lighting design education and its knowledge delivery methods at Kuwait University by integrating lighting design principles and cognitive tools, including digital technology, into a new educational framework.

The first step in creating this framework is to develop a logical argument that governs its elements and structure. This argument is based on analysis of existing literature on general knowledge about lighting, design thinking, design process, lighting design process, and lighting design considerations and challenges. Comparison of available lighting simulation tools' usability and challenges reveals the features most appropriate for an educational digital light simulation tool. The TPACK framework

(Technological Pedagogical Content Knowledge) informs understanding of how to integrate technology in an educational framework, while pedagogical theories of design and literature on curriculum development shapes this research for use in an educational context. The research analyzes lighting design textbooks and established lighting design programs in the United States in order to identify and understand lighting design knowledge categories and domains. Finally, processes for efficient transfer of knowledge from one case study to another are considered. The three knowledge domains are essential for establishing the theoretical basis of this research and subsequently preparing the research instrument (interview questions).

Understanding the existing lighting design education at Kuwait University is a crucial step in developing the "As-Is" model. This is achieved through analysis of documents such as curricula and lighting class syllabi and information from in-depth interviews with lighting design educators currently at Kuwait University. Understanding current lighting design teaching methods, topics and sequence aids in development of the "As-Is" model.

The "To-Be" model is created by comparing established lighting design programs in the United States with both the educational framework and the existing lighting design structure in Kuwait. This draws on document analysis and in-depth interviews with specialized lighting design educators. The "To-Be" model results from gathering information about new ways to introduce lighting design knowledge and cognitive tools into Kuwait University's design curricula. This will enhance students' understanding of lighting design and their design decision-making process.

Because Kuwait University follows an American design pedagogical system, the preliminary pedagogical framework is presented to specialized lighting design educators and professionals from the United States. This followed the Delphi method so as to determine applicability of the framework and how it might be implemented.

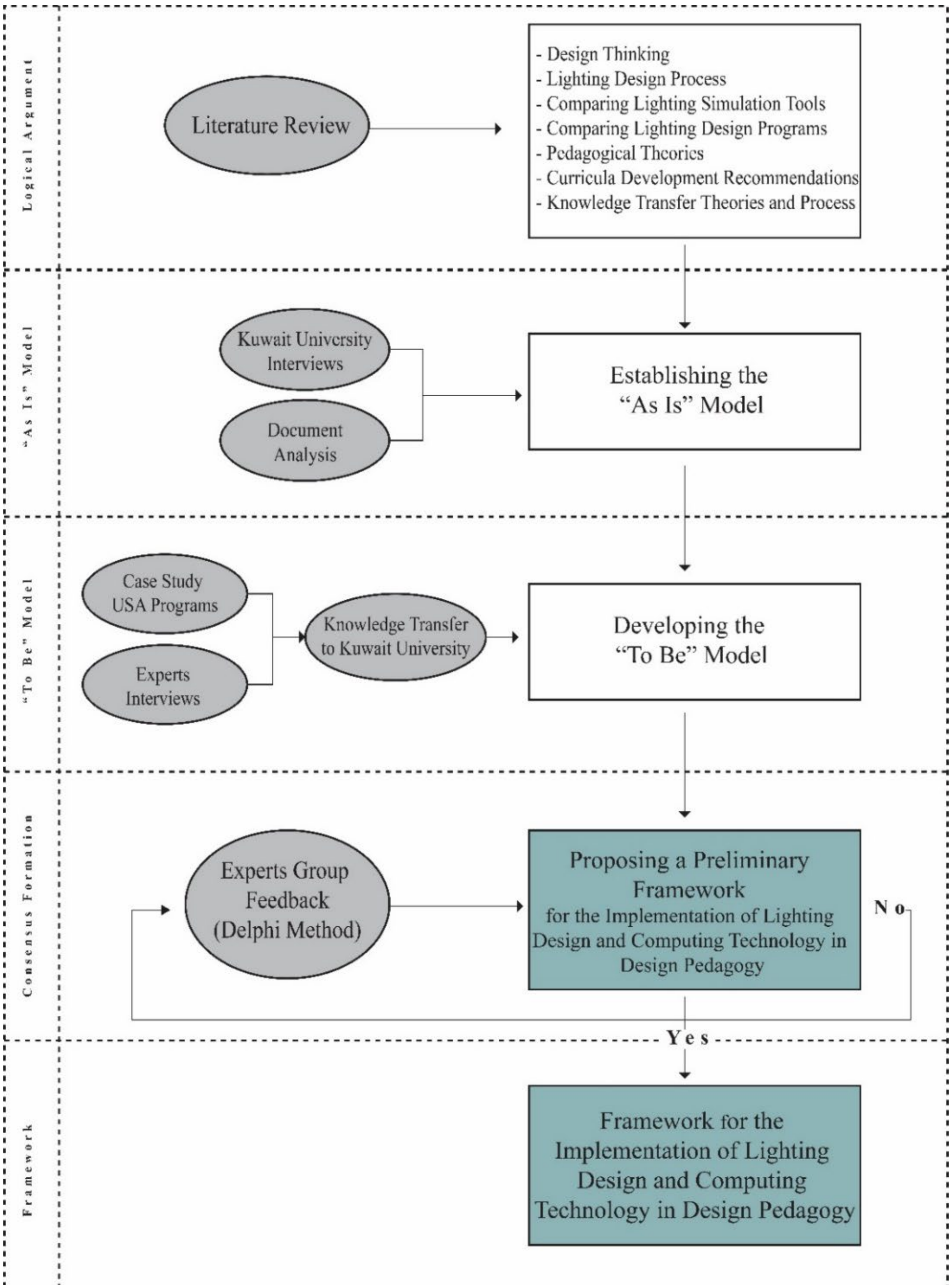


Figure 1-3. The Proposed Framework Stages

1.1- Design Knowledge Domains

Design research draws from three knowledge sources according to Cross (2007): the designer, the process, and the products. As a basis for design research, one must first understand how people design, how they learn to design, and what their design behavior and ability entail. This is tacit knowledge, comprised of design thinking, design training and education, and general knowledge about a specific design domain. One must then understand the process of design and the strategies/tactics that aid in the design process. This is procedural knowledge, which focuses on the design process, its implementation strategies, and tools that aid in the process.

Finally, one must understand the end product and its requirements (Cross, 2007, pp. 100-101). Product-related knowledge is explicit knowledge that encompasses information about a specific product or service, for example, how to create and use a design product or service.

In this research the three sources of design knowledge are addressed as follows:

- Tacit knowledge is identified by understanding design thinking, design education and training, fundamental lighting design knowledge, and the knowledge students need before introduction of lighting design and digital light simulation tools. This is established through literature review, document analysis, and interviews with current lighting design educators in Kuwait and the United States.
- Procedural knowledge that addresses strategies for introducing lighting design knowledge and light cognitive tools into the design process and curriculum is identified. This requires an understanding of the design process, the lighting design process, pedagogical theories, curricula development models, and current design curricula at

Kuwait University and in the United States. This is established through literature review, document analysis of curricula and course syllabi, and interviews with lighting design educators and professionals from established lighting design programs in the United States.

- Explicit knowledge must be identified. This domain addresses the characteristics needed in an educational digital light simulation tool, ways to use the tool, the available digital light simulation tools on the market, and other cognitive tools that can help students better understand lighting design and aid in their decision-making process. This is established through literature review and interviews with lighting design educators and specialists from both Kuwait and the United States.

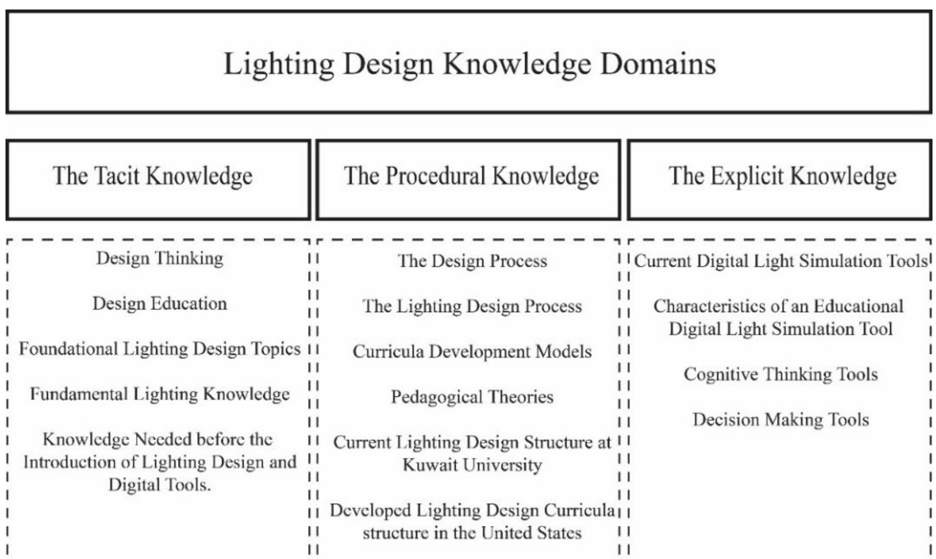


Figure 1-4. Lighting Design Knowledge Domains

1.2- Purpose Statement

Light is a fundamental component in design education and in the profession. Despite its importance, lighting design typically comprises only one part of a broader course that also addresses acoustics or color principles. This leaves students little opportunity to apply the theories they have learned to practical projects, thus leading to late integration of lighting knowledge in the design process.

Therefore, a new pedagogical framework is needed to teach designers to incorporate lighting design knowledge from the ideation phase. This will also help students better understand lighting design and its principles.

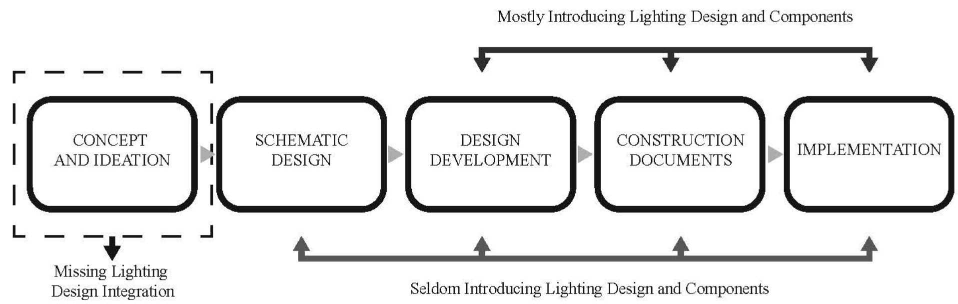


Figure 1-5. Current Lighting Design position in the Design Process (Based on Kuwait).

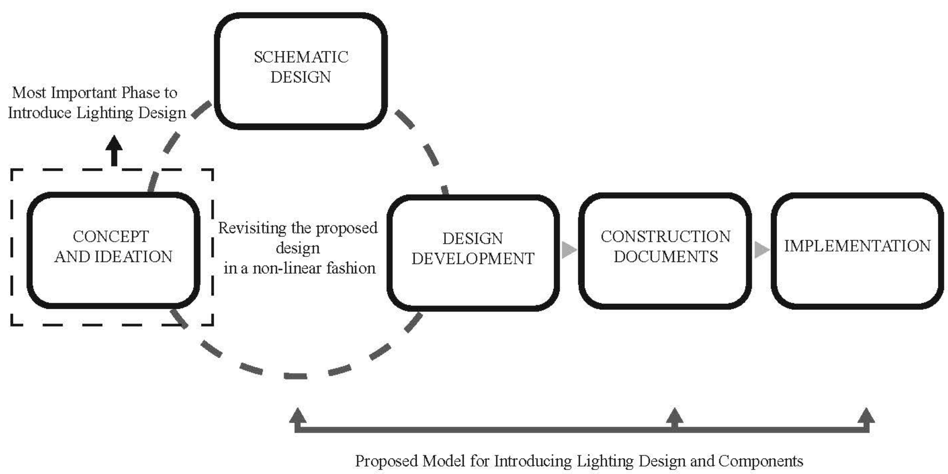


Figure 1-6. The Proposed Lighting Design Position in the Design Process.

The complexity of lighting design presents another critical issue in the pedagogical framework. Lighting requires detailed analysis and calculations to create a high-quality environment. To ensure successful lighting design, a designer must calculate light quantities accurately as well as selecting color temperature, intensity, and distribution based on function and desired atmosphere. These design decisions, calculations, presentation, and analysis are time-consuming and require tremendous effort when using analog tools such as manual calculations, sketching, and physical models. Light analysis and simulation tools are important because they allow designers to analyze, present, and calculate light more efficiently with less time and effort. Lighting design educators are encouraged to introduce such tools to help students in lighting design decision-making and to ease the complexity of lighting design analysis. However, some educators argue that introducing light simulation tools early in design education limits students' creativity. This research addresses the problem by putting forth a new pedagogical framework that integrates light simulation tools in design pedagogy along with other cognitive tools so students will better understand lighting design and its implementation.

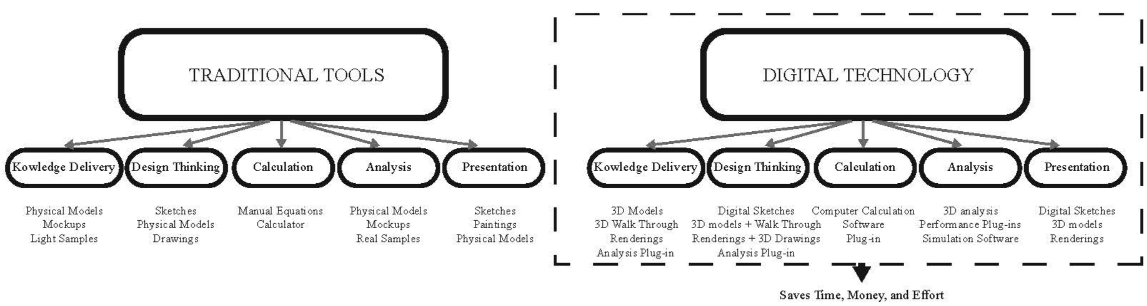


Figure 1-7. The Traditional and the Digital Lighting Design Tools in the Design Process

The purpose of this grounded theory qualitative research is to develop a new pedagogical framework for the integration of lighting design knowledge and cognitive tools into design education. The framework aims to enhance students' understanding of lighting design and to aid their design decision-making process. It also proposes a timeframe for introduction of educational digital light simulation tools and a list of features for such a tool. The framework is developed by analyzing lighting design curricula, exercise sheets, and syllabi from Kuwait University and established programs in the United States, as well as in-depth interviews with lighting design educators. The preliminary framework is then presented to lighting design educators and professionals from the United States using a Delphi method so as to further develop the framework and examine its appropriateness and implementation possibilities.

1.3- Research Questions

The goal of this research is to enhance students' understanding of lighting and to aid their design thinking and decision-making by proposing a new pedagogical framework for the integration of lighting design knowledge and cognitive tools into existing design curricula. The research aims to enhance design pedagogy at Kuwait University to better prepare students for their professional careers. In order to establish the framework, the research addresses the following questions:

- How can Kuwait University integrate lighting design knowledge into the existing architecture and design curricula in a way that enhances students' understanding of light principles and the lighting design process?
- How can Kuwait University integrate digital light simulation tools and lighting design cognitive activities into its design pedagogy in a way that aids students' cognitive thinking and lighting design decision-making process?
  - What are the appropriate features for an educational digital light simulation tool?

1.4- Research Objectives

The objectives of this research are:

- To create a general knowledge framework that will enhance design curricula at Kuwait University through a new approach to lighting design principles and tools.
- To integrate digital light simulation tools and cognitive activities into lighting design pedagogy at Kuwait University in a way that enhances lighting design education and students' decision-making process.
- To establish a list of appropriate features for an educational digital light simulation tool.

1.5- Research Methodology

The first step toward establishing a new pedagogical framework for lighting design is to understand the ontological and epistemological underpinnings of the research questions which in turn enables selection of the most suitable research methodology, methods, and design. Ontology in research addresses the ways one perceives the nature of the world or reality (Ahmed, 2008; Groat & Wang, 2013). Epistemology, on the other hand, addresses the ways one acquires knowledge, providing a philosophical ground for how people come to know (Ahmed, 2008; Groat & Wang, 2013). Through the research questions, this research investigates pedagogical approach based on human thought and subjective interpretation of lighting design education as a means to enhance the framework. Different experts' viewpoints collected through this research expound upon ways to integrate lighting design knowledge, cognitive activities, and simulation tools in design curricula so as to aid students' cognitive thinking. Thus, the ontological research assumptions reside in a socially constructed reality in which people provide meaning, experience, and thought to enhance other people's cognitive processes and experiences in an educational setting. In other words, this research tackles a subjective reality constructed by humans through multiple meanings, interpretations, and thoughts rather than one objective reality.

The epistemological stance, on the other hand, is constructionism, an approach in which people construct knowledge through interaction with each other and their social context. The research questions explore a new way to integrate lighting design knowledge in design pedagogy through methods that emerge from participants' subjective feedback. Hence, pedagogical knowledge is co-constructed with the research participants. The suggestions or findings of the research are based on participants' experiences and thoughts and are open to different interpretations rather than a single right answer or method of implementation.

Based on the ontological and epistemological assumptions of the research questions, qualitative research proves to be the most appropriate research methodology for the proposed framework. Qualitative research seeks knowledge through open-ended methods and is interested in people's interpretations, experiences, and thoughts, especially when there is little to no precedent for the research topic. The case study and grounded theory strategies of inquiry are the most appropriate research design for the proposed questions. The case study strategy develops an in-depth analysis about single or multiple cases that share similar activities, whereas grounded theory inquiry develops a general theory based on participants' feedback in order to create a process of action by organizing the obtained information into categories and concepts (Creswell & Creswell, 2018).

The research questions indicate that a process of action is required to develop lighting design knowledge in a particular case (Kuwait University). It is therefore imperative to understand Kuwait University's context in depth through a case study strategy in order to develop the process of action through a grounded theory approach based on established case studies. The researcher must gather information from lighting design experts to create the process of action. Established lighting design programs in the United States serve as excellent case studies since they have already achieved successful integration of lighting design knowledge in multidisciplinary design curricula. Lighting design educators from these programs are experts in delivering lighting design knowledge and its simulation tools in ways that enhance students' understanding and decision making. Consequently, the researcher aims to transfer lighting design pedagogical knowledge from the United States case studies (the experts in the field) to Kuwait University (the implementation case).

Different qualitative methods such as literature interpretation, document analysis, and open-ended structured interviews with experts in the field are applied to meet the research objectives. A logical argument for the research structure is established by using relevant literature to create a theoretical model. The literature provides knowledge about the most appropriate design pedagogical theories, design thinking, the design process, lighting design knowledge, the lighting design process, curriculum development, digital light simulation tools, considerations from the TPACK framework to integrate technology in education, and finally the process of transferring knowledge from one case study to another. Research findings are compared with existing literature to identify commonalities and contradictions and to add to disciplinary knowledge.

The "As-Is" model emerges from understanding current lighting design education at Kuwait University through document analysis and in-depth interviews. Analysis of design curricula and lighting course syllabi yield a general understanding of the lighting design structure at Kuwait University. Interviews of current lighting design educators lead to an understanding of the lighting design sequence, the design pedagogical philosophies, goals for each design year, methods for delivering lighting design knowledge, lighting cultural context, lighting design topics, perceptions about lighting design knowledge, and challenges of incorporating lighting design knowledge and simulation tools into the curriculum.

Document analysis and in-depth interviews with lighting design experts in the United States generate the "To-Be" model based on the United States case studies. Selected educators from design schools known for their lighting design programs provide insight into effective integration of lighting design knowledge and cognitive tools into design curricula, lighting design knowledge delivery methods, foundational lighting knowledge, ways to integrate both technical and poetical aspects of light in design education, ways to balance lighting design knowledge with other competing classes, tools that students need to understand lighting and to help them in design decision making, intended use of the tool, ways to integrate lighting design in the design process, typology of questions that students need to understand the lighting design process, and ways to integrate digital light simulation tools.

The data analysis process follows steps of grounded theory analysis. Data is prepared by transcribing interviews with the help of a transcriber and by collecting notes from the document analysis. Data is coded in manageable pieces (open and focused coding) for comparison and to create categories and themes (axial coding), using the NVivo software. During coding and combining categories, memoes are also created using NVivo. Data is organized into themes and categories with quotes in a logical order. Finally, the research findings are explained in tables and diagrams to describe the process of action through multiple knowledge domains (tacit, procedural, explicit) and a sequential knowledge delivery method (foundational, intermediate, advanced, elective in years). The proposed framework is also presented for implementation in a theoretical narrative (a studio scenario).

The results are summarized and compared to the literature; limitations are stated and some areas for future research are proposed. Consensus is formed through triangulation, reflexivity, and a Delphi method (experts' feedback). For triangulation, different data collection methods are used to compare the findings. For the sake of reflexivity, the researcher's input and background are included alongside the participants' demographic information. Finally, the preliminary framework is presented to lighting design experts using a Delphi method to develop the proposed framework and its implementation possibilities.

1.6- The Scope of the Research

The research aims to enhance Kuwait University's design curricula by emphasizing the importance of lighting design. It also invites educators to improve their students' design decision-making process. The research enriches existing design education by incorporating lighting design principles and tools into a new structure. It provides suggestions for future research, but it does not develop new light simulation software. Because of the focus on developing knowledge delivery methods, the research targets lighting design educators rather than lighting design students.

1.7- The Role of the Researcher

The researcher's professional experience and training inform the research question. After earning a Bachelor's in Architecture from Kuwait University and a Master of Interior Architecture from Rhode Island School of Design (RISD), she worked for one year as an architect and two years as an interior designer. In the course of studies at Kuwait University, RISD, and Virginia Tech, she attended three luminous undergraduate classes.

A significant problem the researcher recognized from her time as a student and through her discussions with co-workers is that design students do not understand their lighting courses well and rarely apply lighting knowledge in their professional careers. She noticed that different commercial spaces in Kuwait lack in lighting quality, indicating that designers in Kuwait take lighting design for granted. The current design education system in Kuwait would better serve student designers by changing how lighting design is introduced, and by introducing it in more than one class. Incorporating digital technology such as digital light simulation tools would help students understand lighting better and thus design lighting more proficiently in their future careers.

1.8- Summary

This research aims to create a paradigm shift in design education by introducing lighting design knowledge differently into existing design curricula. It aims to broaden students' knowledge of lighting design and to encourage them to apply it in their professional careers. The research also introduces new ways to incorporate digital light simulation tools and other cognitive activities to aid students in the decision-making process. Lastly, it provides a list of features for educational digital light simulation software. In sum, the research goal is to improve lighting design pedagogy, which ultimately will enhance the design profession.

Chapter II

2- Literature Review

The literature review positions the research topic within an existing body of knowledge to understand the research context. The researcher tries to answer the following questions by interpreting the existing literature:

- What is light and why is it important to study?
- What should designers know about lighting?
- What are the design thinking and the design process?
- What is lighting design and where does it fit into the design process?
- How does digital technology affect the design process and the lighting design process?
- What are the digital tools available for light simulation and analysis?
- What are the features needed in a light simulation tool?
- What is the history of design education?
- What are the theoretical models that impact design education?
- Who establishes current design curricula?
- Is there existing research that tackles the impact of digital technology on design or lighting design pedagogy?
- How to transfer knowledge from one case study to another?

This chapter presents lighting design through the following themes: lighting design thinking and process, lighting design technologies, and lighting design pedagogy as shown in figure 2-1. The chapter aims to link the importance of lighting design pedagogy to lighting design practice and to show the impact of current lighting design technologies on both lighting design education and practice.

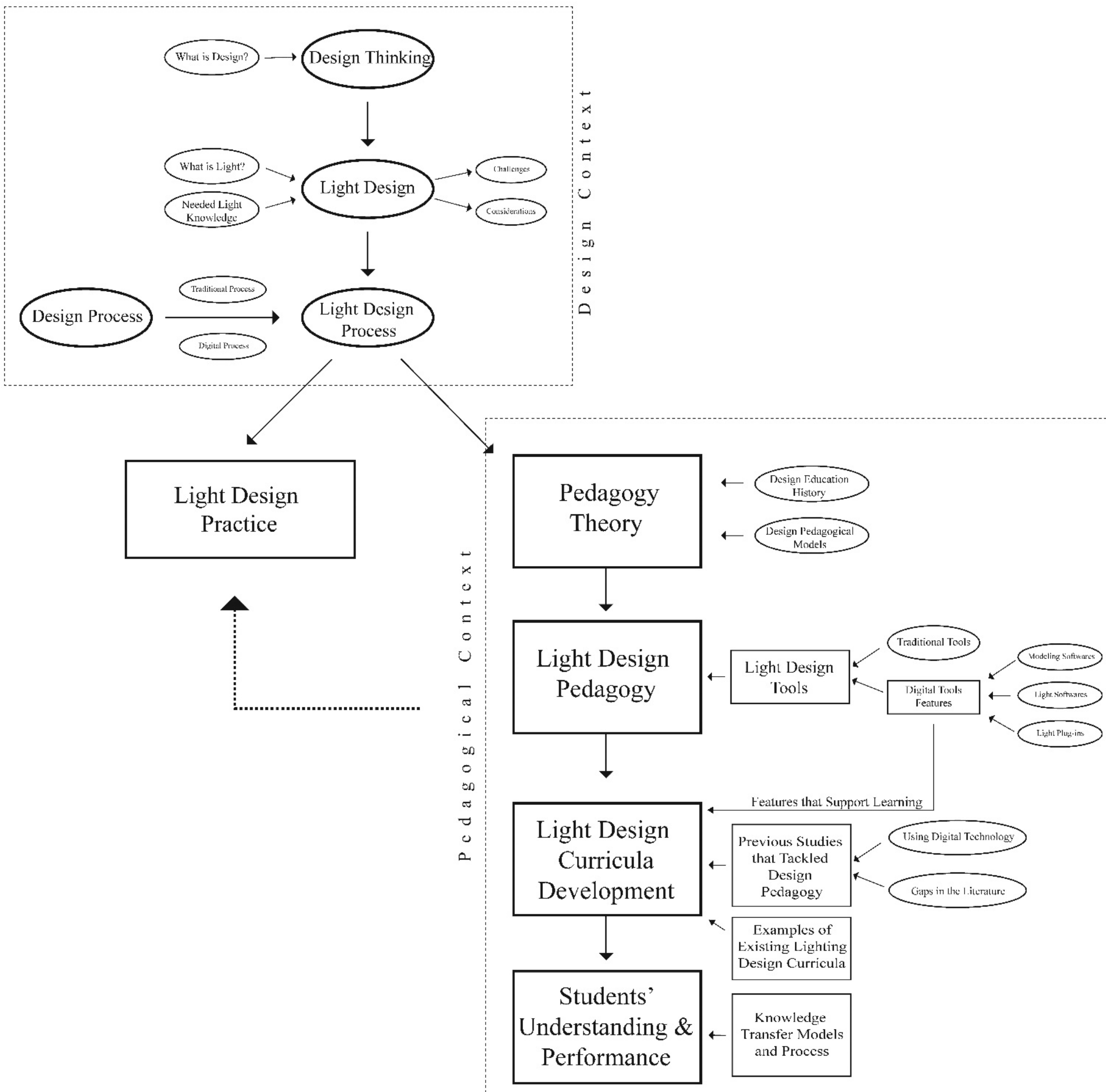
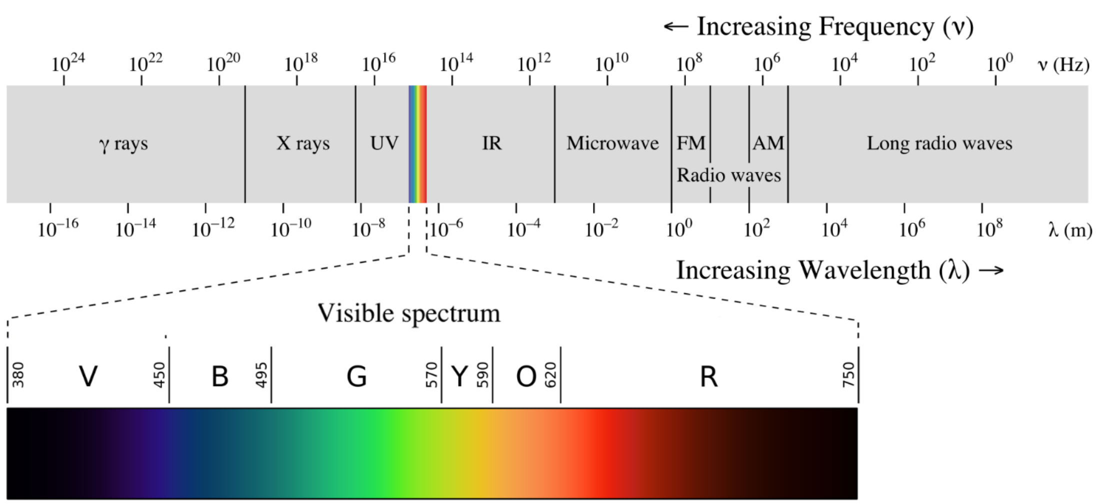


Figure 2-1. Literature Review Diagram

2.1- Light Definition, Composition, and Importance

Light is "part of an electromagnetic radiation that is visible to the human eye" (Brandi, 2006, p. 6). It is both a wavelength and a photon (particle) based on the hosting environment (Livingston, 2014, p. 41). Light wavelengths range from 380 to 770 nanometers (nm), it lies between Ultra Violet (UV) and Infra-Red (IR) radiations (Cuttle, 2003, p. 20; Egan & Olgyay, 2002, p. 50; Russel, 2012, p. 40).

Our brain perceives light's wavelengths as different colors. These colors range between red (700-650 nm), orange (640-590 nm), yellow (580-550nm), green (350-490nm), blue (480-450nm), and violate (440-390nm) (Egan & Olgyay, 2002, p. 73; Winchip, 2005, p. 104). Red is the longest wavelength with the lowest frequency and energy, whereas violet is the shortest wavelength with the highest frequency and energy (Livingston, 2014, p. 39).



By Philip Ronan, Gringer via Wikimedia Commons

Figure 2-2. Light Composition Diagram

Light, both natural and electrical, affects human health, feelings, and behavior (Brandi, 2006, p. 8; Flynn et al., 1988, pp. 11-18; Winchip, 2005, p. 319). Natural daylight boosts people's energy and mood, mitigates high levels of stress, stimulates the production of Vitamin D in the skin, improves the immune system, increases productivity, connects people to their natural surroundings, decreases the risk of many mental and physical diseases such as depression, rickets, and cancer, and reduces energy use (Aloshan, 2016, p. 25; Brandi, 2006, p. 8; Edelstein, Winter 2008, p. 55; Egan & Olgyay, 2002, pp. 44-46; Russel, 2012, p. 115; Winchip, 2005, p. 319). Electrical light, on the other hand, is used as a substitute for natural daylight in areas where natural lighting is scarce (Winchip, 2005, p. 320). For example, in the northern hemisphere, people use electrical lighting as a therapy to cure seasonal affective disorder (SAD). SAD is a type of depression owing to lack of sunlight during winter (Bellia, Bisegna, & Spada, 2011, p. 1986; Brandi, 2006, p. 8; Egan & Olgyay, 2002, p. 45; Gabel et al., 2013, p. 989; Winchip, 2005, p. 323). Light, in general, has a direct effect on hormones activities, heart rates, genes performance, sleep patterns, alertness, body temperature, cognitive performance, productivity, comfort levels, and humans' feelings (Bellia et al., 2011, p. 1985; Chellappa, Gordijn, & Cajochen, 2011, p. 119; Edelstein, Winter 2008, p. 55; Egan & Olgyay, 2002, pp. 44-45; Gabel et al., 2013, p. 988; Institute, 2016, p. 93).

In response, light is a critical element to study due to its effects on human comfort levels, health, behavior, and feelings. It is one of the factors that affect the 'spirit' of the building, which according to Pallasma, it tackles buildings' impacts on users beyond the physical satisfaction of its structure (Pallasmaa, 1965).

2.1.1- Light Preceptors

Our eyes, brain, and senses are the main preceptors of light (Cuttle, 2003, p. 7). Light transforms into electrical signals from the eyes to the brain for interpretation (Lam & Hugh, 1992, p. 32; Livingston, 2014, p. 48). The brain transforms these signals into images and interprets our surroundings and their colors based on our culture, experiences, expectations, and emotions (Egan & Olgyay, 2002, p. 39; Flynn et al., 1988, pp. 55-57; Russel, 2012, p. 18; Winchip, 2005, p. 113).

Light first enters through our pupil which is in the eye's iris. The pupil widens and contracts according to light's brightness and intensity then it directs it to the cornea (Egan & Olgyay, 2002, p. 36; Livingston, 2014, p. 48; Russel, 2012, p. 46; Winchip, 2005, pp. 15-16). The cornea transfers light to the retina; a tissue located in the back of the eyes, through refraction (Egan & Olgyay, 2002, p. 37; Livingston, 2014, p. 48; Russel, 2012, p. 46; Winchip, 2005, pp. 15-16). The retina is the most sensitive part to light, and it consists of rods and cones (Cuttle, 2003, p. 4; Winchip, 2005, pp. 15-16). Rods are located at the periphery of the retina and are responsible for the peripheral vision and vision in low light levels, whereas cones are located in the center of the retina; called the fovea, and are responsible for viewing details and colors in high illumination levels (Egan & Olgyay, 2002, pp. 37-38; Flynn et al., 1988, p. 5; Lam & Hugh, 1992, p. 36; Livingston, 2014, p. 50; Russel, 2012, p. 47; Winchip, 2005, pp. 15-16).

Besides our eyes, senses, and the brain, many factors affect our perception of light such as the objects' textures and sizes, the lamp type and the fixture used, the room sizes, the light direction, the distance between the light fixtures, and the objects, the contrast level between the objects and their backgrounds, the time and duration of perception, and the viewer's age and health conditions (Egan & Olgyay, 2002, p. 53; Livingston, 2014, p. 53; Winchip, 2005, p. 116).

2.1.2- Light Color

The spectral power distribution (SPD), the color rendering index (CRI), and the color temperature (CCT) define light's color. The spectral power distribution (SPD) is "a graphic plot of a light source's radiant power at each wavelength of light" (Livingston, 2014, p. 110). This curve shows what colors are dominant under a specific light source (Livingston, 2014, p. 113). The Color Rendering Index (CRI) is the "complexity or completeness of the spectral output of a light source" (Russel, 2012, p. 53). A CRI of 100 indicates that a light source contains all the visible spectrum, thus rendering objects in their actual color, just like daylight. When CRI is less than 100, objects may appear in different colors based on the light source's spectral power distribution (SPD) (Egan & Olgyay, 2002, p. 79; Flynn et al., 1988, p. 44; Russel, 2012, pp. 53-54). The same number or CRI however, does not mean that two light sources render colors similarly because it does not address the wavelength composition. For LED light sources the color quality scale (CQS) is used instead of the CRI (Livingston, 2014, pp. 116-117). This new scale accounts for the "color rendering, chromatic discrimination, and observer preferences" (Weinert, 2012, p. 37).

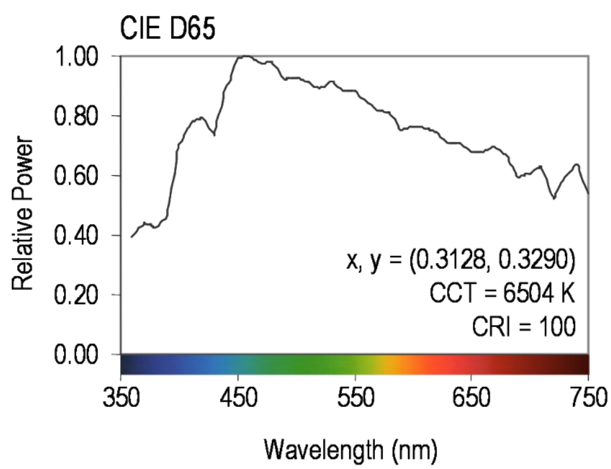


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Figure 2-3. Example of a Spectral Power Distribution Curve

Color temperature, on the other hand, is "the color that a light source appears to the eye due to an imbalance spectral output" (Russel, 2012, p. 53). It usually starts at

1800 K as warm tones, 3000 K as neutral, and ends at 6000 K as cold ones (Russel, 2012, p. 55).

2.1.3- Light Behavior with Surfaces

Light can be reflected, absorbed, refracted, or transmitted through surfaces (Egan & Olgyay, 2002, pp. 9-12). Light reflection can be either in one direction or diffused in different directions based on the surface's finish, color, shape, size, and the incident angle of the light beam (Egan & Olgyay, 2002, pp. 57-59). Polished surfaces usually create specular reflections, whereas rough and matt surfaces, spread and diffuse light (Egan & Olgyay, 2002, p. 57; Flynn et al., 1988, p. 150; Lam & Hugh, 1992, pp. 64-65; Livingston, 2014, p. 68; Winchip, 2005, p. 138).

Refraction is light's tendency to bend through surfaces due to a change in its density and speed (Cuttle, 2003, p. 23; Egan & Olgyay, 2002, p. 63; Livingston, 2014, p. 69). Light refracts to a single point in convex lenses and spreads out in concave ones (Egan & Olgyay, 2002, p. 64). In some cases, such as a glass prism, white light refracts to its original colors of the electromagnetic spectrum (Egan & Olgyay, 2002, p. 63).

Last, transmission is the surface's ability to pass light (Egan & Olgyay, 2002, p. 66). Transmission depends on the surface's characteristics; flat and transparent surfaces pass light in a straight line, itched clear surfaces allow it to spread out, and frosted ones diffuse it (Egan & Olgyay, 2002, p. 66).

2.1.4- Light Distribution

Light distribution can be direct, indirect, direct/indirect, semi-direct, semi-indirect, or diffused. Direct light fixtures distribute light to a specific direction, mostly downwards. Semi-direct light fixtures distribute light in two opposite directions. Usually, 60% or more of the light is downward, and the rest (40% or less) is upward, whereas semi-indirect ones distribute it in the opposite directions. Direct/indirect light fixtures distribute light in two directions equally, and diffused light fixtures scatter light in all directions (Livingston, 2014, pp. 76-77). Designers use different distributions for different functions. For example, indirect lighting emphasizes surfaces, unique qualities, and architectural elements, whereas direct lighting is beneficial in tasks lighting (Flynn et al., 1988, pp. 28-29).

2.1.5- Light Sources

Designing a quality lighting environment requires an integration of both natural daylight and electrical lighting. Daylight contributes to the users' well-being and their psychological and biological needs, whereas electrical lighting is important when daylight is scarce.

Natural light

Daylight is a dynamic design element that changes based on time, weather conditions, and the surrounding environment (Russel, 2012, p. 115; Winchip, 2005, p. 30). It mitigates high-stress levels, enhances visual acuity, imposes positive attitudes, and reveals the true colors of objects (Aries, Aarts, & van Hoof, 2015, p. 7; Winchip, 2005, p. 27). Nevertheless, daylight causes glare and excessive heat (Aries et al., 2015, p. 7; Winchip, 2005, p. 28; Yang, Becerik-Gerber, & Mino, 2013, p. 172).

Daylight is divided into three types of light; direct sunlight, skylight, and diffused sunlight. Direct sunlight is direct light from the sun. It is incredibly bright and can be a source of glare, excessive heat, and UV radiation (Russel, 2012, p. 117; Winchip, 2005, p. 27). Skylight is light reflected and scattered through the atmosphere due to overcast skies, a few clouds, or other atmospheric particles. It is a very soft form of light that is comfortable for long durations. Last, diffused sunlight is sunlight reflected off surfaces and scattered through materials and films. This type of sunlight is softer and more controllable than direct sunlight (Russel, 2012, p. 117).

Electrical light

There are different sources of electrical lights such as arch lamps, incandescent, electric-discharge, neon, fluorescent, high-intensity discharge, mercury, metal halide, high-pressure sodium, tungsten-halogen, compact fluorescent, light-emitting diodes (LED), and organic light-emitting diodes (OLED). These types of light allow people to work for more hours at night and enhance productivity in some workspaces. (Livingston, 2014; Winchip, 2005, pp. 6-12)

Nowadays, most people use Light Emitting Diodes (LEDs) and Organic Light-Emitting Diodes (OLEDs). LED sources are “lightweight, have a long life, require high voltage drivers, and use very little electricity” (Winchip, 2005, p. 95). OLEDs on the other hand, are very similar to LEDs, yet, they are planar and more expensive (Livingston, 2014, pp. 89-90).

2.2- Design Thinking and Process

The design transforms ideas into physical objects (Aspelund, 2015, p. 6) whereas, the design process is a planning and a problem-solving process that turns ideas into reality (Shapira, 1979, p. XXVI). All designers go through a design thinking process to create and execute their ideas. Design thinking is a constructive process where designers use problem-solving strategies to generate alternative solutions for a design problem. The design process starts with a concept that develops into a series of preliminary documents to more detailed drawings for the concept implementation. This process involves thinking about different design elements such as forms, thresholds, safety, circulation, materials, connections, ventilation, acoustics, furniture layout, and lighting.

Lighting design is a combination of "light, shadow, color, form, space, rhythm, texture, and proportion" (IESNA, 1994). It is not only sufficient light quantities within a space but rather a useful design tool that affects the mood of users and their visual acuity (IESNA, 1994). Thus, lighting design is an essential element that needs planning and analysis from the early design stages.

2.2.1- Design Thinking

Razzouk and Shute (2012) define design thinking as "an analytical and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign" (Razzouk & Shute, 2012, p. 330). Design thinking starts with a definition of a problem. Designers try to find a solution to the problem through several problem-solving tactics and design decisions (Rowe, 1991). They translate their thoughts into objects or products that perform particular tasks (Cross, 2007). They use visual communication methods such as sketches, models, and drawings to communicate and transform their thoughts into reality (Cross, 2007; Razzouk & Shute, 2012).

To further elaborate, cognitive activities are an essential part of the design process. In general, cognition is the ability to evaluate and interpret information that we acquire through learning, experience, and perception into knowledge that helps us understand our world (CogniFit, 2018). Several cognitive activities help us gather information from our surroundings to make decisions like "learning, attention, memory, language, reasoning, decision making, etc." (CogniFit, 2018). In addition, Aristotle thinks that our knowledge resides in the questions we ask and the answers we provide. Thus, questions are methods to construct knowledge. Design questions, for instant, encourage designers to seek several answers and ways to solve a problem (Eris, 2003).

To link the cognitive process to the design process, designers need design thinking strategies such as linking ideas and designs to human needs and environmental contexts, relating the defined problem to past experiences and beliefs, working visually, exploring alternative solutions for a problem, following a systematic procedure (the design process), explaining the creative process through language, working in teams, arriving at a final decision by comparing several synthesized alternatives, and evaluating the selected solution (Owen, 2007)

2.2.2- The Design Process

The design process is a planning process that all designers go through to turn their ideas into reality. The design process in the United States includes five phases derived from the American Institute of Architects (AIA) and the American Society of Interior Designers (ASID). These phases are: "programming, schematic design, design development, construction documentation, and contract administration" (Mitton, 2004, p. 21). In the programming phase, designers analyze the needs and the requirements of the project such as budgeting and site analysis and constraints. In the schematic design phase, they brainstorm concepts, solve problems, and create design alternatives. In the design development phase, they refine all drawings and images (Architects, 2009; Mitton, 2004). In the construction documentation phase, they prepare documents needed for construction and implementation, and they choose contractors and suppliers. Finally, in the contract administration phase, they tackle contractual and supervision services and close out the project (Architects, 2009).

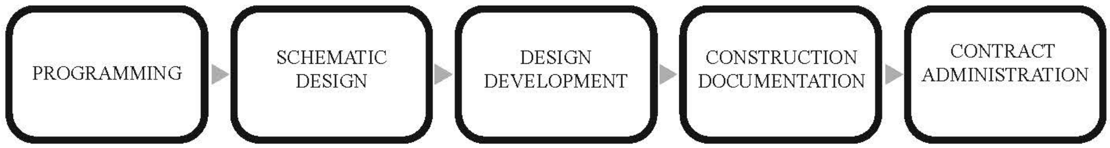


Figure 2-4. The Design Process According to AIA and ASID

In each design phase, designers produce different deliverables. For example, in the programming phase, they present their concepts and design proposals in sketches, diagrams, collages, illustrations, material boards, physical models, or preliminary 3D renderings (Aspelund, 2015, pp. 88-93; Mitton, 2004, p. 181). In the schematic design phase, they produce bubble diagrams, blocking diagrams, fit plans, realistic images, preliminary elevations, floor plans, sections, perspectives, and study models to convey functionality and reliability (Aspelund, 2015, p. 127; Mitton, 2004, pp. 28-40). In the design development phase, they develop plans, sections, elevations, 3D renderings, and physical models. Last, in the construction documents phase, they create detailed plans, sections, elevations, perspectives, 3D renderings, physical models, specifications, schedules, and components' detailed drawings. (Aspelund, 2015, pp. 152-153).

2.2.3- The Impact of Digital Tools on the Design Process

Digital design tools change the perception, process, and presentation of design projects (Aspelund, 2015, p. 107; Inanici, 2001, p. 1175). Designers use many digital design softwares from the early design stages to aid the generation, analysis, and development of design concepts, ideas, and presentations (Donn, 2001, p. 673; Szalapaj, 2005, p. 6). 3D digital models help in creating spatial and formal relationships, analyzing circulation routes, and conducting environmental analyses. In the schematic design phase, 3D softwares are used to analyze structural and environmental performance, and to produce presentable 3D renderings to get permissions and clients' approvals (Szalapaj, 2005, pp. 132-155).

Moreover, digital tools change the traditional linear design process into a non-linear one where designers think about fabrication and materialization from early design stages (Oxman, 2008, pp. 101-108). Digital tools help in producing design ideas and projects faster, with more details, and control. They are useful to visualize the design quickly and to create several alternatives without the need to reproduce physical models or 2D drawings. Thus, it saves time, effort, and money (Aspelund, 2015, p. 107; Szalapaj, 2005, pp. 35-45). Nevertheless, designers need to understand that these tools have limitations in depicting reality. Hence, the goal is to create a somewhat similar presence, human perception, and impression (Mania & Robinson, 2004, p. 200). Designers use different digital representations in each design phase. For example, in the early design stages, fast renderings are more time and cost-efficient, whereas towards the end of the project more accurate and high-quality renderings are desirable (Mitton, 2004, p. 92).

In sum, the introduction of design digital tools changed the traditional linear design process into a non-linear one where designers generate several design alternatives within a reasonable timeframe. The non-linear design process collects data from all design stages to reach the best solution in an interchangeable back and forth process. This process encourages creativity and enhances building performance (Grobman, Yezioro, & Capeluto, 2010, pp. 42-51).

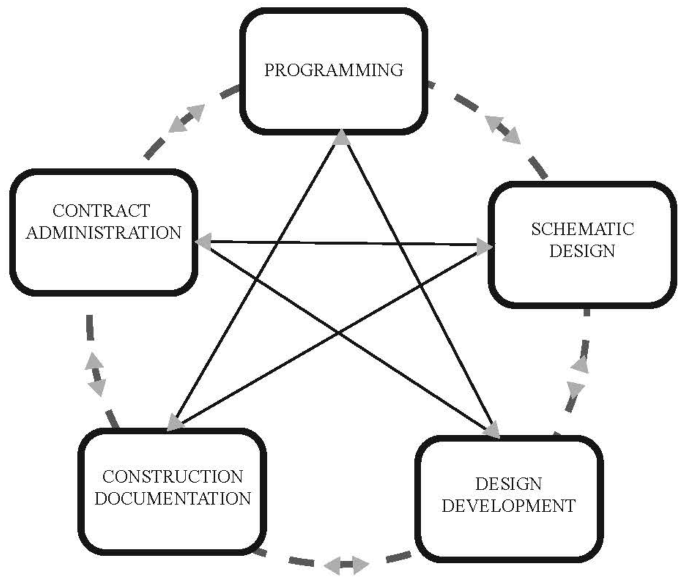


Figure 2-5. The Impact of Digital Technology on the Design Process

2.2.4- The Lighting Design Process

A lighting design project can be pragmatic, conceptual, or aesthetic. In the pragmatic approach, designers specify critical lighting scenarios to solve or tasks to meet. In the conceptual approach, they describe an end goal or a story of light through different solutions. In the aesthetic approach, they focus on the ambiance, mood, or feeling of the space (Livingston, 2014, pp. 23-30).

The lighting design process is very similar to the architectural design process. It follows the following phases; "programming, schematic design, design development, contract documents, bidding and negotiation, construction, and post-occupancy evaluation" (IESNA, 1994, pp. 1-2). The programming phase is a research phase, wherein the designer defines the location of the project, the budget, the client needs, the functions, the constraints, and the objectives. In the schematic design phase, he/she outlines the architectural requirements, the tasks, the desired feelings, the quantities, and the qualities of light. In the design development phase, the designer creates design documents with detailed lighting selections, layouts, and calculations. (IESNA, 1994, pp. 2-12). The designer also evaluates light mockups in the design development phase to find integration possibilities with architectural and structural elements. In the contract documents phase, he/she produces a detailed set of construction drawings for installation such as lighting plans, electrical plans, luminaire schedules, mounting details, and lighting controls. In the bidding and negotiation phase, the designer selects a contractor, and in the construction phase, he/she executes the design with regular site visits to solve emerging problems. Finally, in the post-occupancy phase, the designer assesses the performance of the lighting design and its complaisance with the design objectives (IESNA, 1994, pp. 9-13).

Figure 2-6. The Lighting Design Process According to IESNA

2.2.5- Lighting Design Considerations

The Institute of Research in Construction (IRC) (a technology center in Canada that provides “research, building code development, and materials evaluation services” (AECDaily)), recommends a lighting environment that provides excellent conditions for seeing, supports the task and function needed, encourages social interaction and communication, creates appropriate mood, contributes to human health, and has an aesthetical appeal in an integrated lighting design (Maunder, Donn, Curtis, & Lee, 2001, pp. 1041-1042).

An integrated lighting design delivers light in layers. The first layer focuses on movement and flow to guide the users of the space. The second layer imposes a specific mood or feel through the play of light color, texture, and intensity. The third layer emphasizes certain objects by using direct accent lighting or decorative lighting. The fourth layer reveals or manipulates architectural elements by making the room look taller, more confined, bigger, or simply highlighting an interesting architectural feature. The fifth layer is task lighting which enhances the users' visual acuity, performance, and productivity. (Cuttle, 2003, p. 34/49; Livingston, 2014, p. 13; Russel, 2012; Winchip, 2005, p. 21).

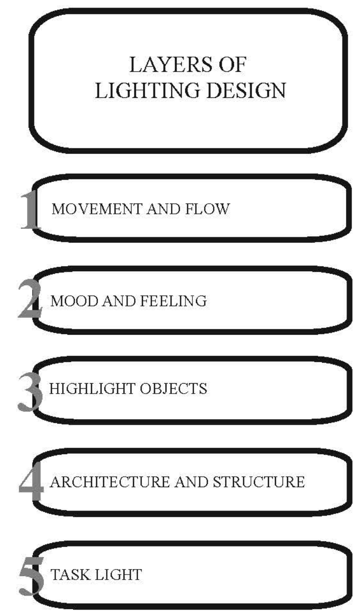


Figure 2-7. Layers of Lighting Design

In addition to lighting, shade and shadow are important elements in any lighting environment. Shadows appear when casting light on surfaces or objects, whereas shades form by moving a three-dimensional object in space (Cuttle, 2003, p. 73). Shadows play a significant role in creating depth cues and in establishing spatial relationships (Sugano, Kato, & Tachibana, 2003).

In summary, a quality lighting environment supports the function of the space, creates hierarchy, gives precise information and guidance, triggers specific feelings or ambiances, provides flexibility, and meets the required quantities of light (Lam & Hugh, 1992, pp. 14-15).

2.2.6- Light Measurements

Designers and engineers calculate light using manual or digital tools. Manual methods include the lumen calculation method, and the point calculation method (Livingston, 2014, pp. 248-253; Russel, 2012, p. 147). The point method, however, only applies to lights with a 12” aperture or less (Livingston, 2014, p. 248). Digital calculation methods, on the other hand, are digital handheld tools and light simulation softwares.

The lumen calculation method

The lumen calculation method measures the average illumination in footcandle (FC) or lux. It considers the lumen output, the number of lamps, and the space’s area. The lumen calculation equation is presented in the following diagram:

LUMEN CALCULATION METHOD

Average Illumination = (Lumens X Number of lamps X LLF X LLD X LDD X LBO X CU) / Area

LLF: light loss factor
LLD: light lumen depreciation factor
LDD: luminaire dirt depreciation factor
LBO: lamp burnout factor
CU: coefficient of utilization

Figure 2-8. The Lumen Calculation Method

Note: designers use the estimated CU factors in the equation to ease the calculation process. These factors are: 0.85 for a direct luminaire or downlight, 0.50 for an indirect luminaire, 0.95 for a spot or accent, and 0.75 for a wash or ambient light (Russel, 2012, p. 152)

The point calculation method

The point calculation method measures illumination of a point or a direct light source. It is sensitive to the light's location, its distance from a surface, and its incident angle. Designers locate the light source's intensity in the candela distribution diagrams that come with the specifications sheets of every light source. (Flynn et al., 1988, p. 119; Livingston, 2014, pp. 248-253; Russel, 2012, pp. 154-161). The following diagram presents the point method equation. This equation, however, is not useful with specular reflective surfaces. Designers are encouraged to use the following equation with specular surfaces: Li=Ei (illumination) XR where Li is the approximate illumination on the surface and R is the reflectance of the surface (Flynn et al., 1988, p. 119).

POINT CALCULATION METHOD

The point source illumination on a surface = CP / d (squared) X cosine of the incident angle X LLF X CU

CP: lcandle power of a light source
d(squared): squared distance between the light source and the surface
LLF: light loss factor
CU: coefficient of utilization

Figure 2-9. The Point Calculation Method

The digital calculation method

Digital tools quantify light quickly and easily. Designers measure light intensity and illuminance using a light meter (Cuttle, 2003, p. 39/107), and light color temperature using a chromameter (Cuttle, 2003, p. 44). Computer softwares, on the other hand, calculate light in complex spaces with less time and effort.

Lighting simulation softwares are either standalone programs or plug-ins in other softwares. These simulation tools need a 3D model of the room with its surfaces' reflectance, furniture, and objects layout, and luminaires with their accurate photometric data (as IES files from manufacturers) to simulate and calculate light accurately (Livingston, 2014, pp. 258-261). The following sections present the algorithms and the programs that are available to calculate, analyze, and simulate light.

2.3- Light Simulation and Analysis

Digital light simulation tools calculate and visualize light to save time, energy, and cost compared to building actual physical mock-ups (Choi, 2002, p. 1107; Donn, Xu, Harrison, & Maamari, 2007, p. 1999; Roy, 2000, p. 2). Lighting simulation softwares produce both qualitative and quantitative deliverables. They present light renderings for subjective perception and calculate light quantities to eliminate the use of excessive light sources (Laiserin, 2001, p. 281; Mantzouratos, Gardiklis, Dedoussis, & Kerhoulas, 2004, p. 43; Roy, 2000, pp. 3-4).

2.3.1- Light Simulation Algorithms

Light simulation tools analyze lighting (radiance) using computer algorithms. Radiance is "the quantity of light passing through a specific point in a specific direction" to form a photographic image in a virtual program (Chadwell, 1997). Radiance is used to quantify light and color in a computer simulation program (Teschner), and it is not sensitive to the distance between the sensor and the surface; it remains constant regardless of the distance (Teschner; Zorin, 2005). It simulates light reflection, both diffused and specular, and light transmission. Nevertheless, it is complex and requires a long rendering time. Radiance is also expensive and hard to store in computer memory. (Teller, Bala, & Dorsey, 1996).

Most lighting softwares use either radiosity, ray-tracing, or both algorithms together (Ashdown, 2010, pp. 32-34; Bickford, 2008, p. 53; Choi, 2002, p. 1107; Franks, 2004, p. 53; Laiserin, 2001, p. 281; Ochoa Morales, Aries, & Hensen, 2010, p. 1; Roy, 2000, p. 5). Raytracing is a computer algorithm that is used to compute radiance (Teschner). It computes radiance at one or more rays for each pixel in the viewport (Teller et al., 1996). It traces reflected, diffused, and refracted light from surfaces to the viewer and calculates light for each scene individually (view-dependent). Radiosity algorithm, on the other hand, divides surfaces into smaller patches and calculates light quantity by solving these divisions together once for every project (view independent) (Ashdown, 2010, p. 32; Bickford, 2008, p. 53; Franks, 2004, p. 53; Laiserin, 2001, p. 281; Möller & Haines, 2002, pp. 278-282; Roy, 2000, pp. 5-6). Ray-tracing is better at generating photorealistic renderings, primarily because it accounts for light reflection, refraction, soft shadows, light diffused reflection, light specular reflection, depth of field, motion blur, and illuminance distribution through complex glazing and shading systems (Chan & Tzempelikos, 2012; Teller et al., 1996; Teschner). Nevertheless, raytracing is "time-consuming and requires heavy computational power and large computational memory especially for surfaces with strong diffuse characteristics" (Chan & Tzempelikos, 2012, p. 3110). Thus, it is not ideal with diffused lighting. Another limitation is that raytracing is view-dependant, meaning that it only computes light at a single view. (Teller et al., 1996). Radiosity is more accurate with diffused lighting and shadows, hence it is suitable for projects with no reflective surfaces. It is not dependant on a single view, thus designers can use it to navigate through a three-dimentional virtiual world (Ashdown, 2010, p. 32; Bickford, 2008, p. 53; cadstudio; Inanici, 2001, p. 1178; Mantzouratos et al., 2004, p. 44; Möller & Haines, 2002, pp. 178-282; Roy, 2000, p. 6; Santos, Teixeira, Farias, Teichrieb, & Kelner, 2012, p. 332).

Rendering uses two types of algorithms: local illumination and global illumination. Radiosity, ray-tracing, and photon mapping are types of global illumination (Birn, 2014, pp. 112-113; Möller & Haines, 2002, p. 181). Radiosity rendering depends on the scene geometry; complex scenes take a longer time to render. Photon mapping renders a scene independent of its geometry; it rather accounts for its photons. Hence, it is relatively fast if we decrease the number of photons used (Birn, 2014, pp. 112-113). Photon mapping also renders highly reflective surfaces where ray-tracing find it hard to quickly simulate (Ochoa Morales et al., 2010, p. 3).

2.3.2- Light Simulation Tools

Designers analyze light performance using light simulation softwares, light simulation plug-ins, or 3D modeling softwares. Nevertheless, 3D modeling softwares lack accuracy in light physical behavior and quantitative calculations. This section introduces the three types with a focus on light simulation softwares and plug-ins that are currently available.

2.3.2.1- Light Simulation Softwares

Light simulation softwares are mostly stand-alone programs that calculate, analyze, and simulate light. They produce both appealing renderings and accurate photometric calculations. However, different programs have different deliverables and traits. Some programs are more accurate in calculating light, whereas others are better at creating photo-realistic renderings. Some of the currently available softwares are listed below to assist designers in their selection.

RADIANCE is the most accurate light simulation software due to combining both ray-tracing (with Monte Carlo) and radiosity algorithms (Laiserin, 2001, p. 281; Ochoa Morales et al., 2010, p. 2; Radsite; Roy, 2000, p. 6). It was launched in 1987 by Lawrence Berkeley National Laboratory in Berkeley California to render, analyze, and calculate light (Bickford, 2008, p. 54; Laiserin, 2001, p. 281; Lucet & Casas, 2001; Radsite; Ward, 1994, p. 459). It is designed to produce accurate natural and electrical light calculations and photo-realistic renderings. RADIANCE addresses different regional characteristics, complex lights, shapes, and materials (Bickford, 2008, p. 54; Ng, Poh, Wei, & Nagakura, 2001, p. 366; Radsite; Ward, 1994, pp. 460-462). It accounts for luminous colors, daylighting, and glare (Bickford, 2008, p. 54; Radsite). It also analyzes any surface such as opaque, translucent, or transparent, as well as any light behavior such as diffused, reflected (even specular), transmitted, or directed (Ng et al., 2001, p. 365; Radsite; Ward, 1994, p. 459). It also gives flexibility in producing images with various qualities; from poor to high quality based on the available time frame (Ward, 1994, p. 469). Another advantage is its availability online (free download), which makes it the most rapidly used software (Raphael Compagnon, 1998; Lucet & Casas, 2001).On the other hand, RADIANCE is not user friendly due to its hard interface (Laiserin, 2001, p. 281; Lucet & Casas, 2001; Ochoa Morales et al., 2010, p. 2) and complex input variables that can easily mislead the user (Donn, 2001, p. 675; Pereira & Guedes, 2012, p. 4). It also lacks proper presentation of quantitative data (renderings are appealing, but number outputs are not) (Donn, 2001, p. 676), consumes so much time in data analysis (Pereira

& Guedes, 2012, p. 4), and lacks accuracy in simulating luminance colors (Ruppertsberg & Bloj, 2006).

Rayfront is a user-friendly light simulation software that uses both radiosity and ray-tracing algorithms (Laiserin, 2001, p. 282). It is a RADIANCE-based independent graphical user interface (Donn et al., 2007, p. 2000; schorsch). So technically it uses RADIANCE for efficient performance, realism, and speed, with a more straightforward user interface (schorsch). This platform can be a standalone software or a plug-in to Autocad, 3D solar, or any DXF supporting program (Laiserin, 2001, p. 282; schorsch). It also supports any photometric file like IES, CIBSE, and Eulumdat (schorsch).

LightTools is an engineering and lighting simulation software developed by Synopsys to analyze light from early conceptual design phases. It simulates light paths quickly and efficiently even through mechanical structures. It creates appealing renderings by using the ray-tracing method. It also gives its users flexibility to model and design light sources and materials or import them from existing libraries. Other noted features include ease of use, accuracy in calculating light, good graphical output data, and ease of controlling parameters and variables (synopsys, 2017).

DAYSIM is a Radiance based lighting simulation software mainly used for daylight simulation. It produces annual daylight simulations, glare assessments, and hourly schedules. It also simulates electrical lighting energy loads, syncs daylight and electrical light performance using sensors and controls, and accounts for thermal performance. DAYSIM can be a standalone software or a plugin into “Rhinoceros, SketchUp, and Ecotect” (Daysim).

AGi32 is an accurate light simulation and calculation tool introduced in 1999 by Lighting Analysts. It is created to help designers visualize their lighting designs, understand the light distribution and interaction with different materials and surfaces, and present luminous projects reliably and effectively. In interior spaces, AGi32 calculates nearly any required luminance calculation such as “illuminance, horizontal, vertical, variable meter aiming, luminous exitance, lighting power density, and unified glare rating luminance” (Analysts). It also calculates direct and reflected natural or electrical light interacting with any surface in any virtual environment using direct point-by-point and radiosity calculations (Analysts; Franks, 2004). Radiosity provides light calculations once for the whole space (Analysts). In addition to radiosity, AGi32 uses a ray-tracing engine to enhance renderings (achieve photo-realism), calculate specular reflections, and render soft shadows and glossy surfaces (Analysts, p. 54; Bickford, 2008; Franks, 2004, p. 53). AGi32 is compatible with AutoCAD and IES files (Bickford, 2008, p. 54), and it provides pseudocolor graphical presentations that give colored gradients for accurate luminance and illuminance calculations (Analysts).

Lightworks is a fast lighting rendering software that supports CAD and HDRI files. It matches light to the background environment and images for realistic renderings. It also supports plug-ins for better performance (Bok, 2004, p. 150).

DIALux is a radiosity light calculation software created in 1994 for Windows XP. It uses ray tracing to create photo-realistic renderings, and it is popular due to its availability online for free. This program is suitable for “daylighting calculations, emergency and street lighting assistants, interior scene planning and documentation, and photo-realized images.”(Bickford, 2008, p. 54)

ShadowFX is a solar and shadow analysis tool that helps designers predict the sun path and shadow orientation and length at any time, day, and location. This software helps design shading devices and plan urban settings based on solar and shadow studies. It also produces shade and shadow animations and walkthroughs for interactive design purposes. The program is compatible with other softwares' files such as 3dsMAX models. (ShadowFX, 2016)

Autolux is a lighting simulation software that is similar to AutoCAD but with lighting analysis options. It calculates light and presents these calculations as points or contours. It also uses photometric data such as IES and CIBSE for accurate calculations. This program quickly measures roadway lighting performance. Thus it is useful for outdoor light analysis (Solutions, 2017).

In summary, there is a wide variety of softwares that simulate light, yet, each program focuses on a specific lighting aspect, making it more suitable for some functions than others. For example, some of these programs are better for daylight analysis such as DAYSIM, DIALux, and ShadowFX. Other programs are mostly accurate for outdoor lighting such as Autolux. Some programs focus on light rendering rather than calculations, like Lightworks. Another trait that affects the selection criteria is usability. RADIANCE is not recommended due to its complex input data and user interface. So, there are different aspects to look for when selecting a software and it all depends on the designer's needs and preferences. The most used softwares are "AGi32, DIALux, and Relux" (Relux discontinued) (Ochoa Morales et al., 2010, p. 2) due to their compatibility with CAD files, incorporating both ray tracing and radiosity techniques and supporting photometric data from manufacturers (Ochoa Morales et al., 2010, p. 2).

Advantages and Disadvantages of the Available Light Simulation Softwares

Software Name	Advantages	Disadvantages
RADIANCE	Accurate calculations (both natural and electrical) Photorealistic Renderings Free online download Accurate with any surface type Supports manufacturers' photometric data Uses both radiosity and ray-tracing algorithms	Hard user-interface Complex input data Quantitative output is not graphically appealing Long simulation Time Lack of accuracy with luminance colors
Rayfront	CAD compatibility Easy-user interface RADIANCE based Supports manufacturers' photometric data Uses both radiosity and ray-tracing algorithms	N/A
LightTools	Easy-user interface Accurate calculations Good graphical output data Ease in controlling parameters and variables	Uses only ray-tracing algorithm
DAYSIM	RADIANCE based Accurate daylight analysis Accounts for thermal performance	Only known for daylighting
AGi32	Accurate calculations (both natural and electrical) Photorealistic Renderings Good graphical output data Accurate with any surface type Speed in analyzing light CAD compatibility Supports manufacturers' photometric data Uses both radiosity and ray-tracing algorithms	Complex to use
Lightworks	Fast light renderings CAD compatibility	Only known for rendering lighting
DIALux	Free online download Photorealistic Renderings Known for daylight calculations CAD compatibility Uses both radiosity and ray-tracing algorithms Supports manufacturers' photometric data	Only known for daylighting
ShadowFX	solar and shadow analysis tool compatible with other softwares like 3DsMax	Only known for solar and shadow analysis
Autolux	Good for outdoor light analysis Supports manufacturers' photometric data	Limited graphical outputs Only known for roadway lighting

Table 2-1. Advantages and Disadvantages of the Available Digital Light Simulation Tools

2.3.2.2- 3D Modeling Softwares

3D modeling softwares are basic digital modeling tools that use standard light analysis. Most of these tools only deliver photo-realistic renderings without accurate light presentation or calculation.

Revit is a BIM software that uses bidirectional ray-tracing and multidimensional lightcuts algorithms. It calculates illuminance for different exterior and interior spaces to meet the required lighting levels (Autodesk). It provides different climates and regions for exterior solar studies and it combines exterior daylight with interior electrical lighting that is either from Revit's lighting library or any manufacture's IES file (Autodesk; Wing, 2012, pp. 9-19). Revit uses CIE sky models that are a simplified version of the Perez sky models (the most accurate models recommended by LEED). It also uses weather data and irradiance values from the Green Building Studio plug-in for accurate daylight analysis. Revit calculations are as accurate as RADIANCE with faster rendering time and an easier user interface (Autodesk).

3DsMAX is a modeling and rendering software that provides two sets of lighting: photometric and standard. Photometric lights are realistic lights that achieve photorealism with a long rendering time. Standard lights, on the other hand, are easy to use lights that are close to realistic lighting with ease of control and shorter rendering time. 3Ds Max Design is similar to 3Ds Max with the addition of light analysis tools (Tsountani & Jabi, 2014). Nevertheless, Michael Donn, Dan Xu, David Harrison, and Fawaz Maamari argue that 3Ds Max is not a reliable software to measure light levels (Donn et al., 2007, p. 2004).

Rhinoceros is a 3D modeling software with a straightforward user interface. It produces 2D drawings, 3D models, and animations. It delivers high-quality real-time renderings using a ray-tracing renderer, and it is a useful tool for digital fabrications like 3D printing. Rhinoceros has many plug-ins for design performance analysis such as Grasshopper and Diva (Associates, 2017).

Google SketchUp is a 3D modeling and rendering software that allows users to render scenes with the region time-specific shadows and daylight. Sketchup uses image-based lighting techniques (lights the scene with High dynamic range images (HDRI))(Tal, 2013). Last, VectorWorks is a design drafting, modeling, and presentation tool with BIM technology. It provides a flexible working platform for designers to work on the same file simultaneously. It presents high-quality renderings and hand-sketched ideas efficiently. This program is especially useful for the performance and show industry (Nemetschek, 2017).

2.3.2.3- Light Simulation Plug-ins

Light simulation plug-ins simulate, analyze, calculate, and render light within an existing 3D model to save time and effort. This section presents different lighting plug-ins for different programs:

Ecotect is a BIM building performance analysis plug-in that designers use to create more sustainable and energy-efficient buildings (Autodesk, 2008). It produces graphically appealing charts and tables (Lee, 2012, p. 44). Ecotect, however, requires excessive training to accurately analyze and simulate lighting within interior spaces due to its hard user interface (Pereira & Guedes, 2012, p. 4). In addition to lighting, it analyzes thermal, solar, airflow, carbon emission, water, shading, and acoustics performances (Autodesk, 2008; Lee, 2012, p. 44). Green Building Studio is a building performance simulation plug-in for any Autodesk software, including Revit. The plug-in simulates energy costs and usages, building materials performance, systems performance like heating, cooling, and water uses, solar interaction with buildings, and occupancy evaluation (Autodesk, 2013). Liadex is a lighting SketchUp plug-in developed by

Lighting Analysts. This plug-in helps SketchUp users analyze light performance by exporting their models to AGi32 (Analysts, 2017b).

Diva is a lighting and energy simulation plug-in developed by Harvard Graduate School of Design for Rhinoceros. Diva produces radiation maps, sun path diagrams, photorealistic renderings, "climate-based daylighting metrics, dynamic shading analysis, glare Analysis, LEED and CHPS daylighting compliance, ventilation and airflow analysis, and single thermal zone energy and load Calculations" (LLC, 2017). Diva exports outputs as numbers, realistic renderings, diagrams, color overlay images, and animations (LLC, 2017). ElumTools is a light simulation plug-in for Revit developed by lighting analysts (same developers of AGi32). It uses the radiosity algorithm for quick and accurate calculations and ray-tracing for better visualizations/renderings. It has an easy user interface and uses existing geometry within the model for fast and easy analysis. It calculates direct and indirect light, as well as daylight and electrical lights illuminances. It also calculates light energy and produces different outputs such as visual photos (renderings) with numbers, pseudo-color renderings, radiosity mesh, grids over Revit views, and schedules (Analysts, 2017a, pp. 2-14).

nXt AccuRender is a light simulation Revit, Auto-cad, and Sketchup plug-in (Autodesk; Laiserin, 2001, p. 282; RenderPlus, 2017). It uses both radiosity and ray-tracing algorithms to create photorealistic lighting renderings (Autodesk; Laiserin, 2001, p. 282). It accounts for automatic daylight simulations and supports IES photometric files, HDRI image-based lighting, and different lighting channels including sun, sky, ceiling lights, and self-glow materials (Autodesk). Sefaira architecture is a Revit plugin for daylight and building performance analysis. Its daylight analysis relies on

RADIANCE and DAYSIM softwares. It allows designers to create high-performance buildings from early design stages with an easy user interface. It also produces many appealing charts and graphs (Trimble, 2017).

Light Simulation Plug-ins Compatibility and Traits

Plug-in Name	Host	Developer	Traits
Ecotect	Autodesk	BIM (Revit)	Appealing graphical outputs. Building performance analysis (thermal, solar, airflow, carbon emission, water, shading, and acoustic).
Green Building Studio	Autodesk	Any Autodesk software including BIM (Revit)	Calculates energy costs and usages. Analyzes building performance (building materials performance, systems performance like heating, cooling, and water uses, solar interaction with buildings, and occupancy evaluation).
Liadex	Lighting Analysts	SketchUp	Analyzes light performance through AGi32.
Diva	Harvard Graduate School of Design	Rhinoceros	RADIANCE and Energy Plus based Plug-in. Appealing output data with photorealistic renderings. Building performance analysis (solar, ventilation, and thermal).
ElumTools	Lighting Analysts	BIM (Revit)	Quick and accurate electrical and natural lighting simulations and calculations. Easy user interface. Proposes different lighting layouts for specific luminaires and illuminance values. Appealing graphical output.
nXt AccuRender	Roy Hirskowitz and Associates	Revit, Auto-cad, and SketchUp	Accurate Lighting Renderings. Light in renderings is adjustable even after the rendering process is completed.
Sefaira architecture	Trimble	BIM (Revit)	Daylight and building performance analysis. RADIANCE and DAYSIM based software. Appealing graphical output. Easy user interface.

Table 2-2. Light Simulation Plug-in Compatibility and Traits

In summary, selecting a simulation plug-in depends on different needs, preferences, and tasks. The first step is to define the hosting program. For example, if a designer is looking for a BIM (Revit) plug-in, Ecotect, Green Building Studio, MicroStation, ElumTools, nXt AccuRender, and Sefaira are all options. The second step is to define the type of analysis needed. If the desired task is daylight analysis, then the most suitable plug-ins are Ecotect, Green Building Studio, and Sefaira, whereas, for indoor electrical light analysis, ElumTools is the one to use.

2.3.3- Light Simulation Tools' Usability and Challenges

The input and output data define the light simulation software's usability. The input data can be a text format, a Graphical User Interface (GUI), or a CAD translating system. CAD translating systems are user-friendly and their commands are within the program itself. Output data, on the other hand, can be either text/numbers, or visual representations like renderings and photometric diagrams (Ochoa Morales et al., 2010, pp. 3-4). One of the challenges of using light simulation softwares is usability, wherein data preparation, analysis, and presentation (how realistic the generated image is) are complex for regular users (requires specific training). Another challenge is that computer softwares make it possible to fake a light scene, like adding additional brightness, shadows, and exposures, which make the image more appealing and realistic but not accurate (Birn, 2014, p. 8; Ubbelohde & Humann, 1998, p. 35).

Donn (2007) presented some features for a preferable light simulation software by designers as listed in the diagram below (Donn et al., 2007, pp. 2002-2004).

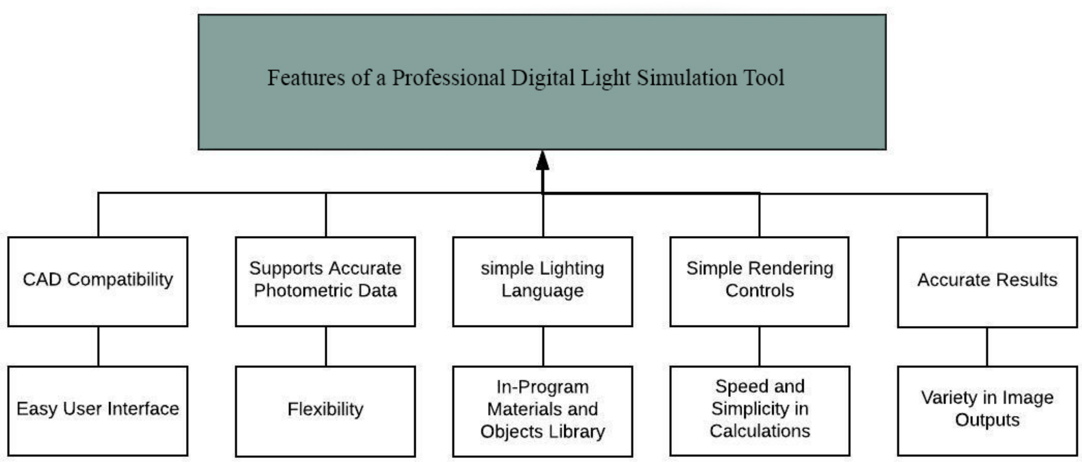


Figure 2-10. Appropriate Feature for a Professional Light Simulation Tool

2.4- Design Education

Design education according to Cross (2007) combines three domains; “the transmission of knowledge about a phenomenon of study, a training in the appropriate methods of inquiry, and an initiation into the belief systems and values of the culture” (Cross, 2007, p. 2). Design education incorporates both theoretical and practical (studio) knowledge. The theoretical inquiry “uses explicit knowledge and deductive logic” while the practical inquiry focuses on “tacit knowledge and inductive/abductive reasoning” (McAuley & Roxburgh, 2017, p. 172). Accordingly, an effective design pedagogy links both theory and practice together (McAuley & Roxburgh, 2017).

Education, in general, transmits knowledge that is valuable to students. It develops students’ cognitive knowledge by making them aware of why they learn certain things (Cross, 2007). Educational institutions not only deliver theoretical knowledge but also focus on the sequence of how to deliver the new knowledge (Baron & Sternberg, 1987; Oxman, 2004). In design education particularly, a studio is the main source of passing design knowledge. It prepares students for their professional careers by engaging them in real-life projects (Oxman, 2004; Tovey, 2015). However, the studio environment is highly dependent on the educator’s teaching style and the student's past experiences (Oxman, 2004, p. 66). Educators need to differentiate between educating and training students. To educate students is to teach them critical thinking and problem-solving skills, whereas to train them is to teach them how to copy what instructors do (Cross, 2007). Educators must invite students to construct design knowledge rather than to passively receive it (Kolb, 1984). To further elaborate, the following sections discuss design education in Kuwait (the focus of this research), design education history, and the knowledge delivery models to better understand the pedagogical context of the research.

2.4.1- Design Education in Kuwait

The Architecture department at Kuwait University is the only architecture school in Kuwait. The department was established in 1997 with a mission to "disseminate and improve the knowledge of architecture [and] to provide a balanced and integrated curriculum which enables the graduate to combine the theoretical and practical skills in finding unique solutions to challenging architectural tasks" (KU, 2018a). The department vision, on the other hand, is "to be a leading department in the region where it provides the highest quality of education and develops responsible, educated, and professional architects who can create a better world through unique and effective architectural ideas and solutions" (KU, 2018a).

The architecture program is a five-year program that follows the Bauhaus design pedagogical model. Students of the department are required to finish 166-semester credits to obtain a Bachelor of Architecture. The program encourages critical thinking, methodological analysis, problem-solving, decision-making skills, creative thinking, and the integration of new technologies and techniques (Al-Nakib, 2014). The program's curriculum follows the Department National Architectural Accrediting Board (NAAB) criteria. NAAB representatives regularly visit the department for consultation and improvements. The 166-semester credits of the program are divided into four categories; 19 credits in compulsory general courses, 99 credits in compulsory architectural courses, 33 credits in architectural elective courses, and 15 credits in elective liberal courses (Al-

Nakib, 2014). Students are required to take at least two courses from each of the four architectural electives categories (visual, cultural, professional, and technical studies).

Currently, the Department of Architecture and the Department of Communication Design and Interiors are under a new college called the College of Architecture. The Department of Communication Design and Interiors offers two degrees, the Bachelor of Science in Interior Architecture and the Bachelor of Science in Visual Communication. The interior architecture program's mission is to "provide students with rich and diverse knowledge and skills in design sustainability, human factors, building systems, visualization, history, theory, and criticism" (KU, 2018b). The program follows the Bauhaus educational model and the United States design education. The program integrates complex design projects with theory courses to enhance students' visualization and problem-solving skills. The offered courses incorporate "technical, social, psychological, cultural, environmental, economic, spiritual, and physical factors" (KU, 2018b) to encourage creative thinking and exploration in different fields. The interior architecture curriculum requires students to complete 134-semester credits in four years. The following diagrams and tables present the architecture and interior architecture curricula.

Kuwait University Bachelor of Architecture Recommended Courses for each Year

Year	First Semester			Second Semester		
	Course Name	Credits	Prerequisite	Course Name	Credits	Prerequisite
1	Introduction to Architecture	1		Design Basics in Architecture	5	
	History of Arab and Islamic Civilization	3		History of Architecture I	3	
	Architectural Communication I	3		Architectural Communication II	3	Architectural Communication I
	Intermediate Writing Skills	3		Physics I	3	
	Calculus I	3		Physics Laboratory I	1	
	Modern and Contemporary History of Kuwait	3				
	Third Semester			Fourth Semester		
	Course Name	Credits	Prerequisite	Course Name	Credits	Prerequisite
2	Architectural Design I	5	Design Basics in Architecture	Architectural Design II	5	Architectural Design I
	History of Architecture II	3	History of Architecture I	History of Architecture III	3	History of Architecture II
	Structural Analysis I	3	Physics I Calculus I Physics Laboratory I	Structural Analysis II	3	Structural Analysis I
				Architectural Elective	3	
	Computer Application	3	Architectural Communication I	Architectural Elective	3	
	Architectural Elective	3				
	Fifth Semester			Sixth Semester		
	Course Name	Credits	Prerequisite	Course Name	Credits	Prerequisite
3	Architectural Design III	5	Architectural Design II Structural Analysis I	Architectural Design IV	5	Architectural Design III
	Theory and Philosophy of Architecture I	3	Architectural Design II	Theory and Philosophy of Architecture II	3	Theory and Philosophy of Architecture I
	Materials and Methods of Construction I	3	Architectural Design II	Materials and Methods of Construction II	3	Materials and Methods of Construction I
	General Elective	3		Technical Writing	3	50 credits
	Architectural Elective	3		Architectural Elective	3	
	Seventh Semester			Eighth Semester		
	Course Name	Credits	Prerequisite	Course Name	Credits	Prerequisite
4	Architectural Design V	5	Architectural Design IV Architectural Design III	Architectural Design VI	5	Architectural Design V Materials and Methods of Construction Building Systems I
	Building Systems I	3	Physics I			
	Urban and City Planning	3	Architectural Design III	Building Systems II	3	Building Systems I
	Architectural Elective	3		Design of the Luminous and Sonic Environment	3	Architectural Design III
	Architectural Elective	3		General Elective	3	
				Architectural Elective	3	
	Ninth Semester			Tenth Semester		
	Course Name	Credits	Prerequisite	Course Name	Credits	Prerequisite
5	Architectural Graduation Project I	2	Architectural Design VI	Architectural Graduation Project II	4	Architectural Graduation Project I
	Professional Practice I	3	Architectural Design VI	Professional Practice II	3	Professional Practice I
	Architectural Working Drawings	3	Architectural Design IV	General Elective	3	
	Architectural Elective	3		General Elective	3	
	Architectural Elective	3		Architectural Elective	3	
	General Elective	3				

Table 2-3. Recommended Courses for each Design Year at the Architecture Department at KU

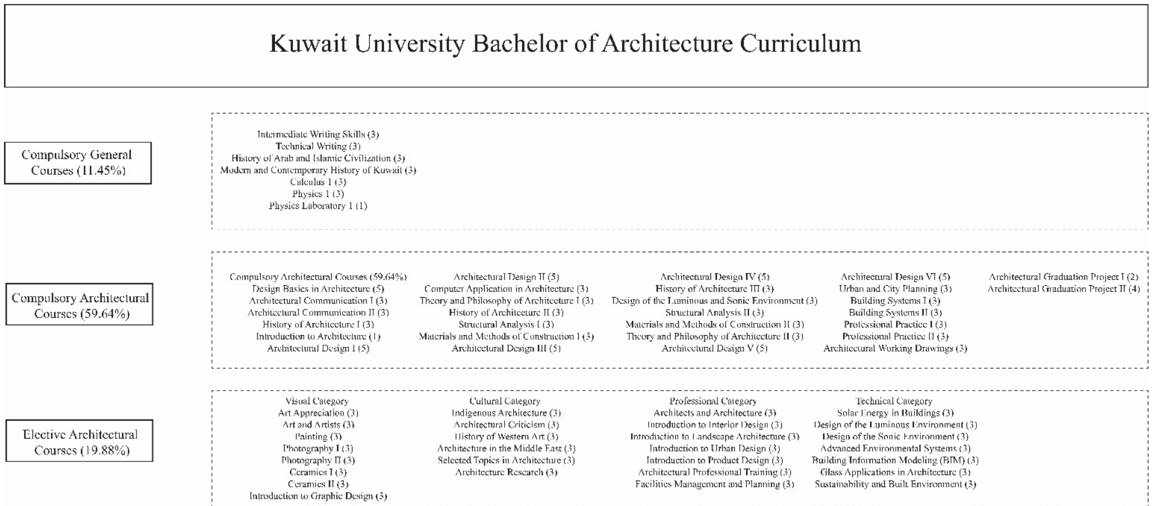


Figure 2-11. The Bachelor of Architecture Curriculum at Kuwait University

Kuwait University Bachelor of Science in Interior Architecture Recommended Courses for each Year

Year	First Semester	Second Semester
1	English I (3) Introduction to design Studio (4) Introduction to Design Theory and Criticism (3) Representation Studio I (3) Language and Communication (3)	English II (3) Studio Spatial Visualization (4) Design History Survey I (3) Department Elective (3) Humanities- Culture and Society (3) Physics (3)
	Third Semester	Fourth Semester
2	Studio Interior Architecture I (5) Computer Aided Design I (3) Design History Survey II (3) Human Factors (3) Humanities (3)	Studio Interior Architecture II (5) Environmental and Building Systems I (Lighting, Color, and Acoustics) (3) Materials and Construction (3) Calculus (3) Interior Architecture History (3)
	Fifth Semester	Sixth Semester
3	Studio Interior Architecture III (5) Sustainable Interiors (3) Islamic Design History (3) Computer aided Design II (3) Creative Expression (3)	Studio Interior Architecture IV (5) Environmental and Building Systems II (Mechanical, Electrical, Plumbing, and Sanitation) (3) Department Elective (3) Language and Communication (3) Leadership and Competency (3)
	Seventh Semester	Eighth Semester
4	Studio Interior Architecture V (5) Structure I (3) Advanced Department Elective (3) Creative Expression (3) Leadership and Competency (3)	Interior Architecture Capstone Project (5) Internship (3) Special Topics in Design (3) Science, Health, and Technology (3) Portfolio Review (3)

Table 2-4. Recommended Courses for each Design Year at the Interior Architecture Department at KU

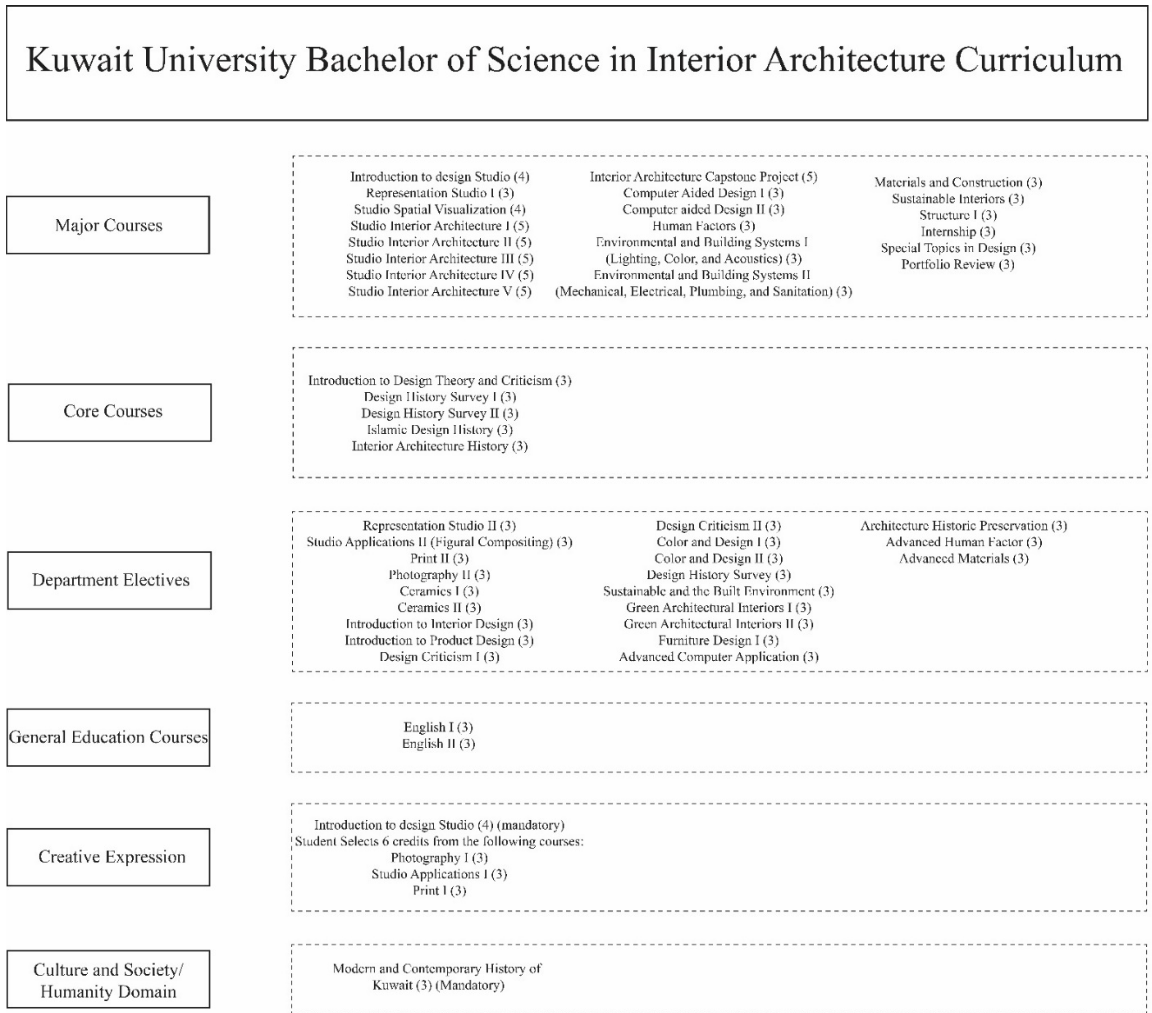


Figure 2-12. The Bachelor of Interior Architecture Curriculum at Kuwait University

2.4.2- Design Education History

Before the seventeenth century, design, arts, and crafts education were passed on to students through an apprenticeship system (Cret, 1941; Ockman, 2012). Design specialists or master builders trained design students using a copying method, where both the design process and the products were predetermined (Aloshan, 2016; Cross, 2007; Ockman, 2012).

During the Renaissance, a separation of arts from crafts, and architects from master-builders appeared. This separation raised a need for specialized educational systems and schools. In the second half of the seventeenth century, two academic institutions opened in the Louvre offering five classes in fine arts, painting, sculpture, architecture, and music. These two institutions developed into the Institute de France and the Academic des Beaux-Arts (Cret, 1941). Architecture education started in the Louvre, where architects (from the Royale Academy of Architecture in Italy) lectured students for three years about "construction, geometry, mechanics, military architecture, and other required branches" (Cret, 1941, p. 5). These lectures and critiques then developed to the Ecole des Beaux-Arts, which during the nineteenth century showed potential growth over the apprenticeship method and got separated from the Institute de France in 1807 (Lerner, 2012; Oxman, 2001).

The Ecole des Beaux-Arts started the atelier and problem-solving paradigm in design education, which then developed to design studios (Lerner, 2012; Oxman, 2001). Design studios are "active sites where students are engaged intellectually and socially, shifting between analytical, synthetic, and evaluative modes of thinking in different sets of activities (Dutton, 1987, p. 16). Students of the Ecole des present their projects to a jury of design professionals in a competition for final criticism (Cret, 1941; Hamlin & Cret, 1908; Oxman, 2001). The school believes that the plan is the most important part of the design (Cret, 1941; Hamlin & Cret, 1908). This emphasis encouraged students to create appealing plans and it developed their draftsmanship skills without focusing on other design aspects (Cret, 1941; Hamlin & Cret, 1908). Other drawbacks of the Ecole des Beaux-Arts were the emphasis on winning competitions, not having a fixed number of years to graduate (students can study until they are 30), and the focus on the artistic side of architecture rather than the practical one. This approach weakened students' professional competency because the focus was on lectures and textbooks only (Cret, 1941). In contrary to the Ecole des Beaux-Arts educational approach, the Bauhaus and the Vkhutemas emphasized experiential learning through abstracted design exercises rather than defined projects.

The Bauhaus (a German design and architecture school established by Walter Gropius in 1919) and the Vkhutemas (a Russian design and architecture school founded in 1920) shared the same design pedagogical philosophy; both treated design studios as laboratories to explore different design exercises and to learn general design principles (Alqabandy, 2012; Oxman, 2001). Both also embraced manufacturing techniques and technology. This pedagogical philosophy was a result of the industrial revolution in the nineteenth century, where designers incorporated technology into the manufacturing process for speed and mass production (Alqabandy, 2012). The Bauhaus integrated technology with art as a turning point in design curricula (Aloshan, 2016).

The Bauhaus and the Vkhutemas developed design education to include experimental learning (Aloshan, 2016; Alqabandy, 2012). The Bauhaus offered a multidisciplinary foundational course proposed by Johannes Itten (Cross, 2007, p. 24). The course included other forms of art and technology such as music, theatre, and industrial technology (Lerner, 2005, 2012). Itten also introduced creative exercises such as developing collages from junk materials to further develop students' cognitive skills. Itten believes that education should touch students' inner self and spirit to develop their creative personalities (Lerner, 2005). Cross (2007) also believes that these "non-verbal, tactile, analogical experiences were intuitively correct aspects of design education" (Cross, 2007, p. 25). The Bauhaus approach to experimental design encouraged activity-based learning and the integration of arts and crafts in a comprehensive curriculum (Aloshan, 2016; Alqabandy, 2012, p. 23).

The third paradigm in design education, according to Oxman, which she believes is missing in the Beaux-Arts and the Bauhaus educational systems, is the design thinking and reasoning process. This paradigm focuses on how designers think and structure their cognitive knowledge in the design process. It is a research-oriented method to design education. The cognitive design approach focuses on design abstract and symbolic representation, design visual reasoning, and knowledge formulation. Design representation presents human thought through "logic, rules, concepts, images, analogies, and connections" in diagrams and sketches (Oxman, 2001, p. 276). Design reasoning uses prior knowledge in visual representations. It links the internal mental reasoning to the extremal visual representation. Last, knowledge formulation helps students to understand and to apply the obtained knowledge. Additionally, Oxman recommends the incorporation of computer laboratories as a radical development to design education. She believes that computational labs combine the three design learning paradigms and complement the studio, especially that computers are tools for "both the construction of knowledge and the modeling and experimental testing of the cognitive content of design thinking" (Oxman, 2001, p. 283).

2.4.2.1- The Influence of the Beaux-Arts and the Bauhaus on the United States Architectural Education.

The Beaux-Arts influenced the beginning of architecture education in the United States. During the Civil War and 10-years after, there was little knowledge about architecture in the United States; thus, architecture as a profession was not appraised or appreciated. However, three architects who were trained in the Ecole des Beaux-Arts tried to raise awareness about it to advance the public taste and the profession. These architects were Hunt, Richardson, and Ware. The three encouraged more American architects to join the Beaux-Arts and to transfer architectural knowledge to the United States. The Beaux-Arts supplied the United States with architectural professional training, new standards of draftsmanship, and monumental planning and design composition (Hamlin & Cret, 1908; Ockman, 2012).

In 1894 there was a conflict between the American systems and the Beaux-Arts because it provided students with knowledge that is not relevant to the real practical world of architecture. The establishment of the American Institute of Architects (AIA) in 1857 and the Morrill Land Grant Act in 1862 were efforts to solve the conflict. These efforts influenced the spread of American public universities in rural areas which reduced the influence of the Beaux-arts structure and emphasized science, practicality, technology, and engineering over aesthetics. In 1912, the Association of Colligates Schools of Architecture (ACSA) was established to evaluate and to progress architectural education in the United States. The ACSA established the first basic curricula requirements for architecture schools. Besides the ACSA, the Carnegie Foundation for the Advancement of Teaching was founded to critique the quality of architectural education in North America (Ockman, 2012).

After the emergence of the Bauhaus and the Vkhutemas pedagogical theory and post-world war II, design and architecture schools in Europe and the United States incorporated new technologies and science with art to better prepare students for the practical and industrial world (Lerner, 2012; O'Sullivan, 2014; Ockman, 2012). The

Bauhaus system emphasized abstracted forms, free artistic expressions, sensory and experiential approaches to design, and engagement in the social context (Lerner, 2012; O'Sullivan, 2014). The Bauhaus influenced schools in the United States (after its closing in 1933), whereas the Vkhutemas influenced schools in Germany and France (Alqabandy, 2012; Findeli, 1990; Moholy-Nagy, 1969; Ockman, 2012). Examples of the influence are Laszlo Maholy-Nagy's influence on the Institute of Design in Chicago, Walter Gropius's influence on Harvard School of Design, Josef Albers's influence on the Black Mountain College and Yale, and Mies van der Rohe's influence on the Illinois Institute of Technology (Lerner, 2012; O'Sullivan, 2014; Ockman, 2012). These influencers introduced practical knowledge and the learning by doing method (Ockman, 2012).

In sum, the Ecole des Beaux-Arts and the Bauhaus influenced many design and architecture schools around the world. Both influenced two opposing pedagogical approaches to design education; the Beaux-Arts influenced the teacher-centered model, whereas the Bauhaus influenced the student-centered and the constructivist models. As such there are significant differences between the two models. The first difference is that the Beaux-Arts focuses on historical precedents while the Bauhaus tries to trigger innovation and creativity by empowering students' learning environment. The second difference is that the Bauhaus tries to link design to society and practical knowledge while the Beaux-Arts does not. The last difference is that the Beaux-Arts emphasizes the product over the process whereas the Bauhaus emphasizes the process over the product. Thus, the Bauhaus emphasizes self-learning and problem-solving skills (Aloshan, 2016, p. 71).

2.4.2.2- Social, Cultural, and Professional Constructs in Design Education

Donald Schon (an influential philosopher in design and design education) proposed a new professional approach to design education (Schön, 1987). Schon and Dewey both see an important integration of education in the practical and professional world and they encourage the learning by doing approach through experiential methods either in laboratories or studios (Waks, 2001). Schon's new professional curriculum directs students to learn basic knowledge or meaning about design, and then ways to apply the knowledge and their experiences in their professional world to solve real-world problems through "reflection-in-action". Teachers in such model review the curriculum, textbooks, and students' feedback then extract meaning for the lesson through a joint experience with learners. They experiment with students and observe the consequences to construct the meaning spontaneously rather than predefine it. Schon encourages the passing of knowledge from practitioners to students by putting in action the tacit knowledge of a subject matter (Schön, 1987; Waks, 2001). Students gain the knowledge through self-instruction, apprenticeship (not recommended), or professional practice, where practitioners supervise and coach them towards the right knowledge domains. In the last approach, students engage with educators in a problem-solving method where both learn and reflect in a joint experience (most recommended) (Waks, 2001).

In addition, Dewey, Findeli, Owen Jones, and Maholy-Nagy emphasize the importance of merging students in their social and cultural surroundings. One way to do so is through community projects which involve public participation in the design process to meet cultural and social demands. These projects are usually small in scale to fit within the educational capacity with an emphasis on the academic outcomes, the community benefits, and the aesthetical objectives of the design (Ockman, 2012; Portschy, 2015).

In conclusion, each historical milestone marked an application of a design pedagogical philosophy; the Beaux-Arts followed a teacher-centered model whereas the Bauhaus used a student-centered constructivist approach. Dewey, Goethe, and Maholy-Nagy encouraged the application of an experiential learning method, and Schon emphasized constructivism and problem-solving approaches. The following sections explain these pedagogical philosophies in detail.

2.4.3- Design Pedagogical and Theoretical Models

Design pedagogical theories "are learning activities that help students to think and act like design professionals" (Tovey, 2015, p. 84). These theories create value for the school practices in the social construct, primarily to deliver the same knowledge and skills to all members of the community despite capitalism and industrialization (Dewey, 2010, 2014). It is important to identify different design pedagogical theories to help all students understand their learning journey, make them life-long learners and encourage them to think like design practitioners (Dewey, 1958; Tovey, 2015). These theories also help teachers support their students' needs and develop their teaching styles (Dewey, 1958; Tovey, 2015).

2.4.3.1- The Teacher-Centered Pedagogical Model

The teacher-centered model creates hierarchy and power within the educational structures, where educators and higher authorities enforce specific knowledge, that is usually affected by political, economic, and aesthetic trends, on students (Dutton, 1987). The teacher-centered model focuses on the outcome rather than the design process. It focuses on a logical learning approach rather than combining logic with students' psychological experiences (Dewey, 1959).

In general, teacher-centered learning is a deductive learning approach that focuses on the teacher's role (Dewey, 1959; Smart, Witt, & Scott, 2012). The teacher presents knowledge from textbooks without any focus on students' needs or activities (Beckett, 2018; Smart et al., 2012). Thus, the teacher-centered approach provides students with theoretical textbook knowledge without delving them into practical exercises (Dewey, 1959). In this learning model, students are passive learners. They receive knowledge from educators to pass a test, complete a project, or win a competition (Emaliana, 2017). They do not participate in activities or other students' projects (Dutton, 1987; Emaliana, 2017). Thus, students usually work alone rather than within a group (Dutton, 1987). Teachers also follow certain textbooks instead of using innovative teaching methods (Emaliana, 2017). On the other hand, there are some advantages to the teacher-centered model. It is suitable for large classes with limited financial resources and time-frame (Emaliana, 2017; Frasineanu & Ilie, 2017). Teachers in this model are more confident as they come prepared to deliver specific knowledge without any surprises (Emaliana, 2017).

2.4.3.2- The Student-Centered Pedagogical Model

The student-oriented model focuses on students involvement and interaction. Froebel, Dewey, Dow, Ross, and Pestalozzi, all favor the student-centered approach (O'Sullivan, 2014). John Dewey (one of the most influential exponents of universal pedagogy) (Ilica, 2017) believes that learners "should interact with the teacher, as well as other students, to allow themselves to gain a tighter mastery of the material" (Dewey, 1958). Students' involvement in the learning process sustains their motive and interest in learning since it simulates more than one sense (Boisvert, 1998; Dewey, 1958; Smart & Csapo, 2007). It also encourages teamwork and raises the sense of community (Boisvert, 1998; Dutton, 1987; Frasineanu & Ilie, 2017). The student-centered model is a flexible learning approach with controlled activities that have clear objectives to help students retain the new knowledge (Emaliana, 2017; Smart & Csapo, 2007). Teachers in this model observe students in action and only offer help when needed (Beckett, 2018). They serve as facilitators where they encourage students' participation in the learning process to meet their needs (Emaliana, 2017). Students are involved in their classmates' projects through peer-review, which helps them gain insights into different points of view (Dutton, 1987).

In sum, the student-centered model teaches students knowledge domains and thinking strategies to solve problems through creative methods such as critical thinking, problem-solving, reflective thinking, self-explanation, and leadership rather than following precedent examples. This approach focuses on the process of learning rather than static knowledge and outcomes (Dewey, 1959; Frasineanu & Ilie, 2017). It empowers students and increases their understanding of a subject matter, their attitudes towards learning, and their learning motivation curve (Aloshan, 2016, p. 72; Frasineanu & Ilie, 2017).

2.4.3.3- The Problem-Based Learning (PBL) Model

Problem-based learning is a student-centered model that emerged in the early 1980s. Two medical doctors from Canada: Barrows and Tamblyn, proposed it to encourage medical students to learn on their own after graduation through self-directed learning (Ulger, 2018). Problem-based learning (PBL) equips learners with skills to understand a problem from different perspectives Educators in the PBL model observe students' self-evaluation and actions, challenge them by asking them open-ended questions or suggesting alternatives, encourage them to get involved in group discussions, and train them with new skills (Aloshan, 2016; Kretchmar, 2013). Thus, PBL emphasizes self-assessment and peer-review (Kretchmar, 2013). PBL aims to empower students with problem-solving skills, critical thinking, self-directed learning, creative thinking, effective collaboration skills, communication skills, verbal reasoning, leadership skills, intrinsic motivation, and analytical skills (Aloshan, 2016; Kretchmar, 2013).

Beckett argues that Dewey, Peters, and Freire (exponents of educational theories and pedagogical approaches), are all advocates of the participatory learning approach where students and their educators work together on their future growth (Beckett, 2018). The emergence of technology encourages the participatory approach, especially since students have access to resources and information online that teachers may not be aware of. Students introduce new knowledge to teachers and new ways to solve a problem making the teacher a learner too. Instructors give guidance only when students face difficulties. This collaborative process ensures an ongoing learning journey for both the students and the instructors (Beckett, 2018). Dewey, Peters, and Freire differ in the PBL application process. Peters believes that the teachers' role is more important at the beginning of the learning process to give students the required knowledge for their explorations. Whereas Dewey believes that the shared experience between the students and the instructors is desired early on to meet students' needs, to motivate them, and to help them grow (Beckett, 2018).

The implementation of PBL has some challenges; it is only applicable to small groups of students; thus, it requires more faculty than the teacher-centered model. Faculty also need the training to implement the model correctly. Untrained faculty may jeopardize the learning process. The training of faculty, however, exerts additional costs on the school. Students may also find the shift from the traditional teacher-centered method to PBL challenging and overwhelming. Thus, educators need to engage students gradually in self-directed learning (AlBuali & Khan, 2018). Additionally, the selected problems profoundly affect the PBL process and success. Educators need to present a problem that is relevant to real-life scenarios, students' past experiences, and the educator's learning objective (Kretchmar, 2013).

The PBL model is relevant to design education, especially in studios, where students try to solve complex design problems. Studio learning connects academic knowledge to the practical world through real-world multidisciplinary design problems (Ulger, 2018). This learning method complies with the constructivist education philosophy, especially in the self-construction of knowledge, the transfer of knowledge to the practical word, and students' engagement in the social context (Kretchmar, 2013; Ulger, 2018).

2.4.3.4- The Constructivist Pedagogical Model

Schon, Dewey, and the Bauhaus encourage the constructivist pedagogical theory. They believe that students' involvement in the practical and social environment is important. The constructivist theory allows the integration of new technologies in art and design education to support the construction of new meanings (Prater, 2001). The integration of technology allows students to choose freely between different presentation media to meet their objectives (Prater, 2001).

In general, the constructivist pedagogical model is a student-centered model that explains how people come to know what they know (Krahenbuhl, 2016; Smart et al., 2012). It is an epistemological theory that emphasizes constructing knowledge rather than objectively receiving it (Boudourides, 2003; Krahenbuhl, 2016; Larochelle, Bednarz, & Garrison, 1998; Prater, 2001). It is a subjective and an inductive approach to learning that has two principles; one is that the perceiver constructs knowledge based on his/her meaning rather than passively receiving it, and the second is that the learner's experience constantly modifies the process of learning (Aloshan, 2016, p. 102; Boudourides, 2003; Larochelle et al., 1998; Smart et al., 2012).

The constructivist theory is mostly referred to as 'learning by doing' (Oxman, 2004). The 'learning by doing' process involves four steps: the experience and the observation of activity, the reflection and the analysis of the meaning behind the activity, the abstraction and the generalization of the activity's meaning in the practical world, and finally, the application of the gained knowledge to solve real-world problems (Boudourides, 2003; Smart & Csapo, 2007; Smart et al., 2012).

This approach to learning views the educator as a facilitator; educators lecture and assess their students in constructing the new knowledge (Prater, 2001; Smart et al., 2012). When students face difficulties, teachers assist them by collaborating as a group members without dictating the process (Ulger, 2018). The educators lead students to the right knowledge domains and resources (Krahenbuhl, 2016; Prater, 2001). They understand how students think by asking them open-ended questions (how did they arrive at a certain answer) or by observing how they perform a task, and then direct them based on their interests to make the learning process more meaningful (Prater, 2001; Slezak, 2010). This model advances learning in design studios as it develops students' thinking, communication, and social skills as well as their drive and motivation to self-learn (Aloshan, 2016, pp. 102-103).

2.4.3.5- The Experiential Pedagogical Model

Experiential learning is a student-centered, personal, and perception-based education that is organized around the learner's experiences (Seaman, Brown, & Quay, 2017). John Dewey: a great advocate of the experiential pedagogy, calls for democracy in education to overcome the power of political, economic, scientific, and other dominant dictators of schooling. Democracy for him is freedom from any historical precedents; it is instead an experimental field for learning. It emphasizes each person's individualism while participating and contributing to the external society. Democratic education encourages group work and provides a multidisciplinary learning environment where all students meet their needs (Dewy, 1916).

Dewey finds a contradiction in the curriculum-centered approach. This contradiction lies in the difference between the student's world and experiences and the curriculum independent classification and broad knowledge, and the difference between the student's active and emotional experiences and the curriculum abstract order, presentation, and objective principles (Dewey, 1959; Ilica, 2017). In response, he proposes a dynamic and flexible curriculum that meets different students' developmental needs. Teachers achieve this by understanding each student's background, environment, and traits and then combining the theoretical knowledge, which directs and guides students, with the practical knowledge to fill the gap between the students' experiential needs and future growth (Dewey, 1959; Ilica, 2017). This approach links the theoretical and the logical knowledge to students' physiological experiences, which in return nourishes the student's motive to learn and to apply the obtained knowledge in the practical world (Boisvert, 1998; Dewey, 1959). The approach also emphasizes individualism where each student expresses him/herself based on their interest (Boisvert, 1998).

Another advocate of the experiential pedagogy is Kolb who is known for Kolb's Learning Cycle. The cycle is based on the learner's experiences, observations, and reflections that are then transformed into actions. The experiential learning approach is very similar to the constructivist learning theory with an emphasis on the learner's experience (Demirbaş & Demirkan, 2003, p. 440). Kolb's experiential learning cycle follows four steps; specific experiences, personal reflections and observations, concept generation through analysis and thinking, and finally the application of the learned knowledge in active experimentation (Demirbaş & Demirkan, 2003, p. 440; Seaman et al., 2017). As implied, the experiential learning theory is highly dependent on the learner's style and perception.

The Learning Styles Inventory (LSI)

The Learning Styles Inventory (LSI) helps in assessing types of learning through a 12-questions test. Kolb defines LSI as part of the experiential learning theory (Demirbaş & Demirkan, 2003). The test identifies four types of learners through two bipolar scales. The first scale is abstract conceptualization (AC) and concrete experience

(CE), whereas the second scale is active experimentation (AE) and reflective observation (RO). The first scale“(AC–CE) is ‘how a student perceives new information or experience, and the second (AE–RO) is ‘how a student processes what s/he perceives” (Demirbaş & Demirkan, 2003, p. 441). The four learners styles identified by the LSI are accommodating learners (AE/CE), divergent learners (CE/RO), assimilating learners (RO/AC), and convergent learners (AC/AE) as shown in figure 2-13 (Demirbaş & Demirkan, 2003).

Demirbas and Demirkan (2003) argue that the Learning Styles Inventory helps in identifying how students perceive and process new knowledge, but it does not indicate that one style is better than another. It instead helps in identifying the strengths and weaknesses of each learning style to better apply it in architectural education. For example, accommodating learners are best in doing things, and they enjoy new experiences, but they are weak in obtaining information. They rely on others for information. Divergent learners are interested in people; hence they are good in observations and comprehensive explanations, but they are weak in theory and systematic decision making. Assimilating learners are thoughtful and concerned with abstract concepts, but they are weak in applying theory in practice. Convergent learners are logical and pragmatic. They are good at organizing thoughts and reasoning information, but they focus on things rather than people (Demirbaş & Demirkan, 2003, p. 442). The understanding of these four learner’s styles helps educators in designating different tasks for different students, especially in teamwork.

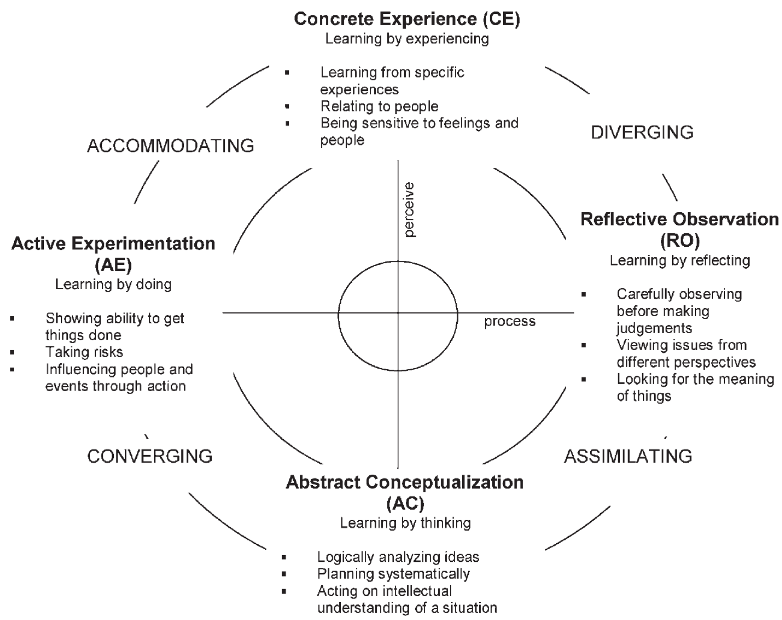


Figure 2-13. The Experiential Learning Theory Diagram

In summary, design pedagogical theories advance the instructors' teaching styles. It helps educational institutions in developing their knowledge delivery structure to better prepare students for their professional careers. Educational institutions can combine more than one pedagogical approach or choose different approaches at different times to meet all their pedagogical needs.

2.4.4- Design Curricula Development

Since the closing of the Bauhaus in 1933 by the Nazis and the closing of the Vkhutemas due to national politics in 1930, there was not any radical development in design curricula (Alqabandy, 2012; Cross, 2007). The Bauhaus and Vkhutemas constructivist pedagogies still influence design and architecture schools in Europe and the United States. The United States architecture curricula adopted the Bauhaus foundational studio, technological advancements, and the integration of science. The Bauhaus combines both theories about materials' properties and practical experimentations to boost students' creativity. Students are required to take a theory course about a subject matter before they join its workshop. In the workshop, they produce products with the assistance of their teachers to gain experience and raise funds for the school (Alqabandy, 2012, p. 27).

The Vkhutemas curriculum also combines theory and practice, but what is unique about their curriculum is the free studio. Students have the freedom to choose their studio master (Alqabandy, 2012, p. 34). Thus, the difference between the Bauhaus and the Vkhutemas curriculum is that the Bauhaus has a rigorous curriculum whereas the Vkhutemas's curriculum is more free-form and abstract (Alqabandy, 2012, p. 42). Schon believes that professional curricula need to be flexible and abstract to give students the freedom of knowledge (Schön, 1987).

Other recommendations that aim to establish an interdisciplinary design curriculum to prepare students for their professional careers are Maholy-Nagy integration of phenomenological and ecological aspects (Moholy-Nagy, 1969). Fuller, Pearls, and Glyphis, incorporation of sustainability courses (Aloshan, 2016; Glyphis, 2001; Lerner, 2012). Frampton integration of indigenous architecture to connect students to the identity and culture of each region (Ockman, 2012), and Feenberg and Coyne incorporation of computing technology to meet social demands (Coyne, 2001; Feenberg, 2012).

Moreover, the Princeton report (1967), the Boyer report (1996), the Carnegie Foundation for the Advancement of Teaching, and the Association of Collegiate Schools of Architecture (ACSA) tried to establish new standards for architecture education to respond to the social, political, and environmental changes in the world, and to fill the gap between architecture education and practice (Boyer & Mitgang, 1996; Ockman, 2012).

The Carnegie Foundation for the Advancement of Teaching is an association that was founded in 1912 to advance architectural research and education. ACSA aspires to link architecture practice and academia, to raise public awareness about architecture as a profession, to offer conferences, workshops, and publications related to architecture, to increase diversity in architectural education, to provide more interdisciplinary programs, and to support architectural research through funds and partnerships (ACSA, 2016).

The Princeton report encourages the integration of practical knowledge, analytical skills, and environmental design in design curricula (Boyer & Mitgang, 1996). It calls for a flexible design curriculum with “a wide range of teaching methods, and diverse architecture programs” (Boyer & Mitgang, 1996). The Boyer Report, on the other hand, calls for sustainability and diversity, professional and civic engagement, and a humane climate of learning in architecture academia (Boyer & Mitgang, 1996; Ockman, 2012). The report's goals are to improve human health through design by creating “wholesome neighborhoods, safer streets, more productive workspaces, a cleaner environment, and more cohesive communities” (Boyer & Mitgang, 1996, p. 31). One way to achieve such goals is to emphasize users’ safety and comfort, natural resources preservation, and students’ engagement in real social and community projects in the design studio.

The second goal of the Boyer report is to ensure diversity in the educational system by introducing different types of architectural philosophies and programs and to hire faculty with various backgrounds and talents to create a more dynamic and versatile academic environment. The third goal is to establish a common framework for students in all programs to meet certain standards without sacrificing the diversity of each program. One of the bodies that establish such standards is the National Architectural Accrediting Board (NAAB). The fourth goal is to establish a curriculum that supplies students with fundamental knowledge and skills, meets accrediting bodies' standards, combines the liberal arts with professional education, integrates design studios, and provides flexibility with more elective classes. The report also encourages continuing education because undergraduate degrees are not enough to supply students with all the knowledge they need.

The fifth goal of the report is to create a supportive learning environment for students that provides "openness, fair play, clarity of communication, inclusiveness, tolerance, caring, joyfulness, and commonly held purposes" (Boyer & Mitgang, 1996, p. 91). The sixth goal is to connect education and practice by supplying students with technical and practical knowledge including computational methods, communication skills, and teamwork. Schools can meet this goal by communicating with professionals and including them in the educational environment either as guest critics or visiting instructors. Schools can also provide students with internship opportunities. The seventh goal is to provide students with professional ethics and to involve them in community service projects to benefit the public (Boyer & Mitgang, 1996).

In addition to the Boyer report, the National Research Council (NRC) urges the incorporation of computer-based technologies, three-dimensional modeling methods, business topics like marketing, finance, budgeting, and methods to accomplish an architecture firm, and developed materials and construction methods in architecture curricula to better prepare students for their practical careers (Dill, 1997).

Today, architecture schools try to embody community-based programs (community service or design-build projects), global studio practice, foreign exchange programs and traveling abroad courses, cultural, regional, and theoretical aspects of design, adaptive reuse and historic preservation concepts, design research, technology, new computation and fabrication methods, and design thinking in virtual media in their design curricula as a new way of experiential design to meet new professional demands (Ockman, 2012).

David Lee Smith gives an example of how to develop architecture curricula through the integration of technologies. Technology according to him is "the scientific study of art or subject" (Smith, 1987, p. 6). He states that environmental technologies such as lightings, acoustics, and thermal comfort affect all our senses and in response change our perception of the physical environment. As a result, it is important to integrate such technologies effectively in architecture curricula. To establish such integration, he proposes the introduction of lighting first followed by acoustics and then the thermal environment. For each topic, he believes that it is crucial, to begin with, the basic principles and theoretical foundation, and then proceed to architectural opportunities, control systems, and architectural implications. He also proposes that a team of instructors with various specialties collaborate to teach an integrated design studio and present several seminars about each technology to advance students' knowledge and to overcome the narrow-focused studio problem. Examples of integrated studios are a solar design studio and a structural systems studio (Smith, 1987).

2.4.4.1- Architecture Curricula Development

The National Council of Architectural Registration Boards (NCARB) develops and organizes architecture curricula in the United States and other countries that follow the United States educational system like Kuwait. NCARB "is a nonprofit organization made up of the architectural licensing boards of 54 states and territories" founded in 1919 (NCARB, 2018a). NCARB's mission is to "Protect the public health, safety, and welfare by leading the regulation of the practice of architecture through the development and application of standards for licensure and credentialing of architects" (NCARB, 2018a). One of NCARB services is to enhance architecture education by accrediting architecture education programs through the National Architectural Accrediting Board (NAAB) and through funding new curricula that improve the integration of education and practice (Aloshan, 2016; NCARB, 2018b).

NCARB establishes a list of standards for architecture education that combines "general studies, professional studies, and optional studies, which together comprise a professional liberal education in architecture" (NCARB, 2016, p. 22). Table 2-14 showcases NCARB's required areas of study in architecture education.

Subject Area and Category	Semester Credit Hour Requirement
General Education	**45 Hours**
A. Communication Skills	3 Hours Min. in English Composition
B. Humanities and Arts	N/A
C. Quantitative Reasoning	N/A
D. Natural Sciences	N/A
E. Social Sciences	N/A
History and Theory, and Human Behavior	**12 Hours**
A. History and Theory	6 Hours Min.
B. Human Behavior	3 Hours Min.
Building Practices	**27 Hours**
A. Structural Systems	6 Hours Min.
B. Environmental Control Systems	6 Hours Min.
C. Construction Materials and Assemblies	6 Hours Min.
D. Building Service and Building Enclosure Systems	3 Hours Min.
E. Technical Documentation	3 Hours Min.
F. Financial Considerations	3 Hours Min.
Design	**42 Hours**
A. Fundamental Design	8 Hours Min.
B. Programming and Site Design	8 Hours Min.
C. Research and Investigative Based Design	8 Hours Min.
D. Integrated Design	8 Hours Min.
Professional Practice	**12 Hours**
A. Stakeholder Roles in Architecture	3 Hours Max.
B. Project Management	3 Hours Max.
C. Business Management	3 Hours Max.
D. Laws and Regulations	3 Hours Min.
E. Ethics and Professional Conduct	3 Hours Min.
Optional Studies	**12 Hours**
Total	**150 Hours**

Figure 2-14. NCARB Standard Architecture Curriculum

In 1940 NCARB and the American Institute of Architects (AIA) established the National Architectural Accrediting Board (NAAB) to accredit schools of architecture for the development of architectural education and profession. NAAB aims to prepare students for their professional careers by setting standards for architectural educational institutions. These standards are:

1- Having facilities and resources that support and develop students' professional learning.

2- Sustaining policies and activities related to “history, mission, culture, self-assessment, and future planning”(NAAB, 2014).

3- Illustrating a clear pedagogical approach, mission, culture, and history.

4- Encouraging innovation, respect, and engagement between students, faculty, and administration.

5- Illustrating diversity in human, physical, and financial sources.

6- Highlighting leadership roles and designing multidimensional processes.

7- Providing professional opportunities through internship and licensure.

8- Supplying students with environmental awareness and responsibilities.

9- Teaching students social ethics.

10- Continuously developing and improving the program through long-range planning.

11- Regularly assess the program's progress towards its mission and objectives.

12- Developing the curricula of the program regularly.

13- Demonstrating efficient human, financial, information, and physical resources for the development of students learning environment.

14- Describing the program's administrative structure and each member's role.

15- Supplying graduates of the program with skills like:

- Critical thinking and range of representation skills.
- Communication, design thinking, decision making, investigative, and architectural design skills.
- Ordering systems, use of precedents, cultural diversity, history of architecture, and global culture.
- Technical skills, technical documentation, building systems (building envelope, structural and environmental systems), and materials.

- Building codes, sustainability, and other standards.
- Site design and building orientation.
- Building performance and financial considerations.
- Research methodologies to inform the design process.
- Theoretical knowledge.
- Professional practice, project management, the business of architecture, and codes of ethics and the law.

16- Having periodic evaluations from a granted permission agency.

17- Including professional studies, general studies, and optional studies with a minimum of 150 semester credit hours.

18- Setting standards for students' admissions.

19- The program must be transparent online for the public, the students, and the faculty.

20- The program must send statistical and progress reports to NAAB. (NAAB, 2014)

2.4.4.2- Interior Design Curricula Development

As for Interior Design, the Council for Interior Design Accreditation (CIDA) regulates the United States' interior design curricula structure. CIDA aims to prepare interior design students for their professional careers through a thriving knowledge delivery framework. CIDA's mission is to "advance the interior design profession as the definitive source for quality standards and accreditation in higher education" (CIDA, 2018a).

CIDA accreditation has sixteen standards:

1- The program's context, goals, curriculum, and educational philosophy all comply with its clear mission. The program offers entry-level professional skills for its students and assesses their performance in the work field after graduation through external feedback.

2- Having appropriate faculty and administrative staff.

3- Providing appropriate facilities and resources to achieve the program's goals.

4- Students of the program show knowledge of social, cultural, environmental, technological, and economic backgrounds in their work.

5- Graduates of the program collaborate within multidisciplinary teams and exemplify leadership roles.

6- Graduates of the program are aware of the importance and the role of interior design in society and the standards of the practice.

7- Students consider human factors and experiences in their work.

8- Students understand the design process thoroughly to solve design problems effectively.

9- Students can communicate their designs through verbal, visual, and written media.

10- Students know the basis of design, architecture, and art history.

11- Students apply design theory and elements in their projects.

12- Students understand the importance and the role of light and color in the built environment and how they affect human well-being and experiences.

13- Students can integrate different design products and materials in their projects.

14- Students show knowledge in acoustics, thermal comfort, and indoor air quality to ensure the wellbeing and comfort of users.

15- Students acquire knowledge about the building construction process, documentation, and methods.

16- Students know the codes, regulations, and laws of the profession to protect the health, safety, and welfare of the users. (CIDA, 2018b)

These standards help interior design programs develop their curricula structure, knowledge delivery methods, facilities, and services to ensure a thriving learning environment, and to prepare students effectively and professionally for their future careers.

2.4.4.3- Lighting Design Programs

The International Association of Lighting Designers (IALD) advances the lighting design profession by recognizing independent/professional lighting designers. It consists of 11-board members, and its vision is "to create a better world through leadership and excellence in lighting design; to cultivate the universal acknowledgment and appreciation of the Power of Light in human life" (IALD, 2018a). IALD also aims to advance lighting design education through its IALD Education Trust, which is a non-profit organization that "provides direct support to educators, students, and new graduates to promote the study of architectural lighting design" (IALD, 2018b). The IALD Education Trust recognizes schools with focused lighting design programs worldwide to grow their admissions (IALD, 2018b). The following section discusses the schools with focused lighting programs in the United States.

Schools with focused lighting design programs

The IALD Education Trust recognizes schools with focused lighting design programs worldwide. For this research, the researcher focused on schools from the United States only as shown in table 2-5 (IALD, 2018c).

Schools in the United States with Programs in Lighting Design

The School Name	Location	Diploma or Certificate	Undergraduate Degree	Master Degree	Ph.D. Degree
New York School of Interior Design	New York, USA			Master of Professional Studies in Lighting Design	
Otis College of Art And Design	California, USA	Lighting Design Certificate			
Parsons The New School for Design	New York, USA			Master of Fine Arts in Lighting Design + Dual Degrees	
Rensselaer Polytechnic Institute	New York, USA			Master of Science in Lighting	Ph.D. in Architectural Sciences with Concentration in Lighting
The Pennsylvania State University	Pennsylvania, USA		Bachelor of Architectural Engineering	Master of Science in Architectural Engineering	Doctor of Philosophy in Architectural Engineering
Texas Christian University	Texas, USA		BS in Interior Design with a Lighting Minor		
The Rocky Mountain Lighting Academy	Colorado, USA	Certificate Programs			
University Of Colorado	Colorado, USA		BS in Architectural Engineering	Master of Science in Architectural Engineering	Doctor of Philosophy in Architectural Engineering
University Of Nebraska	Nebraska, USA		BS in Architectural Engineering	Master of Science in Architectural Engineering	Doctor of Philosophy in Engineering
University Of Oklahoma	Oklahoma, USA			Master of Interior Design	

Table 2-5. Lighting Design Programs in the United States

The following diagrams present the curricula of eight of the programs; The New York School of Interior Design Master of Professional Studies in Lighting Design, Parsons the New School for Design Master of Fine Arts degree, Rensselaer Polytechnic Institute Master of Science (M.S.) in Lighting, Texas Christian University BS in Interior

Design with a Lighting Minor, The Pennsylvania State University Bachelor of Architectural Engineering, The Pennsylvania State University Master of Architectural Engineering (MAE), The University of Colorado BS and MS in Architectural Engineering, The University of Nebraska Bachelor of Science (B.S.) and Master of Science (M.S.) in Architectural Engineering, and The University of Oklahoma Master of Interior Design. Some of the tables present the entire curricula whereas others only present lighting design-focused subjects.

Texas Christian University BS in Interior Design with a Lighting Minor Lighting Subjects

Spring Semester (Freshman Level)
Lighting Fundamentals (3)

Fall Semester (Sophomore Level)
Special Problems: Digital Media in Lighting Design (3)
Fashion Communication (3)
Stage Lighting (3)
Advanced Stage Lighting (3)
Lighting & Design for Dance (3)
Photography (3)

Spring Semester (Sophomore Level)
Fashion Communication (3)
Stage Lighting (3)
Advanced Stage Lighting (3)
Lighting & Design for Dance (3)
Experimental Psychology: Perception (3)
Photography (3)

Fall Semester (Junior Level)
Special Problems: Lighting and the Human Experience (3)
Lighting & Design for Dance (3)
Experimental Psychology: Perception (3)

Spring Semester (Junior Level)
Advanced Stage Lighting (3)
Lighting & Design for Dance (3)

Fall Semester (Senior Level)
Lighting for Visual Presentation (3)

Spring Semester (Senior Level)
Lighting Thesis (3)

Figure 2-15. Texas Christian University Undergraduate Lighting Subjects

The New York School of Interior Design Master of Professional Studies in Lighting Design Curriculum

Fall Semester (12 credits)
727 Science of Light (2 credits)
729 Lighting Design Process (2)
732 Rendering & Representation for Lighting Design (2)
737 Light Source Selection and Evaluation (2)
740 Lighting Design Studio I (4)

Spring Semester (12 credits)
724 Evolution of Lighting Applications, Creativity, and Technology (2)
741 Luminaire Design (2)
744 Lighting Controls and Systems Technology (2)
745 Retail, Art, and Exhibition Lighting (2)
750 Lighting Design Studio II (3)

Summer Session (6 credits)
723 Daylight Design Principles (3)
735 Lighting Historic and Unique Environments (2)
759 Business of Light (2)

Figure 2-15. NYSID Lighting Subjects

Parsons the New School for Design Master of Fine Arts degree Curriculum

Fall Semester (15 credits)/First Year
PGLT 5001 Studio 1: Light, Vision, and Representation (6)
PSCE 5005 Representation and Spatial Reasoning 1: Lecture (0)
PSCE 5006 Representation and Spatial Reasoning 1: Recitation (3)
PGLT 5111 Principles of Lighting 1 (3)
PGLT 5146 Light: Critical Issues (3)

Spring Semester (15 credits)/First Year
PGLT 5002 Studio 2: Natural and Technological Light (6)
PGLT 5143 Daylight Methodologies (3)
PGLT 5112 Principles of Lighting 2 (3)
PGLT 5102 Light, Perception, and Culture (3)

Fall Semester (15 credits)/Second Year
PSCE 5201 Studio 3: Allied (6)
PGAR 5415 Thesis Preparation: Lecture (0)
PGAR 5416 Thesis Preparation: Recitation (3)
PGLT 5116 Systems Technology (3)
Elective (3)

Spring Semester (15 credits)/Second Year
PGLT 5004 Studio 4: Thesis (6)
PGLT 5127 Thesis Seminar (3)
PGLT 5125 Professional Practice (3)
Elective (3)

Figure 2-16. Parsons Graduate Lighting Subjects

Rensselaer Polytechnic Institute Master of Science (M.S.) Lighting Subjects

Fall Semester
Lighting Design
Human Factors in Lighting
The Physics of Light
Lighting Technologies and Applications

Spring Semester
Lighting Leadership Seminar
Lighting Workshop
Light and Health
Master's Project

Figure 2-17. Rensselaer Graduate Lighting Subjects

The Pennsylvania State University Bachelor of Architectural Engineering Lighting Subjects

Fall Semester (Junior Level)
Building Illumination I (3)
Advanced Arch illum Design (3)

Spring Semester (Junior Level)
Computer Aided Lighting Design and Analysis (3)
Design Analysis (3)

Spring Semester (Senior Level)
Senior Project (4)

Figure 2-18. Penn State Undergraduate Lighting Subjects

The Pennsylvania State University Master of Architectural Engineering (MAE) Lighting Subjects

Fundamental of Electric & Illumination Systems
Basic Theory of Bldg Illumination
Advanced Architectural Illumination
Computer Aided Lighting Design & Analysis
Senior Design Project I & II
Daylighting
Luminous Flux Transfer
Luminaire Optics
Color Science for Illuminating Engineering
Light Source Technologies
Current Research in Illuminating Engineering
Stage Lighting Design
Sensation and Perception

Figure 2-19. Penn State Graduate Lighting Subjects

University of Colorado BS and MS in Architectural Engineering Lighting Subjects

Illumination I (basic lighting engineering and design)
Illumination II (lighting design)
Building Energy Laboratory (Mechanical and Lighting Lab)
Advanced Lighting Design
Daylighting
Human Factors in Lighting
Sustainable Lighting Workshop
Luminaire Optical Design
Theatre Lighting I
Psychology of Perception (All senses studied)
Senior Design Project (Interdisciplinary design project with lighting, mechanical, structural, and construction management)

Figure 2-20. University of Colorado Lighting Subjects

University of Oklahoma Master of Interior Design Lighting Subjects

Lighting Controls and Technology
Lighting Design for Dance/Musical Theatre/Opera
Fixture Design
Lighting Design Computation and Visualization

Figure 2-21. University of Oklahoma Graduate Lighting Subjects

University of Nebraska Bachelor of Science (B.S.) and Master of Science (M.S.) in Architectural Engineering Lighting Subjects

Lighting I: Fundamentals for Design
Lighting II: Theory, Design & Application
Lighting Design
Daylighting
Theatrical Lighting
Interdisciplinary Team Design Project
Lighting Metrics
Behavioral Sciences for Lighting Research
Psychological Aspects of Lighting
Current Research in Illuminating Engineering

Figure 2-22. University of Nebraska Lighting Subjects

2.5- Digital Tools in Architecture and Design Pedagogy

Architecture, interior design, and other design-related disciplines are a “result of a pragmatic mix of design problem solving, design process thinking, and the integration of various technical processes that add depth and analysis to the design problem" (Poldma, 2009, p. 20). Digital tools are technical processes that affect the design process and design pedagogy (Inanici, 2001, p. 1175; Oxman, 2008, p. 99). Students nowadays use computer softwares to generate, analyze, and present their design concepts and projects (Han & Li, 2014, p. 110). Lighting simulation softwares are becoming an essential part of architecture and engineering education (Ochoa Morales et al., 2010, p. 1). Designers use these programs to produce photorealistic renderings and to stimulate the physical behavior and the distribution of light (Ochoa Morales et al., 2010, p. 1). It's important to note that digital design tools do not design but they support the designer's vision. They need human supervision and programming to perform designated tasks. (Cross, 2007). This argument relates to the Technological Pedagogical Content Knowledge (TPACK) framework.

TPACK is an educational framework that introduces technology in students' learning process (Graham, 2011, p. 1954; Koehler, Mishra, & Cain, 2013; Niess, 2011, p. 300). It was developed in 2006 in the Teachers College Record to provide a flexible pedagogical framework that focuses on "student thinking and learning; knowledge of the subject matter; and increasingly, knowledge of technology" (Koehler et al., 2013, p. 13). In other words, TPACK introduces an effective educational platform that integrates technology, pedagogy, and content knowledge (Graham, 2011, p. 1954; Koehler et al., 2013, p. 16; Niess, 2011, p. 301). To implement the framework, educators understand the intent of using technology, the challenges and opportunities associated with such integration, students' past experiences, and the effects of the technology on the students' learning and thinking processes (Koehler et al., 2013, p. 16; Niess, 2011). Nevertheless, there are some challenges associated with the introduction of technology in an educational framework like the educators training process, the suitability of the tool for specific tasks rather than others, the availability and affordance of a specific technology, and the lengthy time-frame to learn the new technology (Koehler et al., 2013, p. 14; Mishra et al., 2010, p. 3). Additionally, Dewey believes that passing any new skill on students requires educators to allocate the right place to introduce the new skills, to determine the right method of delivering both the theoretical and the practical knowledge related to the skill, and to supervise the process when students use the skill (Dewey, 1962).

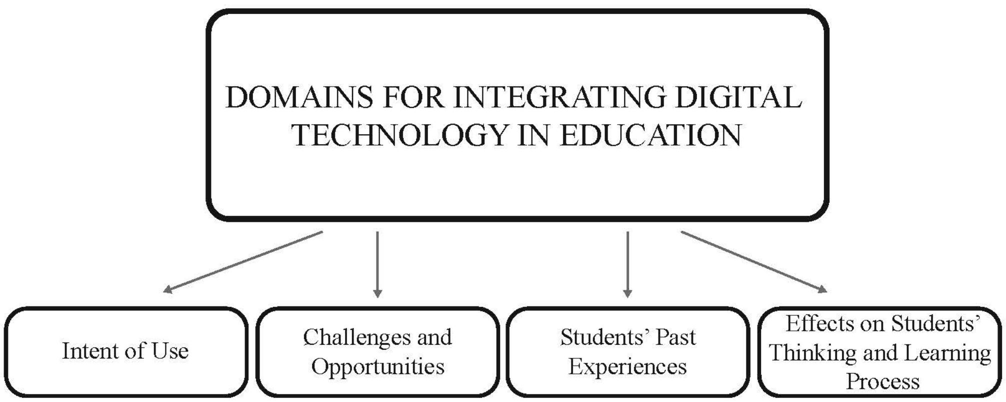


Figure 2-23 Domains for Integrating Digital Technology in Education

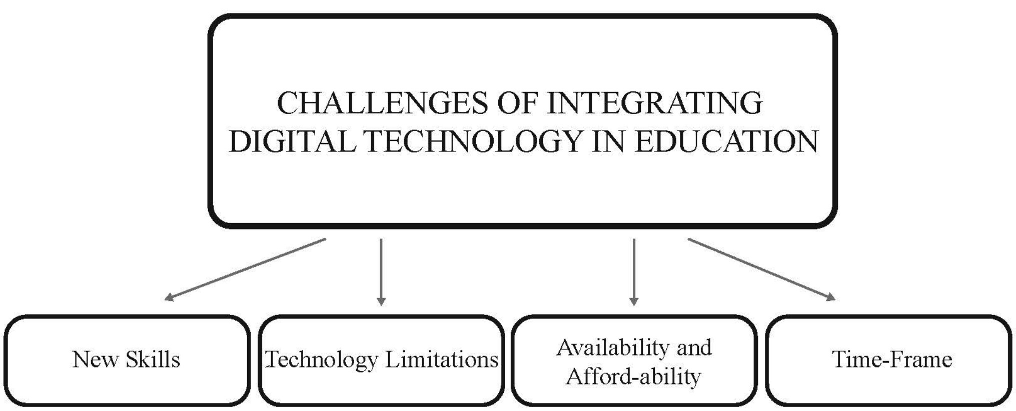


Figure 2-24. Challenges Associated with Integrating Digital Technology in Education

2.5.1- Building Information Technology (BIM) in Design Pedagogy

Building Information Technology (BIM) is “technologies and methodologies based around the creation and coordination of digital building data that is visually represented in ‘three dimensions (3D)’ on a computer screen” (Mathews, 2013, p. 191). This technology is currently the leading digital tool in design and architecture education. BIM integrates all construction and design tools under one platform (Kensek & Noble, 2014, p. 3; Lee, 2012, p. 35; Mathews, 2013, pp. 191-192; Morton, 2012, p. 51). Design educational institutions introduce Revit (BIM software) software to help students in integrating all building parts efficiently, meeting energy codes, and following sustainability recommendations in a reasonable timeframe (Lee, 2012; Morton, 2012).

David E. Morton suggests teaching BIM in the early stages of architecture education to better foster its benefits (Morton, 2012, p. 52). Lee recommends educating interior designers to utilize BIM in creating sustainable interiors to keep up with other disciplines such as engineering and architecture. BIM users indicate that the technology saves money and time, especially when designing sustainable projects. In particular, 60% of designers use BIM for lighting analysis because it is among the top criteria to meet sustainability codes (Lee, 2012, pp. 36-37).

Nevertheless, BIM requires a lot of teaching and training time (Morton, 2012, p. 54). It causes conceptual complexity in early design stages since it requires students to make precise decisions fast and it has a relatively hard user interface (Acosta, Navarro, & Sendra, 2011) Current BIM technology lacks the flexibility in modeling (Kensek & Noble, 2014, pp. 11-12; Morton, 2012, pp. 56-64).

2.5.2- Introducing Light Simulation Softwares in Design Education

Gustina (2009) thinks that digital tools ease the lighting design learning process (Gustina, 2011, p. 522). However, there are only a few studies that evaluated the impact of digital tools on lighting design pedagogy. Lee's (2012) research shows that students prefer Revit's built-in simulation tools to analyze daylight and electrical lighting followed by a web-based external application (Green Building Studio (GBS)). The external web-based application requires fewer steps and less knowledge to analyze light (Lee, 2012, pp. 37-48). Raphael Compagnon's study indicates that RADIANCE needs a long training time and it requires a collaboration between students and a RADIANCE expert which challenges the application of the tool in an educational framework (R Compagnon, 1997).

2.6- Transferring Knowledge from the Theoretical Argument to the Proposed Framework

The research transfers knowledge from the United States to Kuwait to enhance lighting design pedagogy. This section talks about the transfer process.

2.6.1-The Knowledge Transfer Process

The knowledge transfer framework helps researchers save time and effort when transferring knowledge from one case study to another. The framework starts with knowledge infrastructure and evaluation. Knowledge infrastructure includes three steps; "knowledge discovery, knowledge acquisition, and knowledge creation" (Aloshan, 2016, p. 106). Knowledge discovery is gathering information about the existing knowledge from the literature. Knowledge acquisition, on the other, is extracting knowledge from relevant external sources such as the literature review, case studies, and interviews with experts in the field. Last, knowledge creation is creating new knowledge by comparing and relating the existing knowledge to the external sources to arrive at the requirements needed for the framework.

The second step is knowledge evaluation to relate the obtained knowledge from the previous steps to the research goals and objectives to develop the knowledge and to eliminate unnecessary data. The third step is knowledge filtering to classify, organize and sort the obtained knowledge. The fourth step is the knowledge repository to further organize the selected knowledge and to remove obsolete data. The fifth step is the knowledge sharing to obtain a consensus for the proposed framework by sharing it with experts in the field (Aloshan, 2016).

The sixth step is knowledge adoption to generate new knowledge about lighting design education by combining the knowledge obtained from lighting design experts with current lighting design education in Kuwait. The seventh step is developing the new framework to apply the obtained knowledge. Last, is the knowledge delivery step to decide whether the framework is teacher-centered or student-centered and the steps in which the researcher needs to deliver lighting design knowledge to students and educators (Aloshan, 2016, p. 110).

2.7- Summary

Light is a fundamental element in any physical space. It illuminates other objects and affects the perception of different environments. Light influences human health, mood, feelings, visual acuity, performance, and comfort levels. Lighting design helps designers create aesthetical and comfortable spaces that impose certain moods or feelings. It focuses on both light quantity and quality to create an optimal visual environment for different functions. Despite the importance of lighting design, designers usually incorporate it late in the design process. This delay in light integration is a result of the designers' past training and education. Most design schools introduce lighting deductively in a few classes only.

In addition, design schools introduce lighting as a technical and aesthetical element in a limited timeframe. Hence, students graduate with little knowledge and experience in lighting design, especially since lighting knowledge is very complex. To ease the complexity of lighting design and analysis, designers use digital tools for speed, convenience, and minimal cost. Nowadays, some schools introduce digital light simulation softwares to help students visualize and to test lighting performance easily. These tools are either stand-alone light softwares or plug-ins in existing 3D modeling softwares. Digital tools change the linear design process into a non-linear interchangeable one, which integrates all design stages, components, and team members under one platform. Digital light simulation softwares help designers visualize and analyze light performance from early design stages with less time, effort, and cost. However, such tools need special knowledge and training. Hence, to effectively integrate lighting fundamental knowledge and digital tools into lighting design education, a new pedagogical framework is needed.

This research aims to create a new educational framework to introduce lighting design differently within existing design curricula at Kuwait University to help students in understanding lighting better and to aid their design decision-making process. The researcher proposes the integration of lighting design principles, tools, cognitive activities, and technologies at different learning stages to meet the research goal. The researcher referred to the existing design pedagogies, teaching methods, curricula development recommendations, and the knowledge transfer models from the literature to create a logical argument for the integration process (explained in detail in the logical argument chapter). In addition, the literature recommends introducing lighting simulation plug-ins within a BIM modeling software to start the integration of digital light simulation tools in an educational framework.

Chapter III

3- Methodology

This research strove to improve lighting design pedagogy by integrating fundamental knowledge of lighting and lighting-related cognitive tools in a new educational framework. The research followed a qualitative grounded theory methodology to transfer lighting design knowledge from developed lighting design programs in the United States to Kuwait University. This chapter introduces the qualitative research characteristics, the research inquiry strategies, the data collection methods, the analysis procedures, and the research narrative structure.

3.1- Qualitative Research

Qualitative research is an emerging framework of inquiry that focuses on the interactive and explanatory facets of a phenomenon with non-numerical evidence (Groat & Wang, 2013, pp. 69-71). It usually involves open-ended questions that seek participants' interpretation of a phenomenon in its natural setting for a prolonged period (Creswell, 2003; Groat & Wang, 2013, pp. 218-223; Marshall & Rossman, 2016, p. 2; Patton, 1987, pp. 13-14). Qualitative research relies on inductive analysis, meaning that it describes and explains a phenomenon based on open-ended procedures without pre-existing influences. Open-ended qualitative procedures include in-depth interviews, observations, field notes, and written documents and records. Qualitative research aims to establish rapport with the participants (Patton, 1987) and relies heavily on the researcher's explanations of the phenomenon, specifically during the data analysis phase (Creswell, 2003; Groat & Wang, 2013; Patton, 1987). Thus, qualitative research is sensitive to the researcher's background, his/her social beliefs, and how his/her history and beliefs shape the study (Marshall & Rossman, 2016).

Overall, qualitative research describes a program or a phenomenon, its process, its participants, the effect of the program or the phenomenon on participants, and the strengths and weaknesses of the program or the phenomenon (Patton, 1987, pp. 6-7). In qualitative research the researcher establishes a new theory by collecting and analyzing data, then sorting it into codes and themes (Creswell, 2003). The data collection, the data analysis, and the writing up of the research are all interactive processes. The researcher visits the research materials regularly in a back and forth process to summarize the experiences in a holistic theory (Creswell, 2003). Qualitative research can have multiple strategies of inquiry, such as grounded theory and case study (Creswell, 2003).

Qualitative Research Characteristics

Explanatory and interactive with the research participants
Examines a phenomenon in its natural setting without manipulation
Multi-method to reach a holistic understanding of a phenomenon
Open-ended to seek participants' interpretation of a phenomenon
Inductive analysis without any pre-existing influences
Sensitive to the researcher's history, beliefs, and interpretation during the analysis phase
Iterative with a back-and-forth process between the data collection and analysis

Figure 3-1. Qualitative Research Traits

3.1.1- Qualitative Research Reasoning

Qualitative research is the most suitable methodology for studies where the process, explorations, individual experiences, and evaluation of findings are more important to the researcher than the product or program itself. It is used to develop a new theory when there is insufficient precedent data in the literature. It is appropriate when the strengths and weaknesses of the program are of interest and when the research topic is not emphasized enough in the literature (Patton, 1987).

Based on Patton's (1987) recommendations, qualitative research was deemed the most suitable methodology for the current research for the following reasons. The current research focused on educators' lived experiences and their in-depth individual interpretation and understanding of lighting design education. It sought to make meaning based on participants' feedback in their own words and interpretations through open-ended interviews rather than pre-established survey questions. It strove to fill a gap in the literature because not enough studies have investigated lighting design pedagogy. Lastly, its objective was to create a thorough understanding of lighting design in order to enhance lighting design education. For all these reasons, qualitative methodology was deemed the most suitable methodology for the current study, especially because, given the limited timeframe for obtaining a Ph.D. degree, the small sample size was more feasible using qualitative research compared to quantitative or mixed-methods approaches.

3.1.2- Qualitative Research Strategies of Inquiry

The current research combined the case study and grounded theory strategies of inquiry. The case study approach was used to study current lighting design education at Kuwait University and develop lighting design programs in the United States through document analysis and open-ended interviews with lighting design educators and specialists. The grounded theory approach was used to generate a new theory by transferring knowledge from the literature review and the United States-developed lighting design programs to Kuwait University's design curricula.

3.1.2.1- Case Study

The case study strategy of inquiry examines a single group of people to gain a comprehensive and detailed understanding of a phenomenon. It is all about gaining in-depth information about a single case by tackling the rich experiences of individuals or groups (Marshall & Rossman, 2016, p. 19; O'Leary, 2014, pp. 194-196; Patton, 1987). It is also used to investigate a phenomenon in its actual context via multiple data collection procedures. Researchers usually use this strategy to generate practical knowledge (Groat & Wang, 2013; Marshall & Rossman, 2016, p. 19).

In the current research, the case study strategy was used in an exploratory theory-building research design (Groat & Wang, 2013). The primary goal was to gain an in-depth understanding of current lighting design pedagogy for future enhancement; the best way to gain this in-depth understanding was through document analysis and in-depth interviews with current lighting design educators and specialists from Kuwait University, as well as information about developed lighting design programs from the United States. This type of case selection is an oriented selection rather than a random one; the case is chosen based on specific reasons and targets rather than randomly selected.

In sum, the current research tackled two case study analyses: Kuwait University’s current lighting design education and the United States’ current developed lighting design programs. This comparative case study analysis helped the researcher identify the weaknesses in Kuwait University’s lighting design education in order to transfer the appropriate knowledge from the United States for future development and enhancement.

3.1.2.2- Grounded Theory

This research required a strategy to generate a new theory based on the comparisons of the case studies. Ethnography relies heavily on prolonged observations, which was not feasible for the current study due to time and resource constraints. Thus, the current research used a grounded theory approach to further investigate the phenomenon under investigation. The grounded theory strategy provides a strong argument for qualitative research credibility (Charmaz, 2006; Groat & Wang, 2013, p. 235). It aims to generate new theories rather than generalize findings to a population. It provides an explanatory framework rather than a descriptive one (Charmaz, 2006). It generates theories from interpreting and analyzing data rather than generating data from predefined theories and hypotheses (Charmaz, 2006; Groat & Wang, 2013, p. 235; Marshall & Rossman, 2016, pp. 18-19).

The process of the grounded theory strategy starts with open-ended data collection methods, continues to the analysis of the collected data using in-depth coding, and ends with the interpretation of the data analysis in a theory-building narrative as shown in Figure 3-1. This method usually provides a deeper understanding of not fully explained data (Groat & Wang, 2013, p. 235).

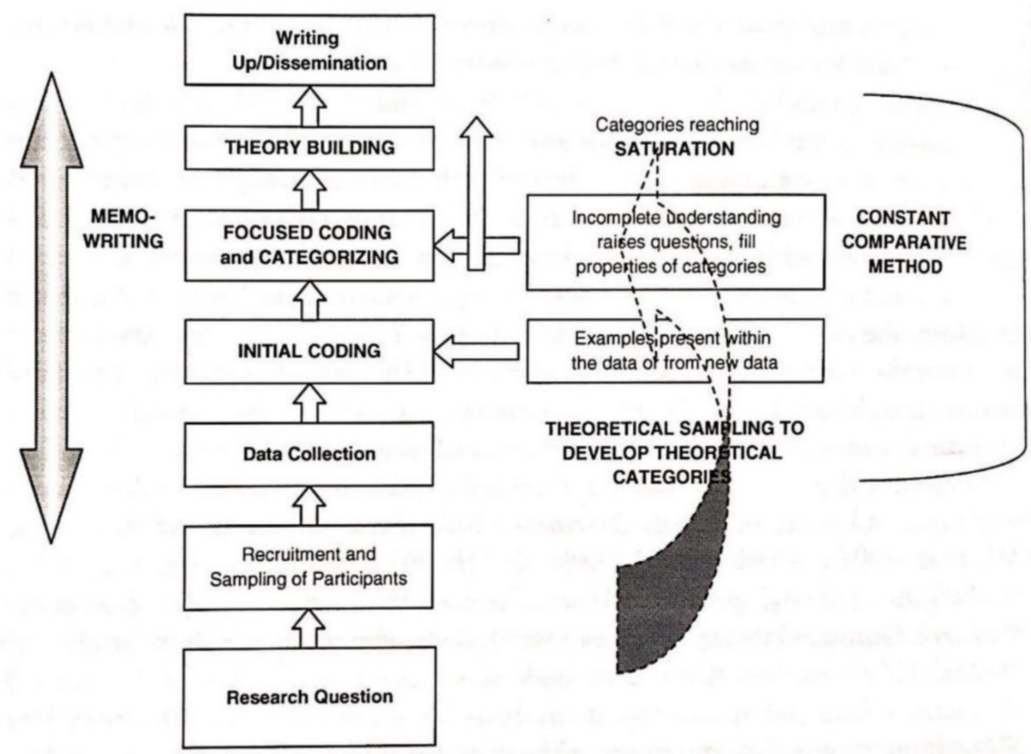


Figure 3-2. Grounded Theory Process (Charmaz, 2006)

The current study used a grounded theory strategy to build a new theory about the integration of lighting design and cognitive tools in design pedagogy. Grounded theory was deemed suitable for the current research because it can be used to generate a new theory from open-ended interviews with participants. In this study, participants were individuals who had experienced lighting design education thoroughly.

3.2- Research Sample

The researcher used purposeful sampling for the current research to gain in-depth information about a specific case (Charmaz, 2006; Patton, 1987). She chose educators from well-developed lighting design programs from the United States and current lighting design educators from Kuwait University. The researcher selected educators rather than students because they possessed the rich knowledge and expertise needed for the study. Educators teach their subject matter for prolonged periods whereas students only experience it for a short time. Educators also update and develop their knowledge consistently. For these reasons, lighting design educators were deemed the most appropriate sample for the advancement of lighting design pedagogy.

The researcher interviewed five lighting design educators from Kuwait University and six lighting design instructors from well-developed lighting design programs in the United States. Initially, the researcher planned to interview educators from the lighting programs listed on the International Association of Lighting Designers (IALD) website (listed in Chapter II). However, the researcher was only able to interview educators from the New York School of Interior Design, Parsons the New School for Design, and the University of Colorado due to time constraints and educators' busy schedules. The researcher then decided to find educators from top theater schools and other successful lighting design educators from the United States. Theater programs were deemed useful for the current study because they focus on qualitative aspects of light and how light affects human factors and movement. The researcher interviewed educators from Boston University School of Drama, the University of California at Irvine School of Drama, and the interior design program at Appalachian State University.

The researcher chose the IALD recommended programs and the top theater schools because each program has at least one educator who devoted his/her time to lighting design. As for the reasons behind choosing Kuwait University, the researcher is a faculty at the institution, which means she could apply the research findings promptly. The researcher recruited participants via emails stating the nature and the purpose of the study, the participants' role in it, confidentiality, risks of participation, and the freedom of withdraw participation before the start of the study.

3.3- The Chosen United States Programs' Background.

The New York School of Interior Design is a private school founded in 1916 to offer interior design education. The school's objective is to create spaces that are "beautiful, functional, healthy, safe, and built-in a socially and environmentally conscientious way" (NYSID, 2017a). The school's BFA and MFA degrees are accredited by CIDA whereas the whole institution is a member of the National Association of Schools of Art and Design (NASAD; NYSID, 2017a). The program's director stated that the school's lighting lab and its experiential learning approach help students understand lighting design and how to work with it as a design medium: "Our state-of-the-art architectural lighting lab is a key tool to build a fundamental understanding of how to work with light as a medium. Students explore lighting in full scale, with hands-on experiences in focusing, composing scenes and color tuning" (NYSID, 2017b).

Parsons, the New School for Design, is an art and design school founded in 1896 to offer a multidisciplinary design education. The school fosters students' critical and creative thinking and links their designs to social and environmental contexts through field research and hands-on activities (Parsons, 2017a). The program aims to connect light theoretical, aesthetical, and technical knowledge in an interdisciplinary curriculum that links lighting design to architecture, product design, and interior design majors. The program focuses on project-based learning, problem-solving skills, and professional internships to combine theoretical and technical knowledge with practice (Parsons, 2017b).

The University of Colorado provides students with new knowledge to solve social, technological, and community problems (UC, 2018a). The university's Department of Architectural Engineering aims to enhance people's lives and health by meeting environmental and community needs. The program helps students solve complex problems to meet ethical and professional standards through teamwork and collaborative projects. Students are required to take five lighting subjects in order to obtain a lighting-focused degree. The program links lighting theoretical and computational knowledge to studio practice (UC, 2018c), providing students with a lighting lab to explore lighting performances, distribution, effects, sources, and design through hands-on activities (UC, 2018b).

The School of Drama at UCI was founded in 1965. Its Master of Fine Arts in Lighting Design prepares students for careers in theatrical lighting, entertainment lighting, concert lighting, and architectural lighting. By providing knowledge about light art and technology, this program tries to balance "the creative, practical, theoretical, digital, scientific, philosophical, and psychological aspects of the nature of light" (UCI, 2020). UCI focuses on collaborative learning, problem-solving skills, critical evaluation and observation, and professional maturity (UCI, 2020).

The Boston University School of Theater was founded in 1954. The school focuses on collaborative learning, art explorations, professional knowledge, critical thinking, hands-on learning, and intellectual growth. The school's undergraduate students learn light "aesthetic exploration and historical consciousness, as well as some of the requirements in communication; diversity, civic engagement & global citizenship; and the intellectual toolkit" (BU, 2021). The graduate program, on the other hand, highlights technical and interpretive lighting design, critical thinking, production skills, communication skills, written and spoken skills (especially storytelling), and lighting design studios (BU, 2021).

The Appalachian State University Department of Interior Design emphasizes sustainability, environmental and global issues, community services, and universal design. The department ties theoretical design knowledge to practical exercises with a multidisciplinary foundational year. The department does not have a lighting design-focused degree, but one of its educators is a lighting design enthusiast who keeps on developing her/his lighting design knowledge (University, 2021). His/her students won several Cooper Lighting Awards.

3.4- Location

The researcher interviewed three educators from Colorado, California, and Boston via Zoom, and conducted in-person interviews with educators from New York, Northern California, and Kuwait. The researcher first contacted educators from the chosen programs to set a date, time, and location for the interview. The in-person meeting locations were quiet and private to obtain a quality interview. The size of the location was adequate for two participants (not too small or too spacious) to establish comfort.

3.5- The Data Collection Procedure

The researcher collected data from the literature review, in-depth interviews, and document analysis. The researcher first reviewed data from the relevant literature to establish a theoretical framework for the research and to prepare the data gathering instrument (interview questions). The researcher then interviewed lighting design educators in the Architecture and Interior Architecture departments at Kuwait University and lighting design educators from the United States to gather in-depth information and feedback. Lighting design educators from Kuwait University possessed the expertise and knowledge needed to understand current lighting design education at their institution, whereas lighting design educators from developed lighting design programs in the United States possessed the expertise and knowledge required to develop lighting design education further. Additionally, the researcher analyzed lighting design curricula from the chosen programs and lighting classes' syllabi for more information and to triangulate the collected data.

3.6.1- The Theoretical Structure (The Logical Argument)

The first step of the data collection procedure is to interpret the data from the relevant literature to form a logical argument. The literature review provided knowledge about lighting design and processes, design education, design pedagogical theories, curricula development recommendations, precedent research for incorporating computing technology in design education, available light simulation tools, schools with developed lighting design programs, and knowledge transfer methods.

3.6.1.1- The Relative Literature Interpretation

The researcher started the research by reviewing relevant textbooks, journal articles, online databases (from several universities), online websites (such as IESNA, and IALD), dissertations, and other documents to understand lighting design education, cognitive process and tools related to light and lighting, light simulation software, and ways to integrate the knowledge domains into design education.

Interpreting the collected data from the literature review is similar to the initial process of knowledge transfer (discussed in the previous chapter). The researcher gathered the relevant data, then evaluated and filtered the data to eliminate unnecessary information that was not relevant to the research purpose and objectives. Next, she classified the filtered data into categories to understand different factors that influence lighting design education. The categories were design thinking and process, lighting design process and design tools used in the process, foundational lighting design knowledge, weaknesses of lighting design education, computing technology's influences on lighting design education, features of an educational digital light simulation tool, pedagogical design theories, lighting design curricula structure, curricula development theories, and ways to enhance lighting design education. These categories/factors informed the research instrument (interview questions).

3.6.2- Interviews

In-depth interviewing is "a directed conversation…that permits an in-depth exploration of a particular topic or experience" (Charmaz, 2006, p. 25). Researchers select individual interviews as a data collection method to increase the participants' response rate, clarify unclear questions, triangulate the collected data, and gather data that cannot be observed objectively, such as feelings, personal experiences, perspectives, and intentions (Babbie, 1990; Patton, 1987). The researcher chose to conduct individual interviews with formal open-ended questions, probes, and follow-up questions to capture different points of view without any external influences and achieve better control over the discussed topic. The standardized open-ended interview "consists of a set of questions carefully worded and arranged to take each respondent through the same sequence and ask each respondent the same questions with essentially the same words" (Patton, 1987, p. 112). This type of interview removes bias, And works better with time-constraints.

For the current research, the researcher formed two sets of interview questions for the two case studies. The Kuwait University questions targeted current lighting design sequence, design pedagogical philosophy, intentions of each design year, methods used to deliver lighting design knowledge, lighting cultural context, lighting design topics that relate specifically to Kuwait's culture, perceptions about lighting design knowledge, and challenges of incorporating lighting design knowledge and simulation tools into the curriculum. The United States questions, on the other hand, targeted lighting design knowledge delivery methods and sequence, important lighting design topics, foundational lighting design knowledge, ways to integrate both technical and poetical aspects of light in design education, ways to balance lighting design knowledge with other competing classes, tools that students need to understand lighting and to help them in design decision making, ways to integrate lighting design in the design process, types of questions that students need to ask in order to understand the lighting design process and direct their design thinking, and ways to integrate digital light simulation tools in design education. Figure 3-3 summarizes the targets of both interviews.

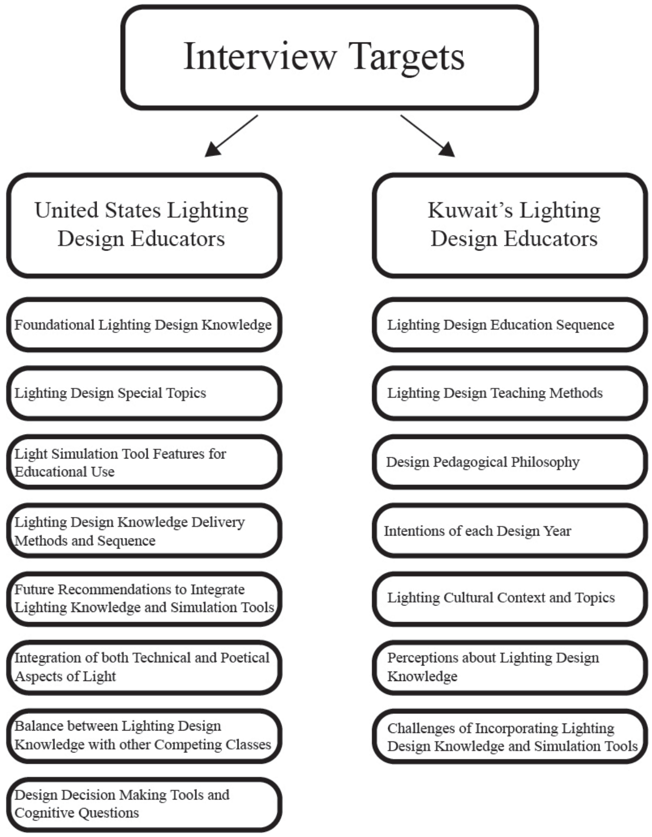


Figure 3-3. Interviews' Target Themes

3.6.2.1- The Interview Process

The researcher formed the questions based on recommendations made by a variety of researchers (Becker, 1986; Charmaz, 2006; Creswell, 2003; Patton, 1987, 2015). She organized the questions into the following sections: demographics, past experiences, current experiences, opinions, values, feelings, and future recommendations. Each section of the interview questions had an introduction. The interview questions were singular (focusing on one topic at a time), open-ended (rather than yes or no questions), and simple. The researcher tested the questions in a pilot study before the actual data collection procedure.

The researcher started a pilot study in summer 2018 at Kuwait University to test and develop the interview questions and her interview skills. She asked three design educators from Kuwait a set of questions to get feedback about the data collection instrument for future enhancements. The researcher first explained the study to the participants, describing its process, its duration, and the participants' role in it. Before the interview, the researcher sent recruitment forms via email to get the participants' approval to initiate the process. She then met with the participants for an orientation interview to give them some information about the data collection interview and to set its meeting time. Some interviewees preferred combining the orientation interview with the data collection interview. The researcher audio recorded the interview on a digital external hard drive and took some personal notes. In addition to Kuwait University's pilot study, the researcher conducted another pilot study in the United States following the same procedures in Fall 2018, interviewing three lighting design educators from Virginia Tech University.

After the pilot study, the researcher started the actual data collection interviews in Spring 2019. She interviewed four lighting design educators from Kuwait University and one educator from PAEET to understand current lighting design education in Kuwait. The researcher sent recruitment forms via emails, and requested some lighting design class-related documents that were not available online. The researcher then met with the participants for the orientation and the data collection interviews. The researcher audio recorded the entire interview on a digital external hard drive along and took some field notes.

After the Kuwait interviews, the researcher traveled to the United States in Fall 2019 to gather data from instructors from developed lighting design programs. She interviewed six specialized lighting design educators from the New York School of

Interior Design, Parsons the New School for Design, the University of Colorado, Boston University, the University of California at Irvine, and Appalachian State University. She followed the same process of recruiting participants via email and meeting them for the orientation and data collection interviews. The researcher only traveled to New York and Northern California for in-person interviews; the rest of the interviews were conducted online via Zoom. The researcher requested some lighting class-related documents before the interview to understand the different programs. The researcher analyzed the obtained documents as a third data collection procedure. (Note: Some participants did not submit class documents.) The interview questions for both Kuwait and the United States are shown in Appendix A.

3.6.3- Document Analysis

Documents are accessible sets of data that are prepared in advance (Creswell, 2003). They are an objective source of data that are not interrupted by the researcher's actions. In the current study, the researcher analyzed the architecture and interior architecture curricula and lighting design classes' syllabi from Kuwait University to further understand the collected data and to find commonalities or contradictions. The classes' syllabi and the students' assignment sheets provided the researcher with additional information about the classes' activities and contents. In addition to Kuwait University, the researcher analyzed developed lighting design programs' curricula and lighting classes' syllabi and assignment sheets from the United States. She obtained the documents from the schools' websites and the lighting design educators. This analysis helped the researcher compare Kuwait University and the developed lighting design programs' contents and exercises.

3.6.4- The Strengths and the Weaknesses of the Qualitative Data Collection Procedures

In-depth interviews and document analysis are procedures for data collection in qualitative research. Each one of these tools has some strengths and weaknesses. Therefore, using multiple data collection procedures enables the researcher to triangulate the data and overcome each instrument's limitations. The use of various data collection procedures gives the research credibility and strength.

Interviews allow the researcher to obtain in-depth information about qualities that cannot be observed like participants' history, feelings, beliefs, and experiences. This tool allows the researcher to control the quality of the data with predefined questions and probes, which in return saves time and effort. Nevertheless, the information obtained from the interviews is selective. Participants only tend to share what they think is valuable. They may hide some information due to personal reasons. The researcher's presence may also limit the participants' natural responses. Another limitation is the participants' personalities. Some participants may be introverts, meaning that they find it hard to share their feelings and experiences. Lastly, researchers usually conduct interviews in private spaces that are not the interviewees' natural settings, which may affect the quality of the collected data (Creswell, 2003).

Documents are resources that give information in a visual or text format. The researcher can access the documents at his/her convenience, which saves him/her effort and time. Additionally, documents are rich sources of data because people paid specific attention to developing them. Some documents, however, may contain inaccurate or incomplete information that yields false interpretations. Other documents may be hard to access for particular reasons (i.e., they are protected or not publicly available; Creswell, 2003).

Strengths and Weaknesses of the Qualitative Data Collection Procedures

Data Collection Mathod	Strengths	Weaknesses
Interviews	Provide information that cannot be observed like feelings and experiences. Control over the quality of data. Save time and effort.	Selective information (participants may hide some information). Participants may give false information to please the researcher. Unnatural data collection method. Hard to obtain information from introverts.
Document Analysis	Accessible sources of data that are not disrupted by any external activities. Flexibility in obtaining the data. Documents are crafted with attention (rich information). Save time and effort when accessible.	Some documents may be incomplete or have inaccurate information. Some documents are hard to access.

Table 3-1. Strengths and Weaknesses of the Qualitative Data Collection Procedures

3.6- The Data Analysis Procedure

The researcher followed a grounded theory qualitative approach to data analysis (Charmaz, 2006). She analyzed the interview transcripts and documents to uncover main codes and categories. The researcher then analyzed the codes and categories to find commonalities and contradictions to generate new themes and a new theoretical framework.

The researcher first read through all the data to get an overall sense and general meaning. After developing a preliminary understanding the data, she developed codes from excerpts that had different topics, patterns, and meanings. The researcher then combined the codes into different categories based on shared meanings, concepts, and overarching themes. She compared the categories to each other to find relationships and themes. The themes describe the categories in detail, including people's actions, feedback, and knowledge. The themes also determined the headings for each section in the results chapters, followed by supporting quotes, diagrams, and tables.

In detail, coding is "categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data" (Charmaz, 2006, p. 43). Coding in the grounded theory approach follows four stages: initial coding, focused coding, open coding, and axial coding. In the initial coding stage, the researcher codes each word or sentence based on its meaning. In the focused coding stage, the researcher uses "the most significant and/or frequent earlier codes to sift through large amounts of data" (Charmaz, 2006, p. 56). In open coding, the researcher finds overarching words and categories for thoughts and phrases in the data (Marshall & Rossman, 2016, p. 19). Finally, in the axial coding phase, the researcher "relates categories to subcategories, specifies the properties and dimensions of a category, and reassembles the data fractured during initial coding to give coherence to the emerging analysis" (Charmaz, 2006, p. 60). The initial coding stage relates closely to the data, capturing significant actions or meanings in as much detail as possible. Initial coding helps the researcher find gaps in the data to gather more information for a complete theory. Axial coding, in contrast, helps the researcher to compare, link, and find relationships among codes and categories to bring the data back together coherently for the new theory generation. This phase mostly incorporates constant comparative procedures and diagraming (Charmaz, 2006, p. 60;

Groat & Wang, 2013) between emerging categories and themes to find similarities and differences (Groat & Wang, 2013, pp. 236-237).

In the current study, the researcher first combined the answers for each question and color-coded each participant's answer in a Microsoft Word document. She separated the United States responses from Kuwaiti responses for later comparison. She then initiated the coding process by dissecting the responses into excerpts, which are sentences with different meanings. Each meaningful sentence is an excerpt that can have one or more initial codes. The researcher revised the initial codes for focused coding, then used them to generate categories for the axial coding analysis. The researcher used the NVivo software to help her generate and organize the codes and the notes, as well as eliminate bias by using the word count feature. This feature looks for the most frequent words for each question, code, category, or the entire data for credibility. In general, coding and word mapping helped the researcher downsize and organize the large data into manageable pieces of information for later comparisons and analysis.

The researcher sorted the codes that had similar meanings and concepts into categories. She described the beliefs and assumptions behind the categories using quotes that supported them. Next, she arranged the categories into major categories and sub-categories based on their content for conceptual and theoretical development by constantly writing memos, or are "preliminary analytic notes" (Charmaz, 2006, p. 3). Memo-writing "is a pivotal intermediate step between data collection and writing drafts of papers" (Charmaz, 2006, p. 72), telling a spontaneous story about what participants said, the reasons behind choosing specific codes, and the relationships between the codes and their categories (Charmaz, 2006). Each memo has a specific title, and it helps in analyzing data early in the research process to keep track of emerging theoretical ideas for refinement and development (Charmaz, 2006; Groat & Wang, 2013). Memoing primarily refers to writing down any thoughts, comparisons, and connections among the data, codes, ideas, and categories. This tactic helps the researcher discover ideas about the data; define conceptual connections between the codes and the categories within a hierarchy; and interpret participants' knowledge, behavior, and experience.

After the initial memo writing, the researcher performed the axial coding process to relate the categories and the subcategories to each other and to find overarching concepts or themes. In this phase, the researcher diagrammed the categories and named them based on their shared concepts and causal explanations to generate a new theory. The researcher then organized the categories, subcategories, and themes in a logical order with more detailed memos.

In addition, the researcher coded her documents' notes separately. She arranged the lighting design topics from the documents (syllabi, class documents, and the list of topics she asked the interviewees to arrange into foundational, intermediate, advanced, and elective lighting design categories. Within each category, the researcher color-coded each participant's recommended topics to count their frequency and arrange them in a sequence. The researcher wrote memos for each category and organized the findings according to the categories and subcategories previously established from the interviews.

The coding process, the categories, and the themes proposed ways to meet the research objectives through emerging concepts, ideas, and recommendations in a multi-dimensional and sequential knowledge delivery approach. At the end of each category, the researcher stated which findings are more credible/ frequent than others based on the

NVivo words count feature. The researcher related the findings to the research aim, questions, and objectives to establish a new theory. She compared the new theory to the existing literature, and she presented the preliminary framework to lighting design specialists for further development. The following diagram shows an example of the NVivo words count. Other examples of the data analysis are listed in Appendix B.

Figure 3-4. Example of the NVivo word cloud (Frequently Occurring words). Each word is linked to its corresponding quotes.

3.7- Development of Consensus

In qualitative studies, researchers seek credibility, transferability, dependability, and confirmability rather than external validity. Researchers achieve credibility through different data interpretation and collection methods. They tackle transferability by describing how two cases are similar. They achieve dependability through methodological transparency (describing the data collection, analysis, and interpretation processes in detail), and they achieve confirmability through triangulation and reflexivity. Triangulation addresses different data collection methods, whereas reflexivity requires the researcher to lay out his/her beliefs, assumptions, and position towards the studied phenomenon to understand his/her influence on the research (Groat & Wang, 2013, pp. 84-86).

In the current study, the researcher tried to achieve credibility through triangulation by using two data collection methods (interviews and document analysis). She described the data collection, recording, analysis, and research methodology in detail to achieve transferability and dependability. She used more than one data collection procedure and reflected on her own experiences, beliefs, assumptions, and position toward the phenomenon under study to achieve confirmability.

Additionally, the researcher tested the data collection instrument in a preliminary pilot study, adjusting the interview questions based on the participants' feedback. Before the pilot study, she asked her research committee members to review the interview questions for preliminary feedback because they are experts in the research field. The researcher also used a computer coding software (NVivo), and she hired a transcriber to remove bias. For the final framework, the researcher used the Delphi method.

3.7.1- Delphi Method

Delphi is a method used to achieve consensus in subjective research based on experts' knowledge and feedback to help the researcher in decision-making—especially when he/she is faced with uncertainty—through a series of questionnaires (Dalkey & Helmer, 1963; Pill, 1971). The group of experts is people with the needed knowledge and experience for a certain study (Pill, 1971). This method has three features: "anonymity, controlled feedback, and statistical group response" (Pill, 1971). The success of the method depends on the ability of the facilitator's questions to prevent the dominance of one opinion over the others, and the strength of the method lies in the constructive feedback of the panel of experts rather than just one specialist (Dalkey, & Helmer, 1963; Pill, 1971). The first use of the method can be traced back to a 1953 study by Dalkey and Helmer, who used a panel of seven experts with a series of controlled questionnaires.

In the current research, the researcher presented the preliminary framework to eight lighting design educators and professionals from the United States in an email thread with a set of open-ended questions to develop the framework. The open-ended questions sought recommendations to enhance the weaknesses of the preliminary framework. The researcher gathered similar responses in themes and represented them to the experts in the second round with closed-ended questions to rate the final action plan. After the second round, she formed a statistical group response using a central tendency analysis (means, medians, modes, and standard of deviation) to reach a percentage of agreement for the implementation process.

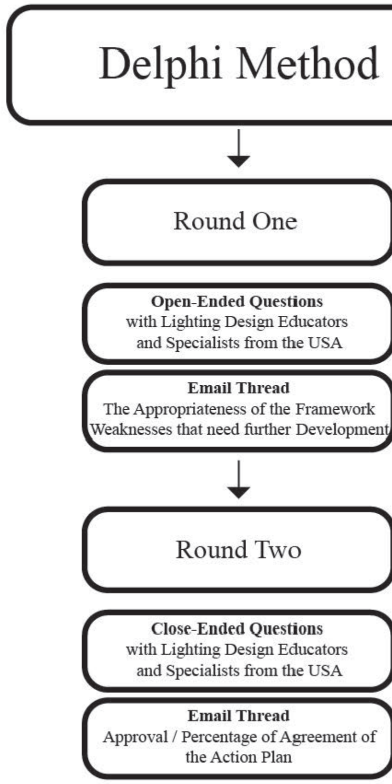


Figure 3-5. The Delphi Method Process

3.8- The Narrative Structure

The end goal of this grounded theory qualitative research was to generate a new theoretical framework for the integration of lighting design knowledge, computing technology, and lighting design cognitive activities in design pedagogy to fill a gap in the literature. The generated theory aimed to enhance lighting design pedagogy and create a new theoretical framework for similar future studies.

To elaborate further, a theory is an imaginative interpretation of emerging concepts and relationships between them to explain and understand an abstracted phenomenon (Charmaz, 2006). The researcher generated concepts and theories from the collected data by finding relationships and hierarchies between experiences and events, rather than describing the data as codes and categories. The framework targeted lighting design curricula to improve design students' experiences, facilitate their decision-making process, and enhance their understanding of lighting as a design element. The researcher structured the framework by transferring knowledge from the United States-developed lighting design programs to Kuwait University. She added new knowledge to the "As-Is" model to develop the "To-Be" model.

The researcher wrote the data interpretation and the analysis results using a constructivist theorizing narrative approach, which "places priority on the phenomenon of study and sees both data and analysis as created from shared experiences and relationships with participants" (Charmaz, 2006, p. 130). The researcher embodied participants' thoughts and feedback, which are the focus of the study, within the text as short quotes and long paragraph quotes whenever necessary. She also presented some of the results in tables and diagrams for clarification. The researcher organized the data in a logical order. She first explained the "As-Is" model to present the current lighting design context at Kuwait University. She then presented how the "As-Is" model developed into the "To-Be" model by adopting knowledge from the United States lighting design programs.

3.9- Developing the Proposed Framework

The proposed framework provides a multi-dimensional and sequential pedagogical structure to enhance students' understanding of lighting design and improve their design decision-making process by providing them with various analysis tools. The researcher developed the framework in five stages. Stage one entailed knowledge acquisition, interpretation, and organization. In this phase, the researcher collected and organized the data from Kuwait University interviews, documents analysis, and literature interpretation. The literature provided the researcher with a logical argument of how to integrate different lighting design topics and tools based on the design pedagogical theories, curriculum development recommendations, cognitive process domains, and literature on digital light simulation tools. Interviews with Kuwait University personnel focused on the following domains: existing lighting design pedagogy and structure, social beliefs about lighting design, the cultural stance toward lighting (cultural topics), lighting design principles and process, and the impact of computing technology on lighting design decision making and education. After gathering the data, the researcher interpreted and organized it to find gaps in Kuwait's current lighting design education and inform the required knowledge for phase two.

Phase two entailed knowledge development by experts. In this phase, the researcher interviewed lighting design educators and specialists from developed lighting design programs in the United States for new knowledge to develop lighting design education in general and lighting design pedagogy at Kuwait University in particular. The researcher filtered the obtained data to determine what fit the Kuwaiti case by comparing the new knowledge to Kuwait University's lighting design culture and knowledge gaps. The United States case studies provided recommendations to introduce lighting design topics, knowledge delivery methods, and tools to enhance lighting design pedagogy.

In phase three, the researcher transferred the United States knowledge to Kuwait while weaving in Kuwait's cultural and social contexts to establish a comprehensive lighting design pedagogical structure. Kuwait's cultural and social contexts informed lighting design topics that are specific to Kuwait's region, whereas the knowledge transfer from the United States helped the researcher establish the criteria and the principles for lighting design knowledge and decision-making tools.

After adopting and weaving in information from both case studies, the researcher structured the proposed framework with two objectives in mind: to improve students' understanding of lighting design through the integration of various lighting design topics and knowledge delivery methods and to enhance their decision-making skills by adopting light analysis and cognitive tools. The first dimension of the framework included synthesized criteria, topics, and categories from each framework objective. The second dimension included synthesized knowledge from both objectives concerning lighting design cognitive domains (theoretical/tacit knowledge, procedural/application knowledge, and explicit/analytical knowledge). Relating the obtained knowledge from both objectives to lighting design cognitive domains helped the researcher organize and filter the data to better prepare it for the fourth framework dimension, the yearly sequence of lighting knowledge.

The framework sequential structure includes a learning map with inputs, procedures, and evaluation of categories. The sequence also includes an arrangement of topics, methods, and tools to meet foundational, intermediate, advanced, and elective/future lighting design knowledge. In other words, it explains how to deliver lighting knowledge and topics in layers and how to merge simulation tools and other cognitive activities in the sequence. The sequence approach increases the clarity and efficiency of lighting knowledge delivery for the implementation phase. After establishing the sequence and the cognitive knowledge domains, the researcher synthesized a narrative for the framework implementation.

The narrative explains how to apply the framework sequence in Kuwait University, presents a lighting design studio, and provides recommendations to enhance current digital light simulation tools. The sequence describes how to introduce the cognitive knowledge domains. For example, it starts with theoretical knowledge (principles and topics), progresses to empirical knowledge (application), and ends with the analytical knowledge domain (decision-making tools). The theoretical domain merges the United States and Kuwait's knowledge. The application domain discusses the implementation possibilities from the framework into a studio scenario. The analytical domain, in contrast, explains the role of simulation tools and other decision-making tools in the application process (this domain is integrated into the studio scenario as well). In addition, the researcher included projects, exercises, and cognitive questions from the framework in the studio scenario (the framework narrative).

The cognitive knowledge domains, the lighting design knowledge sequence, and the framework narrative provided the researcher with an initial framework. The researcher shared the preliminary framework with lighting design specialists to form a consensus for its implementation, which was the fifth phase of the framework development. In this phase, the researcher asked experts from the United States some questions using a Delphi method. Gathering the United States lighting design experts' feedback was deemed the most appropriate way to develop the framework further because Kuwait University's design curricula are based on American systems. In this phase, the theoretical knowledge of the framework was translated into practical knowledge for the framework implementation.

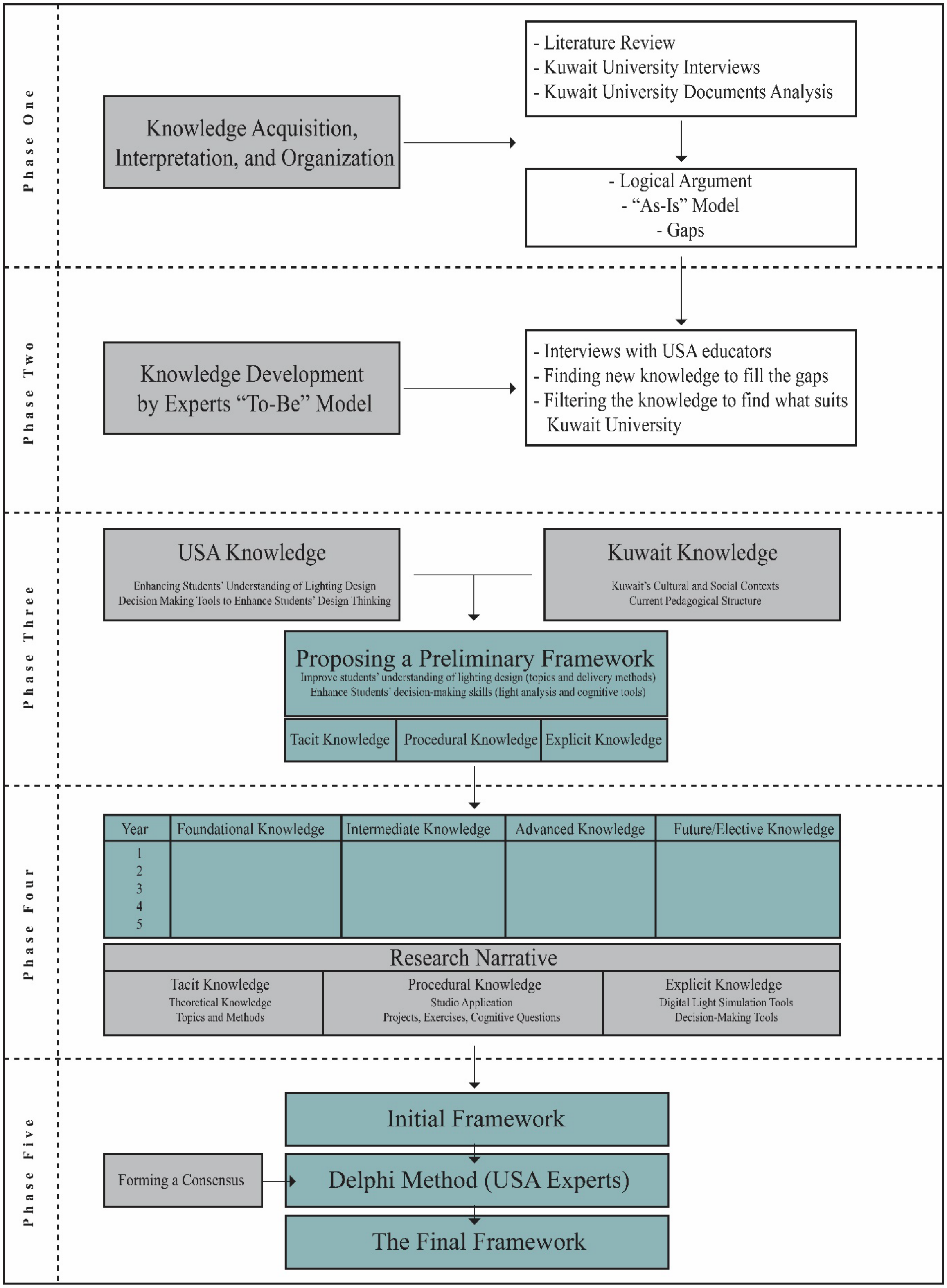


Figure 3-6. The Framework Development Phases

3.10- The Significance of the Study

The researcher reviewed the literature to understand the current body of knowledge related to lighting design education. The researcher found some research about lighting design education and ways to teach lighting in a lighting design-centered class (Brown, 2004; Gustina, 2011; Poldma, 2009), locating some studies about students' feedback on digital light simulation tools (Compagnon, 1997; Lee, 2012). However, there is limited if non-existent research about new approaches to introduce lighting design knowledge and digital light simulation tools into existing design curricula. Current design programs introduce lighting design deductively in one or a few classes over the 4 or 5 years of design education. Most lighting design educators teach it as a theory and principles that are then applied to design problems rather than in-studio projects. Thus, design students mistakenly perceive it as an additive element and usually add it toward the end of the design process rather than in the early conceptual stages (Gustina, 2011; Poldma, 2009, p. 20; Theodorson, 2006).

As for the integration of digital light simulation tools in design education, the researcher only found two studies that explored students' perceptions (Compagnon, 1997; Lee, 2012), and could find no prior research on how to integrate them in design education to develop students' design thinking and decision making. There is also a gap in the literature about digital light simulation tools that are effective for educational use, although some research has been conducted regarding the preferred digital light tools and tools' features in the design profession (Donn et al., 2007; Laiserin, 2001), as well as studies about the most widely used digital light simulation tools in the United States

(Ochoa Morales et al., 2010). However, no research could be located that provides recommended features for an educational digital light simulation tool.

As a result, the scholarly contribution of the proposed framework is to fill a gap in the literature on three pedagogical levels. On a department or university level, it tries to develop architecture and design curricula by integrating lighting design knowledge in a general sequence of years through multiple knowledge domains to enhance students' understanding of lighting design. It also tries to integrate digital light simulation tools and other cognitive activities to improve students' design thinking and decision-making.

On a class or a course level, the proposed framework helps educators deliver lighting design knowledge more effectively to develop students' awareness and knowledge about lighting design. The experts in the field provided knowledge about what tools, activities, topics, and experiences students need to understand lighting design better and to apply it in the early design stages.

Lastly, on a tool level, the proposed framework provides recommended features for an educational digital light simulation tool to help educators select the most optimal tool for design pedagogy. The features can also help software developers to create a student version for ease of use.

The Research Contribution

University Level	- Develops architecture and design curricula by integrating lighting design knowledge in a general sequence of years through multiple knowledge domains. - Enhances students' understanding of lighting design. - Integrates digital light simulation tools to improve students' design thinking and decision making.
Course Level	- Helps educators deliver lighting design knowledge more effectively to develop students' awareness and knowledge about lighting design. - Provides tools, activities, topics, and experiences that students need to understand lighting design better to apply it in early design stages and their professional careers. .
Tool Level	- Provides recommended features for an educational digital light simulation tool to help educators select the most optimal tool for design pedagogy. - The features help software developers to create a student version of digital light simulation tools for ease of use.

Figure 3-7. The Research Contribution

3.11- Summary of the Research Methodology

The current research aimed to establish a new theoretical framework for the advancement of design education at Kuwait University by implementing lighting design and cognitive tools in a new educational structure. To establish the framework, the researcher created a theoretical structure from the relevant literature. The theoretical structure helped the researcher understand the research context and prepare the research instrument. The researcher then examined current lighting design education at Kuwait University through in-depth interviews with lighting design educators and document analysis. After that, she extracted knowledge from advanced lighting design programs in the United States through in-depth interviews with professional lighting design educators and document analysis.

The literature review interpretation, the in-depth interviews with Kuwait's lighting design educators, and Kuwait University's lighting design document analysis established the "As-Is" model, whereas the in-depth interviews with lighting design educators and specialists from the United States and the lighting design knowledge transfer established the "To-Be" model. The "To-Be" model presents a preliminary pedagogical framework to advance lighting design education in Kuwait, proposing a new structure for the integration of lighting design knowledge and methods, lighting design cognitive activities, and digital light simulation tools. The framework also recommends features for an educational digital light simulation. Lastly, the researcher presented the preliminary framework to lighting design educators and professionals from the United States using a Delphi method to develop it further for the implementation process.

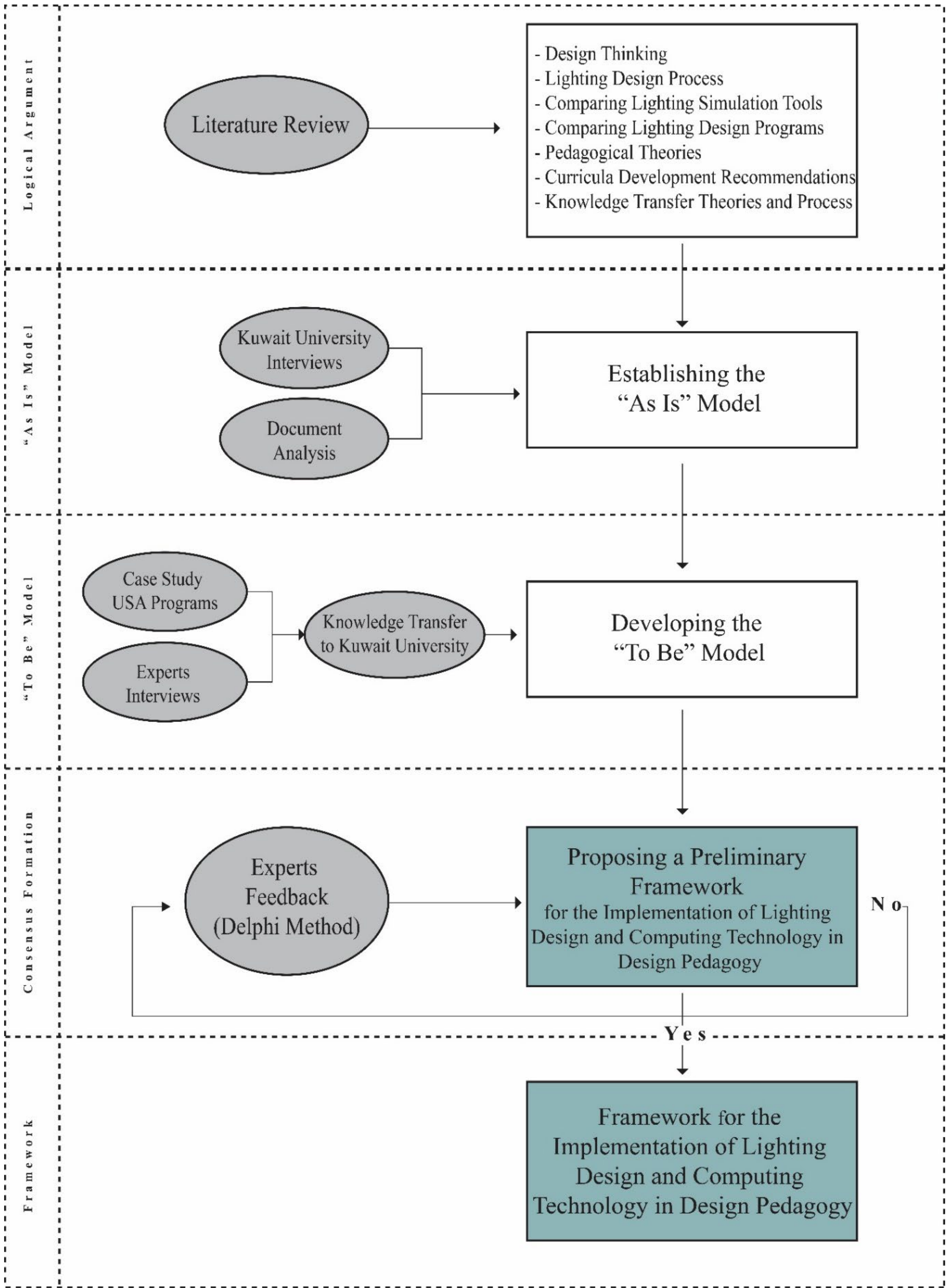


Figure 3-8. Research Methodology Process

Chapter IV

4- The Theoretical Framework (The Logical Argument)

This chapter explains the relevant literature to the framework's structure and instrument (the interview questionnaires).

4.1- Lighting Design Education's Position Toward Design Pedagogical Models

The researcher has only found a few resources about lighting design education:

- Milham specified that "lighting education is not in a good place… fewer schools have faculty that are qualified to teach lighting" (Rosen, 2014, p. 21). Thus, one of the drawbacks of current lighting design education is the lack of specialized lighting design faculty.
- Design education often introduces lighting deductively as a theory in only one or a few classes, after which lighting is then applied to design problems. Thus, designers perceive it as an additive element that is incorporated late in the design process (Gustina, 2011; Poldma, 2009, p. 20; Theodorson, 2006).
- Brown (2004) asserted that there is a gap between technical and qualitative lighting knowledge in interior design education. She thinks that students deal with lighting design in terms of a fixture placement rather than a visual influencer. She believes that such understanding is a result of a systematic educational system. Brown proposes integrating light in design studios and exploring light effects and behavior through physical models, computer programs, and real-scale mockups.
- Gustina (2011) agrees with Brown that interior design students focus on technical lighting knowledge rather than light's behavior and effects on

human factors. He thinks that design schools focus on design principles but forget to integrate lighting design in the same scope and depth. He feels that a lack of facilities, like light labs, limits the incorporation of lighting knowledge in design education.

- Poldma (2009) believes that the separation between light and color courses, as well as between light theories and light practical/experiential exercises. is a true weakness of design schools. She encourages an interdisciplinary approach to light design education, through which light is tied to other related design subjects and where light theories are linked to practical projects and exercises with an emphasis on reflective thinking.

The deductive approach to lighting design education and the aforementioned drawbacks suggest that lighting design education currently falls under a teacher-centered pedagogical model. Educators passively deliver lighting design knowledge from textbooks in a lecture format. They teach lighting technical and theoretical knowledge without linking it to its qualitative aspects and practical exercises. The teacher-centered approach depends on teachers' feedback and critiques, offering students problem-based learning, but leaving little room for students' critical thinking and experiential learning.

The proposed approaches by Brown, Gustina, and Poldma encourage the use of constructivism, problem-based learning, and experiential pedagogical theories in lighting design education. They suggest linking lighting theory to its practical knowledge through hands-on activities, observations, multidisciplinary experiences, and different analysis tools like computing software and reflective thinking. They propose relating lighting to other design components and classes like color and design studios to better prepare students for their professional careers. They also suggest integrating qualitative and quantitative knowledge of lighting.

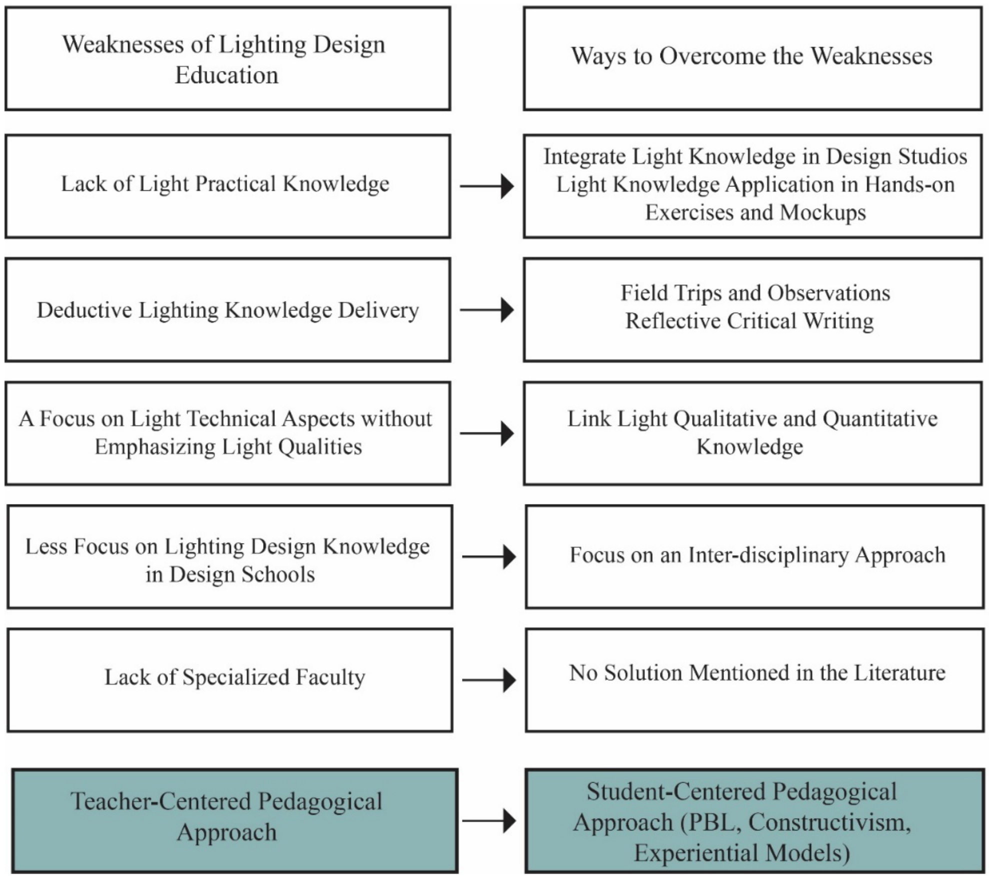


Figure 4-1. Ways to Overcome the Weaknesses of Lighting Design Education

4.1.1- Relevant Pedagogical Theories to the Proposed Framework

Pedagogical theories are important in order to position the proposed framework within a theoretical structure. The most relevant theories to architecture, design, and lighting education are constructivism, problem-based learning (PBL), and experiential learning models. The PBL method guides students to solve complex design problems in a self-learning studio environment (Ulger, 2018). Studio learning encourages students to apply design theoretical knowledge in practical real-world projects using problem-solving and critical thinking skills. The constructivist and experiential learning models help students construct their knowledge, link design theoretical knowledge to practical exercises, and encourage the incorporation of technology to meet professional demands. The following sections present the interpretation and the implementation possibilities of the three kinds of theories in the proposed framework.

Recommendations from the PBL Pedagogical Model:

- Challenge students with open-ended questions in a participatory approach through group discussions.
- Select design problems that relate to real-world scenarios, the learning objectives, and students' past knowledge and experiences.
- Encourage students to highlight the strengths and weaknesses of their designs, as well as to give critical feedback to their peers (peer-review and self-assessments).
- Integrate technological innovations to develop the participatory learning approach.
- Teachers only guide students to specific knowledge domains for more research in addition to teaching them the needed skills for design.

Recommendations from the Constructivism Pedagogical Model:

- Schon (1987) recommends engaging students in their social, environmental, and political contexts, involving them in the studio experimentation, and providing them with a flexible curriculum that includes different electives.
- Peters (2001) proposes two ways to apply the constructivist approach in art and design education. One way is to give students introductory facts and information about a specific topic and to allow them to explore it freely by looking into different resources and sharing their findings. The second way is to introduce students to the task without any direction and to let them search for relevant knowledge.

- In the constructivist model, educators only direct students to the right domains of knowledge by observing them and asking them questions without dictating the learning process.

Recommendations from the Experiential Pedagogical Model:

- Dewey (1916, 1958) encourages engaging students in their society and culture through real-life experiences. He praises individuality, group work, hands-on activities, a dynamic and flexible curriculum, and a multidisciplinary approach to education. He encourages linking the theoretical and practical knowledge to each student's experiences to internalize the gained knowledge.
- Schon (1987) recommends that students experiment in labs or studios and reflect on their personal experiences.
- Kolb encourages students to translate their experiences, observations, and reflections into action. Kolb's experiential learning cycle follows four steps: specific experiences, personal reflections and observations, concept generation through analysis and thinking, and finally the application of the learned knowledge in active experimentation (Demirbaş & Demirkan, 2003, p. 440; Seaman et al., 2017).

Additionally, Dewey (1962) provides several steps to implement the experiential learning model and prepare students for their professional careers. The steps are as follows:

- First, teachers observe their students.
- Once the teachers understand students' psychological needs, they then provide them with theories, projects, and problems that interest them.
- The third step is to link the theoretical knowledge to the practical knowledge.

- The fourth step is to allow students to teach something after they acquire the skills they need from step three. In this step, teachers give students maximum liberty to choose a subject and ways to deliver its knowledge.
- The fifth step is to encourage students to criticize their work by highlighting its strengths and weaknesses, in order to develop their critical thinking.

4.1.1.1-The Influence of the Design Pedagogical Theories on the Proposed Framework:

The following steps describe the influence of constructivism, PBL, and experiential learning theories on the proposed framework:

- To begin lighting design knowledge delivery, educators are invited to first understand their students' past knowledge and experiences through a set of either questions or observations while they are conducting a warm-up project.
- Educators are encouraged to facilitate and participate in their students' learning journey and group discussions using open-ended questions and directing them to the right knowledge domains when needed.
- Students are invited to self-assess their projects, their colleagues' projects, and their teachers' performance through critical pin-ups, teamwork, rubrics where students write down their projects' strengths and weaknesses, and teachers' evaluation forms.
- Educators are advised to dedicate class time for students to present new lighting design knowledge that interests them. Such an approach helps students to grow as self-learners in a participatory environment.

- The integration of technology is fundamental to encourage students' self-learning, providing them with various presentation tools that meet their needs and preparing them for future professional demands.
- Social, cultural, and environmental experiences through field trips and community projects are endorsed to help students internalize the obtained knowledge using observations and reflections.
- Hands-on activities (in labs or studios) are important for the application of theoretical lighting knowledge. Educators can present lighting design projects in the lighting class, provide a design studio that is focused on lighting, or encourage students to work on their studio projects' lighting components in the lighting class. It is important to carefully select the lighting projects and exercises to meet the learning objectives, students' past experiences, and professional demands.
- Finally, the literature recommends a flexible design curriculum with different electives, including lighting design electives, to meet students' needs and interests, as well as to create a multidisciplinary learning environment.

4.2- The Influence of the Curricula Development Literature on the Proposed Framework and the Research Methods

The curricula development literature recommends ways to improve students' cognitive thinking and understanding of lighting design (see Chapter II, section 2.4.4). The Bauhaus pedagogy shows the importance of an explorative foundational year and the integration of theory and workshops. Students are required to take a theory course about a subject matter before they join the corresponding workshop (Alqabandy, 2012, p. 27). The Bauhaus constructivist approach immerses students into their social and practical world and provides interdisciplinary subjects like music and industrial design to broaden students' design thinking. This model influenced the framework in two areas. One is the multidisciplinary first year with experimentations in different design components such as light, shade, and shadow. The other component is the importance of theory comprehension before engaging in practical workshops. Students first learn light theory and fundamentals and then apply them in practical exercises and projects.

Other literature that influenced the proposed framework included the Princeton report, the Boyer report, the Carnegie Foundation for the Advancement of Teaching and the Association of Collegiate Schools of Architecture (ACSA) recommendations, the National Research Council (NRC) recommendations, the National Architectural Accrediting Board (NAAB) standards, and the Council for Interior Design Accreditation (CIDA) standards. These sources endorse the same recommendations mentioned previously, with a focus on using different teaching methods, architectural philosophies, and diverse faculty to meet students' needs. They recommend a studio with regular seminars offered by different educators. They emphasize the importance of teaching students a variety of skills and competencies, such as analytical skills, critical thinking, design thinking, decision-making, technical skills, computational skills, practical knowledge, communication skills, and teamwork to prepare them for their professional careers and to immerse them into their society and community.

In response, the proposed framework focuses on providing a flexible curriculum with a sequence of lighting design knowledge that is integrated into several classes, including a design studio, to enhance students' understanding of lighting design by combining theoretical lighting knowledge with practical exercises and projects. The framework also emphasizes the integration of different design thinking tools like digital light simulation tools, manual design tools, and diverse knowledge delivery methods (including theory, exercises, field trips, webinars, teamwork activities, and community projects) to promote students' critical thinking and decision-making processes.

The previous recommendations informed the interview questions as well. The researcher formed questions that focused on topics of how to introduce lighting design knowledge in a sequence, how to integrate light theory with hands-on activities, and how to deliver lighting design knowledge to enhance students' understanding of lighting design. The questions also sought the best ways of integrating digital light simulation tools in design education to aid students' decision-making process.

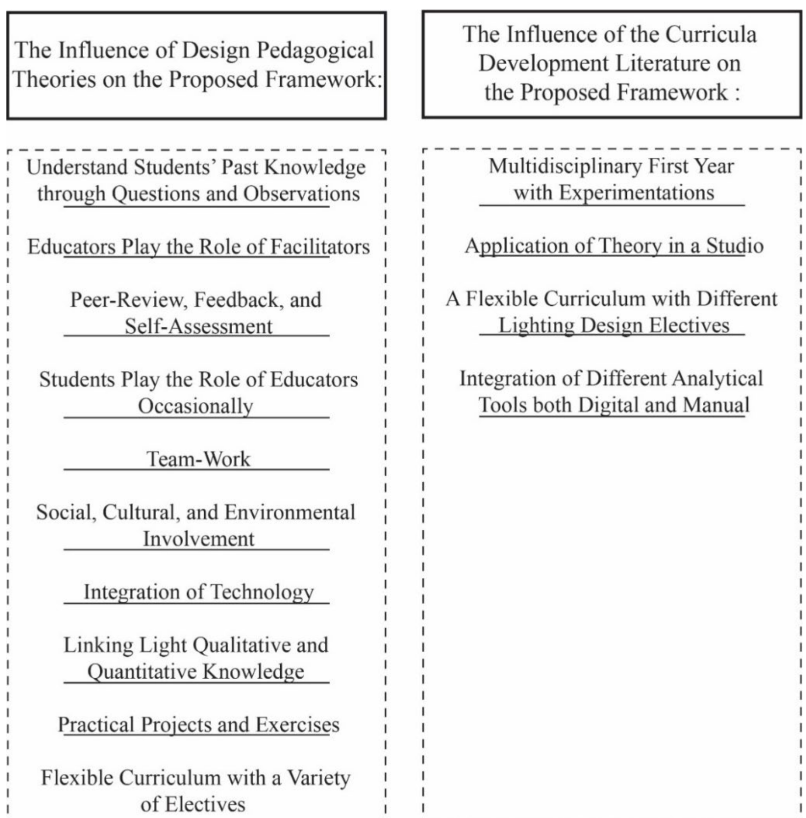


Figure 4-2. The Influence of Design Pedagogical Theories and the Curricula Development Literature on the Proposed Framework

4.3- The Influence of the Cognitive Design Literature on the Proposed Framework and Methods:

The proposed framework supports two domains of cognitive activities. The first domain is enhancing students' understanding of lighting design through a knowledge delivery sequence and the use of different teaching methods. The second domain is supporting design decision-making via the integration of diverse design thinking and analysis tools such as digital simulation tools, physical exercises, analog tools, research tools, and cognitive questions.

The literature implies that the cognitive process incorporates an understanding of knowledge domains (theory), the synthesis of knowledge domains for future application (application), and an evaluation of the analysis to meet certain objectives (decision-making). These three cognitive processes influenced the proposed framework's structure. The framework has three main categories. The first category is the theoretical/tacit lighting design knowledge that students need to know and that the researcher needed to understand before applying the framework and making decisions. This category includes topics such as fundamental knowledge about light and lighting design, current pedagogical approaches to lighting design education, the current sequence of lighting design education, the current relationship of light education to other classes and studios, challenges of integrating lighting design knowledge and tools, weaknesses of lighting design education, culturally-related foundational knowledge, the knowledge that students need before using digital light simulation tools, and how students currently think about lighting in the design process.

The second category is the procedural knowledge that educators need to enhance lighting design education and students' understanding of lighting. This category focuses on the application process needed to make the change. It includes topics about lighting design knowledge delivery sequencing and methods. For example, how to incorporate light knowledge and digital light simulation tools in a sequence to support certain pedagogical theories and intentions of each year, and how to advance lighting design knowledge delivery methods. The third category is the explicit knowledge that tackles lighting design decision-making tools. This category includes topics such as the types of questions that trigger students' cognitive thinking, the intent of the use of different lighting design analysis tools, the positives and negatives of light simulation tools (both digital and physical), how simulation tools help students understand light and aid its design process, and how to advance current digital light simulation tools to further support students' design decision making.

The framework first establishes a theoretical argument about current lighting design education based on theoretical and contextual lighting knowledge. It then proposes a sequence to deliver lighting design knowledge in categories of foundational, intermediate, and advanced knowledge with the integration of topics related to Kuwait's culture. It also introduces a sequence for integrating digital light simulation tools and typology of cognitive questions. For each phase, the framework proposes lighting design delivery methods and activities. It explains how different lighting design tools help students in lighting design decision-making and also presents recommendations to advance digital light simulation tools for educational use. Lastly, the framework presents a studio scenario that follows certain pedagogical theories, utilizes the cognitive questions, and links lighting design theoretical knowledge to practical exercises using several design analysis tools.

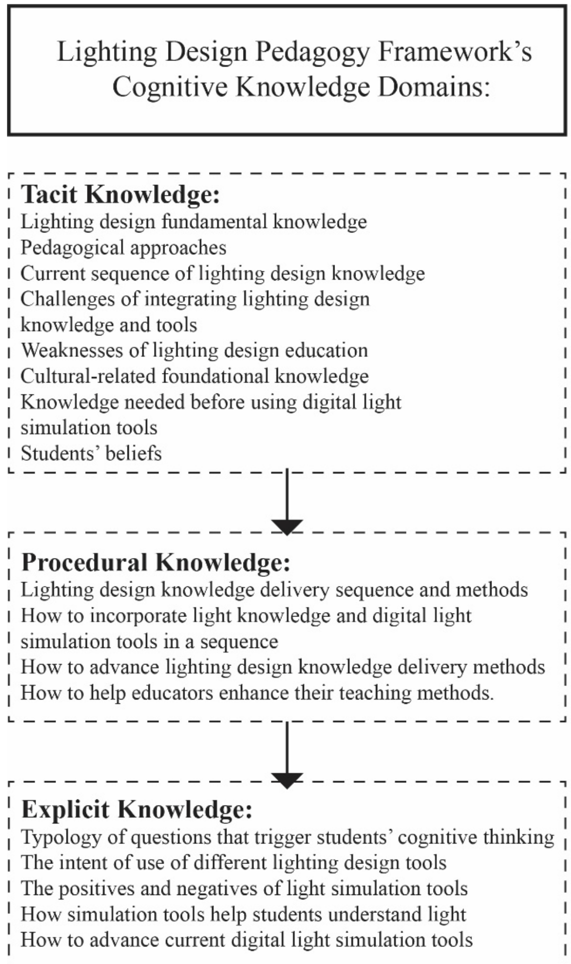


Figure 4-3. The Cognitive Knowledge Domains of Lighting Design Pedagogy

4.3.1- Cognitive Questions

The use of questions in design ignites students' cognitive thinking and guides their decision-making process. The researcher sorted the potential design questions into groups based on Eris's (2003) categories, the interpretation of the cognitive design process literature, and her personal experience. The established categories were as follows:

- Tacit questions that seek designers' or students' past lighting design knowledge, skills, or experiences. For example: Is the design problem relevant to students' and designers' past knowledge? What skills and knowledge do designers need before starting the lighting design process?
- Conceptual or generative questions that look for overall ideas and design goals. For example: What is the lighting design focus area? What is the overall theme?
- Contextual/cultural questions that embed lighting design in its surrounding environment, society, culture, and community. For example: What lighting design features represent a certain culture or community?
- Descriptive questions that search for facts and the nature of things. For example: What are the color components of white light?
- Qualitative questions focus on the phenomenological and poetical aspects of light, such as how light affects mood, human behavior, and feelings. For example: What is the desired mood? How can we create a relaxed environment through light manipulation?
- Explorative questions that seek relationships between different design components. For example: What is the relationship of the building's openings to the sun's orientation? What is the relationship between a fixture design and light distribution?
- Functional or application questions that try to find task-oriented answers, practicality, and the intent of the use of different lighting tools. For example: How can we place light fixtures within an existing structural, mechanical, and

building systems? What is the intent of using light controls? How can we distribute light to minimize shadows on a critical task?

- Procedural questions that target steps or processes. For example: On what lighting design aspects should students focus in each design phase? What design tools and activities are the most beneficial in each lighting design phase to convey and deliver designers' ideas and objectives?
- Explicit questions that look for specifications about a certain design component or object. For example: What tools are needed to perform certain light design objectives or tasks?
- Reasoning or analysis questions that focus on explanations and causes. For example: What materials absorb light? What surfaces reflect light the most? What causes glare?
- Quantitative questions that target magnitudes and quantities. For example, How many fixtures or how much light does a designer need for a specific function or task? How can we meet energy codes and building standards?
- Evaluative questions that seek different design alternatives to solve a lighting design problem. For example: Which lighting design alternative creates the most sustainable design? Which lighting design alternative maximizes the use of daylight at different times of the day?
- Affirmative questions that pursue validation of results concerning the design objectives. For example: Does the chosen lighting design alternative consume the least energy? Does the chosen lighting design alternative create the desired energetic mood?

- Delegation/executional questions that seek teamwork participation. For example: Which design task does the designer need to delegate to other team members or other people like contractors? What information is needed for other people to perform the delegated task?

In sum, each question directs designers' attention to specific aspects of light in the lighting design process to solve a lighting design problem, to help in lighting design decision-making, or to meet a lighting design objective. The following diagram relates the questions to the design process phases.

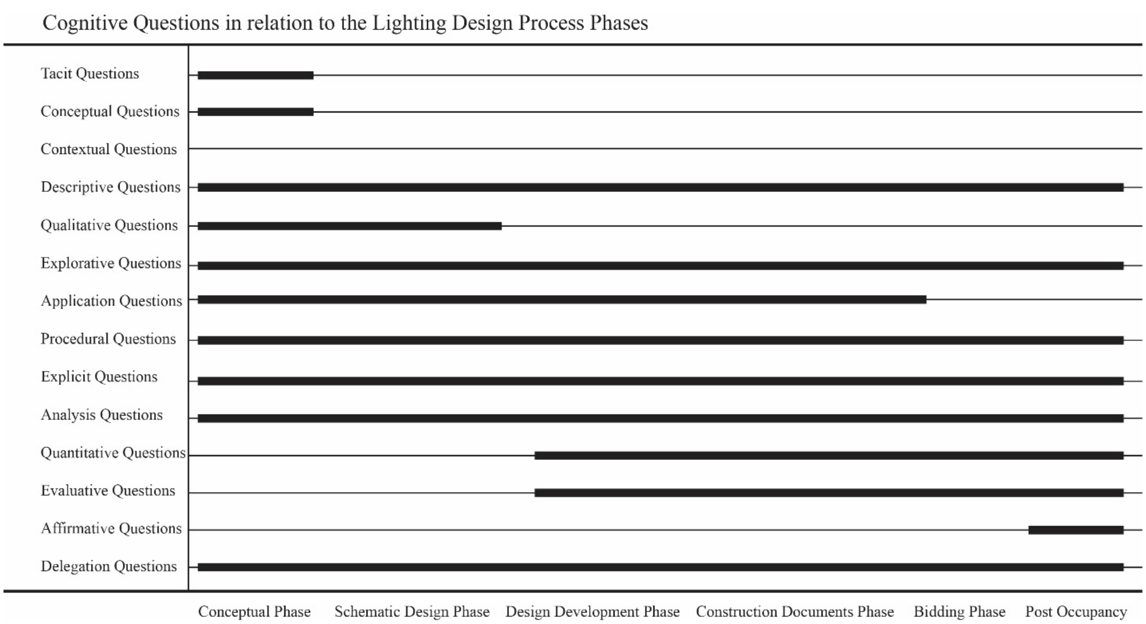


Figure 4-4. The Cognitive Questions' Position in the Design Process

4.4- Lighting Design Topics from the Literature:

The researcher obtained lighting design topics from six lighting design textbooks and eight developed lighting design programs' curricula from the United States (mentioned in Chapter II, section 2.4.4.3). The six textbooks were: *Designing a Quality Lighting Environment* (Winchip, 2005), *Architectural Lighting* (Egan & Olgyay, 2002), *The Architecture of Light* (Russel, 2012), *Heating, Cooling, Lighting: Sustainable Design*

Methods for Architects (Lechner, 2015), *Designing With Light: The Art, Science, and Practice of Architectural Lighting Design* (Livingston, 2014), and *Architecture for Light* (Mercier, 2014).

Table 4-1 summarizes and categorizes the topics into common lighting subjects among the six textbooks, topics mentioned in only a few books, and extra topics from the developed lighting design programs. The researcher presented these topics to lighting design educators to sort them into foundational, intermediate, advanced, and elective categories, with some additional subjects that they thought were important. The topics and feedback from both the literature and the educators are integrated at different stages in the proposed framework (discussed in detail in the following chapters).

Lighting Design Knowledge that Was Mentioned in most of the Books
Light Definition and Purpose (what is light + importance of light)
Physics of Light + Light Behavior with Surfaces
Light Perception (how humans perceive light)
Daylight Integration and Influence (Daylight Strategies)
Layers of Lighting Design (General, Task, Accent, Decorative Lighting)
Lighting Design Tactics (Example: How to Create Certain Moods)
Electrical Light Sources
Light Color
Light Distribution, Texture, and Optical Control
Brightness and Glare
Light Measurements and Calculations
Luminaires Types and Operation
Energy and the Environment
Human Factors (Light Effects on Human Health, Vision, Emotions, Perception, and Behavior)
Light Applications and Case Studies (Activity Needs) + Lighting Critical Issues (Example: Designing for the Elderly)
Light to Enhance Architecture and Interior Spaces (Poetry of Light)
Lighting Design Process, tools, and Deliverables
Lighting Design Knowledge that Was Mentioned by some Books
History of Light
General Knowledge about Electricity
Color Theory
Outdoor Lighting
Safety and Security (Wayfinding and Communication)
Light Art and inspirational mediums (Example: Installations and photography)
Lighting Design Profession (professional Practice)
Design Thinking (as basis before introducing lighting design)
Additional Lighting Design Knowledge from Lighting Design Programs in the United States
Fixture Design
Lighting Design Digital Computation and technologies (Digital Rendering, Representation, and Analysis)
Design Studio Focused on Lighting Design
Theatrical Lighting
Light Theory and Philosophy (Placemaking, Critical Regionalism, Steven Hall, James Turrell, Pallasmaa)

Table 4-1. Lighting Design Topics from the Literature

4.5 - The Influence of the Digital Simulation Tools' Literature on the Proposed Framework

The interpretation of the literature supports the integration of digital light simulation tools in design education to meet professional, social, environmental, and cultural demands. Light simulation tools help in building performance analysis, especially lighting design analysis, to adhere to sustainability and energy codes.

In addition to other digital tools, BIM links design theory to practical knowledge. It ties abstract design concepts to detailed materials and structures that are required to turn the design into a reality. BIM also encourages students to think about design details, like lighting, from early design stages to help them in design decision-making and in creating high-performance lighting environments. Lee's (2012) findings support the integration of BIM-compatible light simulation plug-ins in design education.

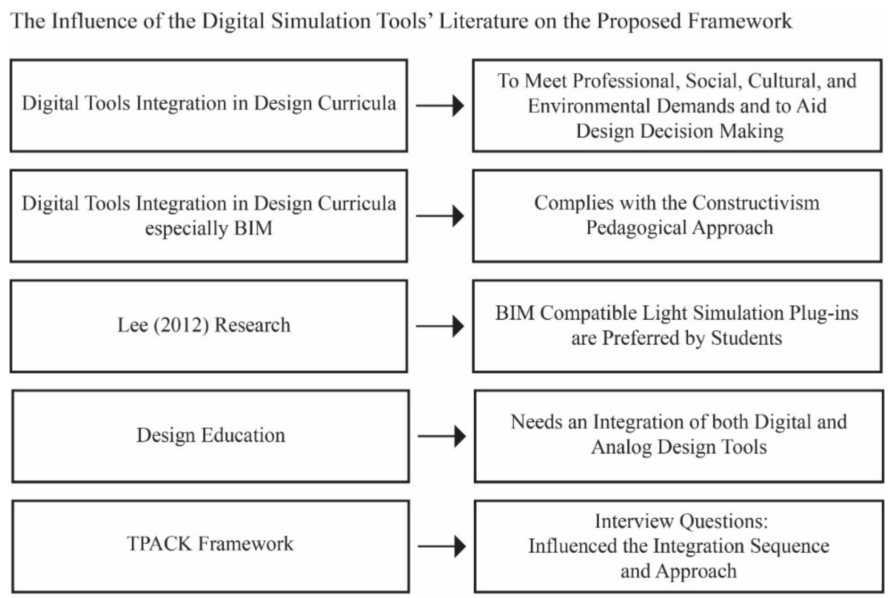


Figure 4-5. The Influence of the Digital Simulation Tools Literature on the Proposed Framework

The TPACK framework, in contrast, gives suggestions to ease the integration of digital tools in education, as discussed in Chapter II. It recommends understanding the intent of using the tool, the challenges and opportunities that may occur, students' and educators' past knowledge, and the available educational timeframe to introduce the tool. These recommendations informed some of the research instrument's questions (shown in Figure 4-6) and in turn informed the proposed framework integration process.

TPACK Influence on the Interview Questions

Intent of using the tool:
Describe the tools that you think students need in the lighting process. What do you think is the intent of using the tools?
What tools help students in lighting design decision making?

Challenges:
Can you describe the strengths and weaknesses of the current lighting design education at your university?
Tell me about your thoughts on the negative implications of integrating digital lighting simulation tools?

Opportunities:
Can you describe when light is currently introduced as a design subject in your education structure/curricula?
Tell me about the unique features of your university's lighting design program?
Tell me about your thoughts on the positive implications of integrating digital lighting simulation tools?

Students' and educators' past knowledge:
Educators' demographic questions
Can you describe the prior theoretical knowledge that students need to know before using a digital light simulation tool?
What are students' perspectives towards digital light simulation tools?

Time frame:
Can you tell me about the key educational intentions and outcomes of each design year/level?
Can you describe the best ways to introduce simulation tools in lighting design education?
How do you think digital light simulation tools relate to the key educational intentions of each design year?

Figure 4-6. The Influence of TPACK on the Proposed Framework

The literature shows that both analog and digital tools are essential in design education and process to overcome each tool's weaknesses. The same applies to light analysis. Light renderings can be deceptive; they are never the same as experiencing light in real life. They are also weak in depicting daylight's temporal effects. Physical models have limitations too. They consume a lot of money and time, and physical study models are inaccurate in depicting actual light behavior and performance due to the difference in scale, materials, and light fixtures' intensities. Each tool, however, has a positive contribution to visualizing light performance. Digital tools are useful for approximating electrical lights' behavior with surfaces and volumes. They are more effective in analyzing and calculating light intensity, distribution, and behavior with different materials, surfaces, textures, and colors, whereas physical models are useful for testing daylight factors and temporal effects. Thus, the proposed framework required the integration of both digital and analog light analysis and presentation tools.

4.6- Summary of the Logical Argument's Contribution to the Cognitive Knowledge Domains

The following diagram sums the logical argument's contribution to the framework's tacit, procedural, and explicit knowledge domains.

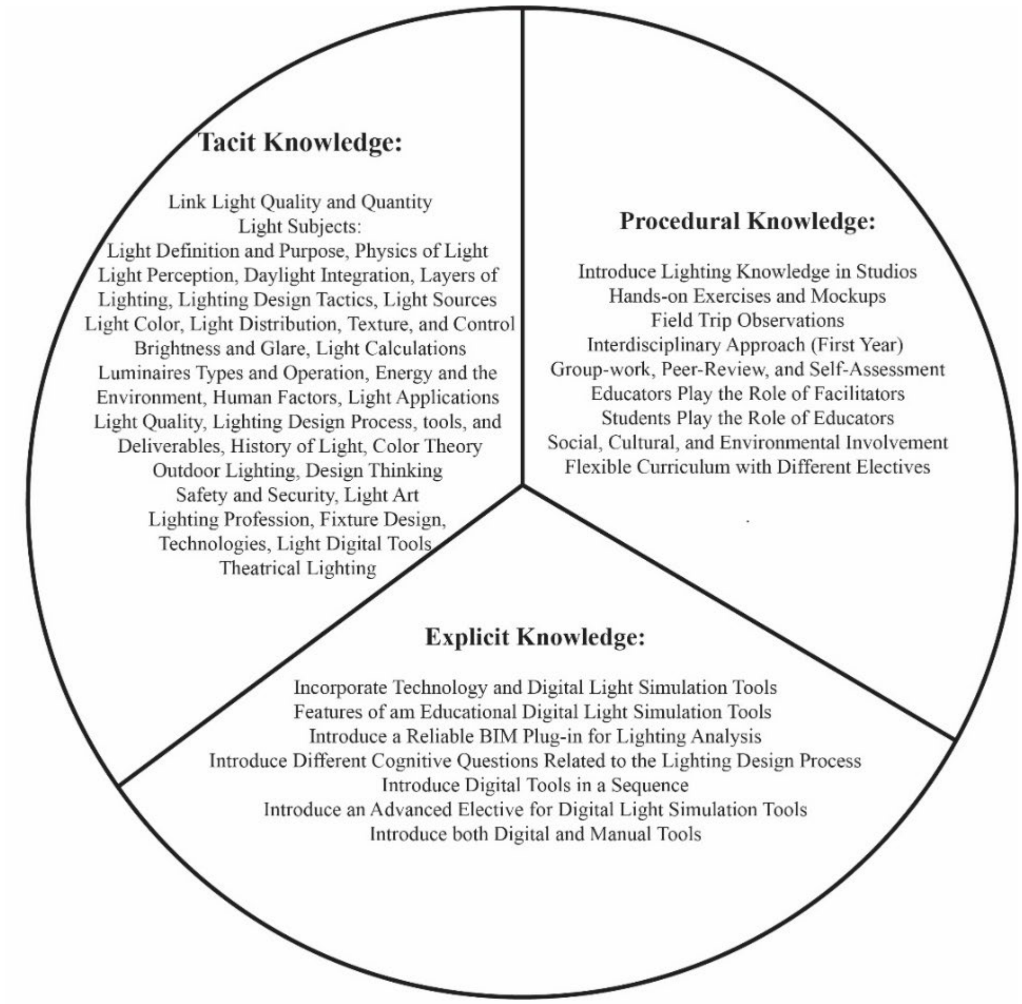


Figure 4-7. The Logical Argument Summary

Chapter V

5- Kuwait As-Is Model

The researcher developed the As-Is Model, the current lighting design pedagogical model at Kuwait University, by analyzing documents (curricula, lighting-class syllabi, and exercise sheets) and interviewing five current lighting design educators from Kuwait. The As-Is model presents current lighting design knowledge, topics, structure, sequence, pedagogical approaches, teaching methods, light analysis and cognitive tools, and cultural topics at Kuwait University.

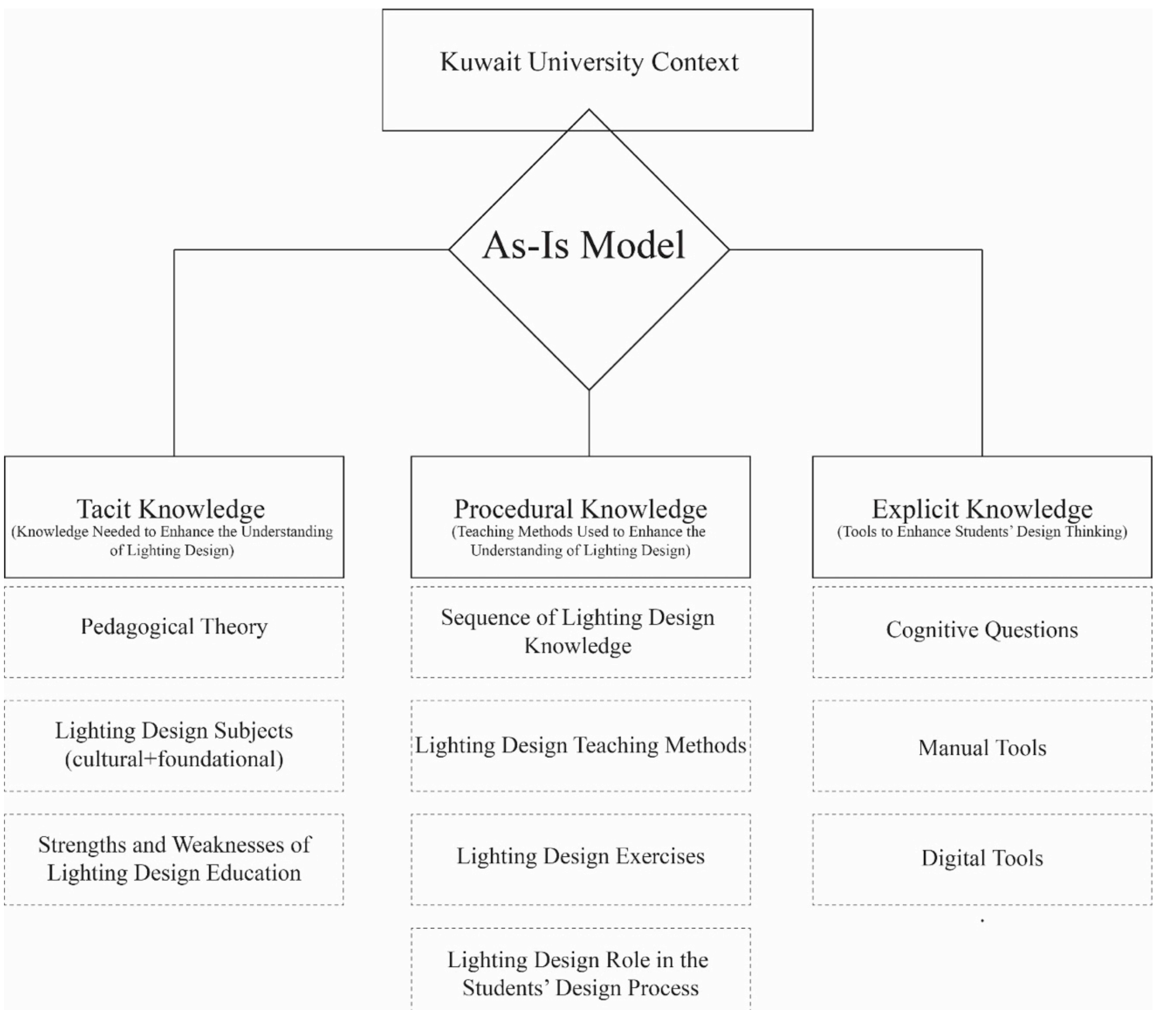


Figure 5-1. Kuwait University's As-Is Model

5.1- Kuwait University Context

Kuwait University's College of Architecture hosts two departments: the Architecture Department and the Interiors and Visual Communication Department. Architecture is a 5-year program whereas interior architecture is a 4-year program. The two departments share some faculty, yet each educator has his/her own unique teaching methods. This chapter presents the results from the interviews with lighting design educators from both departments with some additional findings from the document analysis. Each section of the chapter presents a theme with two results: one from the interviews and the other from the documents. However, some sections present findings that were only found in the interview or documents analysis.

5.2- Kuwait's Interviews

The objective of the interviews with faculty from Kuwait was to understand cultural aspects of lighting design and the educational context at Kuwait University. The interviews targeted Kuwait's cultural context and topics related to lighting, current lighting design sequence, the design pedagogical philosophy, the intentions of each design year, the methods used to deliver lighting design knowledge, perceptions of lighting design, and challenges associated with the integration of lighting design knowledge and digital light simulation tools.

5.2.2- Participants' Demographic Information

Participant A has a Bachelor's degree in Architectural Engineering, a Master's degree in City and Regional Planning, and a Ph.D. in Sustainable Architecture. He/she teaches at the Architecture Department and has 20 years of experience in teaching lighting. He/she teaches Environmental Control Systems in Buildings, Advanced

Environmental Control Systems in Buildings at the Master's level, Solar Energy Applications in Buildings as an elective class, and Indigenous Architecture.

Participant B has a Bachelor's degree in Architecture, a Master's degree in Interior Architecture, and a Ph.D. in Interior Architecture with a focus on environmental psychology. He/she teaches at the Interior Architecture Department and as 1 year of experience in teaching lighting. In addition to lighting design, he/she teaches Introduction to Design Studio, Design Theory, Interior Architecture Studio II, Sustainable Interiors, Building Systems I, and Interior Design Studio IV. He/she teaches lighting components in all his/her classes.

Participant C has a Bachelor of Fine Arts in Interior Design, a Master of Science in Design, and a Ph.D. in Architecture with a focus on lighting design. He/she teaches interior design at the Public Authority of Applied Education and Training (PAEET) and a 2-day lighting design workshop at the Kayan Office. Participant C keeps up to date with lighting technologies, control systems, and applications by attending conferences and exhibitions regularly.

Participant D teaches at the Interior Architecture and the Architecture Departments. He/she has a Bachelor's degree in Architecture, a Master of Fine Arts in Interior Architecture, and a Ph.D. in Design Construction and Urban Planning. He/she has 5 years of experience in teaching lighting. He/she teaches Sustainable Interiors and Building and Environmental Systems II in the Interior Architecture department.

Participant E teaches at the Interior Architecture Department. He/she has a Bachelor's degree in Architecture, a Master of Science in Interior Architecture, and a Ph.D. in Architecture History and Theory. He/she has 4 years of lighting pedagogy experience, and teaches the Building Systems class, Design Theory, Design Studio, and Computer Applications. His/her academic specialty is design pedagogy and the use of information technology in design education.

5.3 - Kuwait's Lighting Design Cultural Context

Kuwait is a small Muslim country that is located in a very hot and arid climate with an abundance of sunlight all year long. In Kuwait's culture specifically and Islamic societies in general, light is closely tied to religious acts. It imposes a positive feeling among Muslims. For example, during Ramadan, people fast from sunrise to sunset and pray five times a day based on the sun's location in the sky. Even mosques, places of worship, are designed with attention to light. Light is also a festive element in Islam. Muslims use lanterns and other electrical light sources in their Islamic Festivals like Ramadan festivals, as Participant B indicated:

> In our society, light represents faith and God … It's always tied to faith, purity, and hope. It has a positive psychological impact, like tying religious aspects such as the method of fasting in Ramadan … how fasting happens between sunrise and sunset … Also, there are the festive aspects, especially in Ramadan or cultural celebrations, you know festive lights and lanterns.

Despite the importance of light in Islamic cultures, Participant A thinks that Kuwaiti society, in general, pays little attention, if any, to daylight strategies or any sustainability measures in buildings. The public in Kuwait focuses more on cost, building aesthetics, and the size of their houses, rather than lighting quality, as he/she explains:

> The general public, usually, they care about the cost. They care about how their house should look, how beautiful it is, and how many rooms they have, but

> lighting is like a second thought. When they finish everything, then they think about lighting.

Nevertheless, Participant A mentioned that with LEED awareness, more professionals are considering sustainability measures in their projects, including lighting design. Participant D thinks that there is an emerging interest in lighting design nowadays:

> There's an improvement in the interest of lighting design and the quality of light, and how it affects the mood and the quality of the space, compared to how it was just a functional purpose, providing enough lights and that's it.

Unfortunately, even people who realize the importance of lighting design have little knowledge to apply it in the market. Participant C feels that architecture and interior architecture graduates focus more on lighting's quantities and aesthetics rather than its qualities and effects on human behavior:

> What I experienced, for example, interior designers or architects, they know, a little bit of, "Oh, we heard about Kelvin. We heard about CRI," but they don't know the difference. They don't know when this is important … Kuwait, or in the Middle East, they are more focused on the quantity of light, which is like lumens and watts … So, they don't understand the quality of light.

In response, the public in Kuwait needs more education about the importance of lighting design, as Participant E indicated, "[light is] something that we need to keep educating people about, especially its importance." Participant D concurred with Participant E that Kuwait as a country needs development in lighting design education: "educate the public before you bring people into the market."

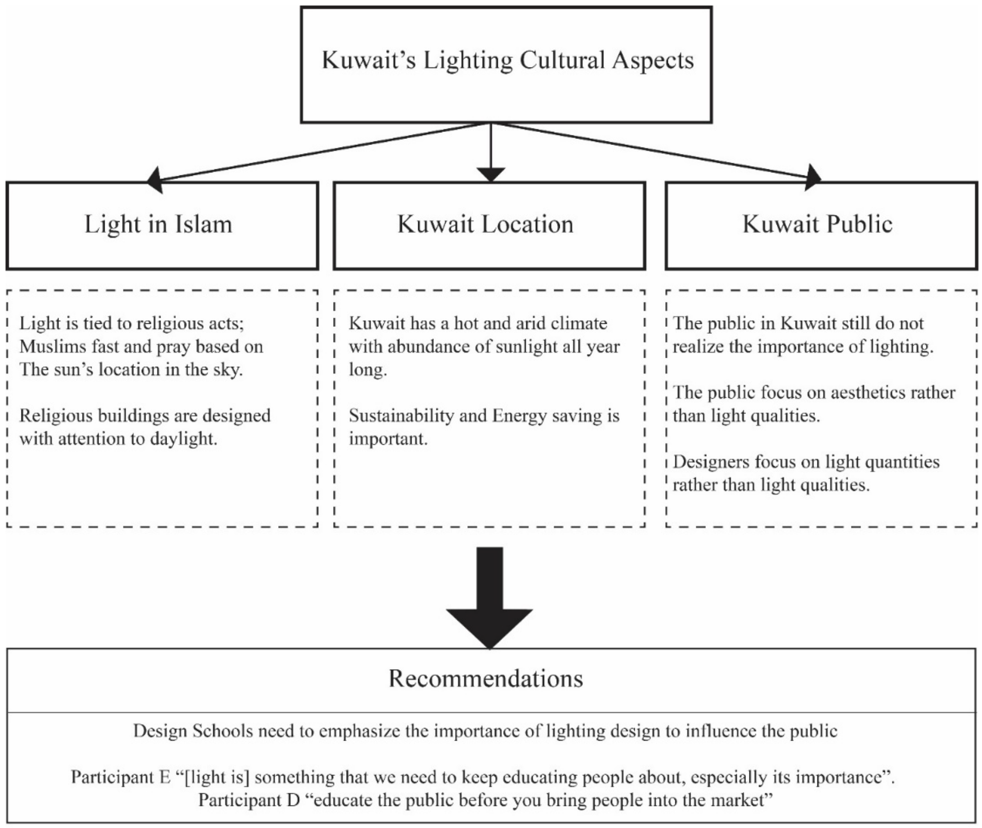


Figure 5-2. Kuwait's Lighting Cultural Context

5.4- Kuwait University's Pedagogical Philosophy

The document analysis indicates that Kuwait University's Architecture Department follows a student-centric model; however, the interview results imply that it follows the teacher-centric model. The Interior Architecture Department, in contrast, combines both the teacher-centric and the student-centric approaches.

5.4.1- Kuwait University's Pedagogical Philosophy from the Documents

The Architecture department's mission and written objectives indicate that the program follows the constructivism and PBL pedagogical models. The program encourages critical thinking, methodological analysis, problem-solving, decision-making skills, creative thinking, awareness of the impact of design on society, and the integration of new technologies and techniques (Al-Nakib, 2014).

The Interior Architecture program, in contrast, follows the Bauhaus educational model and the United States design education. The program integrates complex design projects in its courses to enhance students' visualization and problem-solving skills. The courses offer "technical, social, psychological, cultural, environmental, economic, spiritual, and physical factors" (KU, 2018b) to encourage creative thinking and exploration in different fields. Thus, just like the architecture department, the interior architecture program follows constructivism and PBL theories.

5.4.2- Kuwait University's Pedagogical Philosophy Based on Interview Responses

The Architecture department at Kuwait University follows a teacher-centered pedagogical approach. In the department, educators decide what students need to learn based on NAAB criteria and professional demands, as Participant A explained:

> We plan the syllabus based on NAAB … We don't follow the students' needs or wishes. No, of course not. The students should follow the curriculum …we look at the market, see what the market needs … We do listen to the professionals.

Lighting design education follows the same pedagogical philosophy; lighting design theoretical knowledge is not linked to the design studio due to time constraints and a lack of communication between educators. Participant D indicated: "the architecture department has a theme for every studio that is not particularly connected to the theory class or the technical class."

The Interior Architecture department combines both teacher-centered and student-centered pedagogical approaches. Educators follow the guidance of accreditation agencies to set the curriculum, focusing on students' experiential and collaborative learning. Participant D stated: "the syllabus… is set by the curriculum and the learning objectives, and it's based highly on the academic accreditation organization." Participant B said that "they focus on the students and their experiences, rather than what the teacher wants to enforce."

Teachers in the department link theoretical knowledge to real-life projects and practical exercises. Participant D stated: "we're not heavily relied on a theory-base. We have some theories, but it is based on activities and exercises through the studio work."

In conclusion and based on the NVivo software word counts, the College of Architecture at Kuwait University follows accreditation agencies to structure the curriculum and tries to link theoretical knowledge to practical exercises.

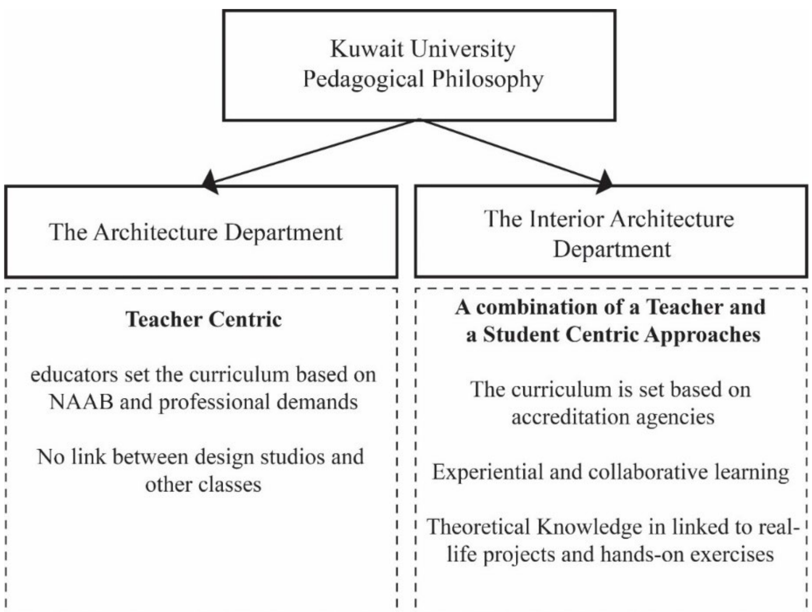


Figure 5-2. Kuwait University's Pedagogical Philosophy

5.5- Intentions of each Design Year at Kuwait University Based on Interview Responses

Each department at the College of Architecture has its yearly intentions and goals. Until now, the two departments have been two separate entities; thus, they do not share the same intentions, objectives, or pedagogical philosophy.

5.5.1- The Department of Architecture Yearly Design Intentions

The Architecture department follows a design manual that specifies the intentions of each design year. The first year focuses on form-making; the second year emphasizes function; the third year targets building systems, structures, and other technical matters; the fourth year covers both environmental and social sustainability; and the last year is a comprehensive year with large scale projects. Participant A explained:

> In the Department of Architecture … in general, in the first year, we concentrate on the form. In the second year, we concentrate on the function. In the third year, we concentrate on the technical aspects; structure, systems, [and] lighting. In the fourth year, we focus on sustainability. The first part, technical sustainability, environmental sustainability, and the other one is social sustainability. Year five, an integration in urban design level.

5.5.2- The Department of Interior Architecture Yearly Design Intentions

The first year of the Interior Architecture department focuses on general aspects of design elements and principles that students apply in small projects. The second year focuses on residential and commercial interior design projects and computer-aided technology. It also engages students in design details, materials, finishes, and design styles. The third year focuses on sustainability and cultural aspects of interior design. It also introduces students to form, function, computer visualization, and building systems. In the fourth year, students combine all the knowledge they gain in a comprehensive design problem with design details and cultural, political, technical, and structural factors, as Participant B explained:

Freshman year, students must be exposed to the world of art and design in general … teaching them design principles, theory, and elements … For the sophomore year … We started from residential and then commercial and try to solve problems. We introduce computer-aided design … with an emphasis on detailing and finishes. So, they delve into the history of interior architecture, and they come up with different styles … Then, in the third year … issues of environmental sustainability and cultural recognitions ... form, function, [and] building systems…the fourth year … students must fully express their knowledge and skill of interior architecture by postulating a conceptually mature design problem.

Yearly Design Intentions of the Architecture and Interior Architecture Departments

Year	The Architecture Department	The Interior Architecture Department
1	Form Making	Design elements and principles
2	Functions	Residential, commercial, and computer technology
3	Technical stuff: building systems and structures	Sustainability, building systems, computer visualization, form, and function
4	Sustainability	Comprehensive year
5	Comprehensive year	

Table 5-1. The Yearly Design Intentions at Kuwait University

5.6- Current Lighting Design Knowledge Sequence at Kuwait University

The two departments offer different degrees that vary in length and yearly intentions; thus, the sequence of lighting design knowledge is different in each curriculum.

5.6.1- The Current Sequence of Lighting Design Knowledge at the Department of Architecture from the Documents

Lighting design is addressed in the Design of the Luminous and Sonic Environment, Building Systems I, Solar Energy in Buildings, and Design of the Luminous Environment courses in the Architecture Department. The first two courses are mandatory whereas the latter two are electives. Based on the recommended study plan, students are encouraged to take the Design of the Luminous and Sonic Environment and Building Systems I classes in the fourth year and the elective courses between the second and the fifth years.

5.6.2- The Current Sequence of Lighting Design Knowledge at the Department of Architecture Based on Interview Responses

The Architecture Department has only one mandatory lighting class, the Design of the Luminous and Sonic Environments, which includes aspects of both lighting and acoustics in the fourth year. As participant A noted, “We have only one required class in light, called the Design of the Luminous and Sonic Environments… We put it in the fourth year because it is technical and advanced.”

In addition to the mandatory class, the Architectural Communication class in the second year incorporates aspects of light, shade, and shadow. The department also hosts an advanced lighting and acoustics class for the master’s level, and a solar energy class that addresses natural light, solar geometry, and thermal energy as an elective in the third year, as Participant A pointed out:

> The class is called Solar Energy Applications in Buildings. This class is elective and introduces the students to solar geometry… we teach them how to locate the

sun, the altitude and the azimuth angle, and how much energy goes through the building. This is in the third year … Architectural Communication Skills … they draw all the shadow of that object, shade, and shadow, that's about it.

5.6.3- The Current Sequence of Lighting Design Knowledge at the Department of Interior Architecture from the Documents

Lighting design knowledge is introduced in two mandatory classes in the Interior Department; Environmental and Building Systems I, and Sustainable Interiors. Based on the study plan, the Environmental and Building Systems I class is recommended in the spring of the second year. The following classes also include some lighting design knowledge:

- Mandatory classes: Studio Spatial Visualization, Introduction to Design Studio, Interior Architecture Studio I, II, III, IV, V, Human factors, Sustainability and the Built Environment, and Interior Architecture Capstone Project.
- Elective Classes: Photography I and Photography II.

5.6.4- The Current Sequence of Lighting Design Knowledge at the Department of Interior Architecture Based on Interview Responses

Light is introduced in the Introduction to Interior Design course in the first year in the Interior Architecture department. This class is an elective for the Architecture department. As Participant D explained: "we introduce lighting from the earliest as the Intro to Interior Design … it's open for non-major even … It's a first-year class." In the second year, light is introduced thoroughly as part of the Building Environmental Systems class and the Human Factors class. In the Human Factors class, students learn about the quality of light and its effects on human behavior, whereas in the Building Environmental Systems course they learn about building systems and technical aspects of light, as Participant D indicated:

> In the second year … Human Factor… which talks about lights, from the quality of light, so human view and the mood that the light can create, and the effect of light on human behavior … Then … the Building and Environmental Systems which focuses on lighting and acoustic, and this is when they get the majority of knowledge related to lighting … Technical knowledge.

Other classes that address aspects of lighting include the Environmental Sustainability class in the third year and the Innovative Interiors in the fourth year. Some design studios, like the second and third-year studios, also introduce lighting design factors.

Participant B indicated that second-year students learn how daylight penetrates interior spaces and basic general knowledge about how to choose lighting fixtures that match different design styles. They also learn how to model both daylight and electric lights using computer software. In the third year, they learn about vernacular and cultural aspects of light. In the final year, students apply detailed lighting solutions in their projects:

> For the sophomore year … one of their problems is daylighting and artificial lighting but at a very basic level. We introduce computer-aided design, so they start modeling and start placing openings and finding out how light filters through spaces … they try to understand how to pick lighting pendants or chandeliers that support or enhance their projects … Third-year, fall … culture, vernacular

architecture… Senior year … the placements of skylights, openings, clerestory, or lighting shelves. Any knowledge they took, they start to apply it into a more complex form.

Sequence of Lighting Design Knowledge at the College of Architecture at Kuwait University

Year	The Architecture Department	The Interior Architecture Department
1		Introduction to Interior Design (some lighting aspects) This is an elective for Architecture students
2	Light, shade, and shadow in the Architectural Communication class	Building Environmental Systems class (technical, digital, fundamental, and general knowledge of light) Human Factors class (qualitative aspects)
3	Solar geometry and energy in the Solar Energy elective class	Environmental Sustainability class (environmental, vernacular, and cultural aspects of light)
4	Mandatory lighting class: Design of the Luminous and Sonic Environments	Innovative Interiors Class Comprehensive application of light
5	Advanced Lighting and Acoustics class for the master level	

Table 5-2. The Sequence of Lighting Design Knowledge at Kuwait University based on the Interviews

5.7- Strengths and Weaknesses of Current Lighting Design Education at Kuwait University

5.7.1- Strengths Derived From the Interview Responses

Kuwait University has the funds to buy advanced lighting tools, create new labs, and develop lighting design education, as Participant D indicated:

> The strength is … we have the funds, to request a lot of advanced tools…. For example, we have requested a solar dome in our new facility…. We also have an environmental lab that would have a lot of lighting aspects.

The faculty of the Interior Architecture department have departmental meetings to communicate and apply the theoretical knowledge in design studios. as Participant B indicated: "we do this in departmental meetings … to make sure everyone is on the same page and we don't repeat stuff in design courses. Strengths are their application of knowledge in lighting design in their projects." The department is also interested in introducing more lighting design electives, hiring lighting design specialists, and funding scholarships to advance lighting design education, as Participant D stated:

> We need to have specialists, faculty that are specialized in lighting design. This is what we're working on through providing scholarships, through Kuwait University, and through also attracting people that are in the market … we need to introduce new classes to the curriculum ... We do have elective advanced classes as well that can provide lighting, so the program is ready to open more lighting classes or offer more lighting knowledge.

One key strength of the Architecture department is that it provides students with advanced tools to help them analyze their lighting designs. For example, Participant A stated: "we use advanced tools in our class … We teach them how to use VELUX ... we give them handheld light meters to measure …and they can use it as a research tool."

According to NVivo software word count, the most emphasized strength in the College of Architecture is the advanced tools.

5.7.2- Weaknesses Derived From Interview Responses

The weaknesses of lighting design pedagogy in the Architecture department are:

1. There is no clear structure for the integration of lighting design knowledge.

2. There is only one mandatory class for lighting design, which also includes acoustics.
3. The department does not have enough electives about advanced lighting design knowledge and its digital simulation tools.
4. Lighting design knowledge is integrated very late in the curriculum; in the third or fourth year, as Participant A said: "Still, lighting and acoustic is not something that unfortunately we think about, here in the college, from year one."
5. There is no communication between the lighting design educator and the design studios' instructors.
6. Participant A does not take students on field trips to experience lighting design in real projects due to time constraints: "Field trips we didn't do.… The field trips take time. That's another problem."
7. The department focuses more on natural light, as Participant D mentioned: "I see that the daylighting is much more advanced than the artificial lighting."

In contrast, the weaknesses of lighting design pedagogy in the Interior Architecture department are:

1. The department focuses more on qualities of light rather than technical knowledge, as Participant D noted: "We need an improvement to focus on the technical part, advance it more to a level of calculation and simulation …We focus more on quality."
2. The department focuses on natural daylight, as Participant B stated: "Students mostly depend on natural light in their project."

3. The department does not have a studio that is focused on lighting design, as Participant B implied: "It's just there is no specific course for lighting or studio."
4. No faculty members are specialized in lighting design.

In conclusion and according to the NVivo word count, the most emphasized weaknesses of the College of Architecture are little knowledge about artificial lighting, lack of faculty who are specialized in lighting design, and poor student drive to develop their lighting design knowledge. Figure 5-3 summarizes the strengths and weaknesses of lighting design education at Kuwait University.

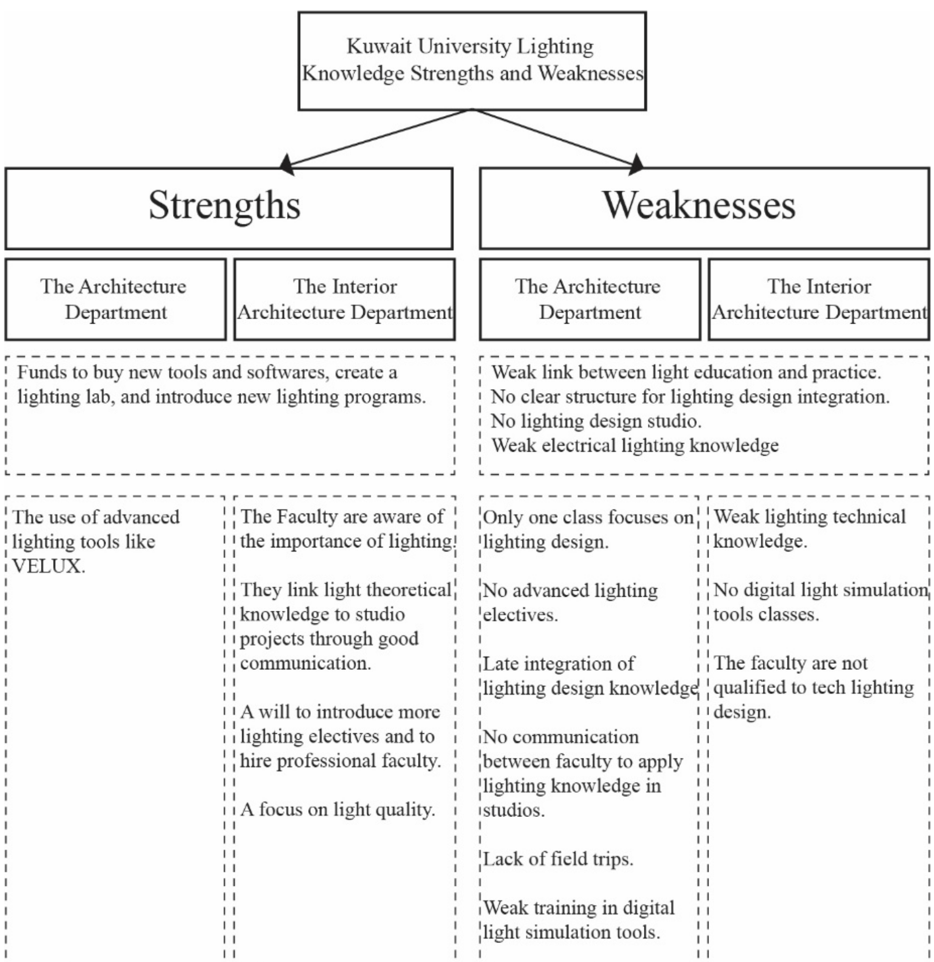


Figure 5-3. Kuwait University's Lighting Knowledge Strengths and Weaknesses

5.8- Lighting Design Foundational Knowledge at Kuwait University

This section discusses foundational lighting knowledge and the basic knowledge that students need before engaging in lighting design and using digital light simulation tools.

5.8.1 - Lighting Design Topics in the Architecture and the Interior Architecture Departments from the Documents

The Luminous and Sonic Environment course from the Architecture Department includes topics such as lighting and acoustics perception, effects, spatial experiences, visual perception, properties of light, natural light in buildings, electrical light, light and form, and lighting calculation methods. The objective of the course is to equip students with knowledge about the physics of light and sound, light and sound quantity to evaluate their performance, quantitative aspects of both media, and digital software that helps them design and analyze light and sound in buildings.

The Environmental and Building Systems I class from the Interior Design Department includes topics such as the quantitative and qualitative aspects of light, color, and acoustics. It focuses on the qualities and functions of light, how to incorporate light in design projects, environmental lighting, lighting construction, light presentation, lighting fundamentals (what is light, brightness, glare, and light pollution), light perception, history of light, light technologies, light controls, electrical light sources and strategies, natural light strategies, human factors in lighting, and the sensory experiences of light in a collaborative environment (teamwork). It also addresses the aesthetic, technical, practical, psychological, physiological, and sensory qualities of light and sound. The Sustainable Interiors class covers economic, environmental, and social sustainability in the built environment. The class aims to develop students' creative thinking, enhance their knowledge of international sustainable bodies and organizations, and help them understand sustainable practices and products.

In addition to the syllabi, the researcher gave the participants a handout with lighting design topics and asked them to sort the subjects from beginner level to advanced lighting design topics. The following sections present the results of this process.

5.8.1.1- Beginner Level Lighting Design Topics:

Two or more educators thought that the following lighting design topics were beginner level:

- Light Definition and Purpose (what is light + importance of light)
- Physics of Light + Light Behavior with Surfaces
- Light Perception (how humans perceive light)
- Daylight Integration and Influence (daylight strategies)
- Layers of Lighting Design (general, task, accent, decorative lighting)
- Electrical Light Sources
- Light Color
- Brightness and Glare
- History of Light
- General Knowledge about Electricity
- Design Thinking (as basis before introducing lighting design)

5.8.1.2- Intermediate Level Lighting Design Topics:

Two or more educators thought that the following lighting design topics were intermediate level:

- Daylight Integration and Influence (Daylight Strategies)
- Lighting Design Tactics (example: how to create certain moods)
- Electrical Light Sources
- Light Distribution, Texture, and Optical Control
- Light Measurements and Calculations
- Luminaires' Types and Operation
- Human Factors (light effects on human health, emotions, and behavior)
- Light to Enhance Architecture and Interior Spaces (poetry of light)
- Lighting Design Process, Tools, and Deliverables
- Color Theory
- Outdoor Lighting
- Safety and Security (wayfinding and communication)
- Light Art and Inspirational Mediums (example: installations and photography)
- Light Theory and Philosophy (e.g., Placemaking, Critical Regionalism … etc.)

5.8.1.3- Advanced Level Lighting Design Topics:

Two or more educators thought that the following lighting design topics were advanced level:

- Energy and the Environment
- Light Applications and Case Studies (Activity Needs)
- Lighting Critical Issues (e.g., Designing for the Elderly)
- Lighting Design Process, Tools, and Deliverables
- Outdoor Lighting
- Lighting Design Profession (professional practice)

- Lighting Design Digital Computation and Technologies
- Design Studio Focused on Lighting Design
- Light Theory and Philosophy

5.8.1.4- Elective Lighting Design Topics:

Two or more educators thought that the following lighting design topics were electives:

- Fixture Design and Theatrical Lighting

The following diagram summarizes the lighting tacit knowledge domain from Kuwait University's documents.

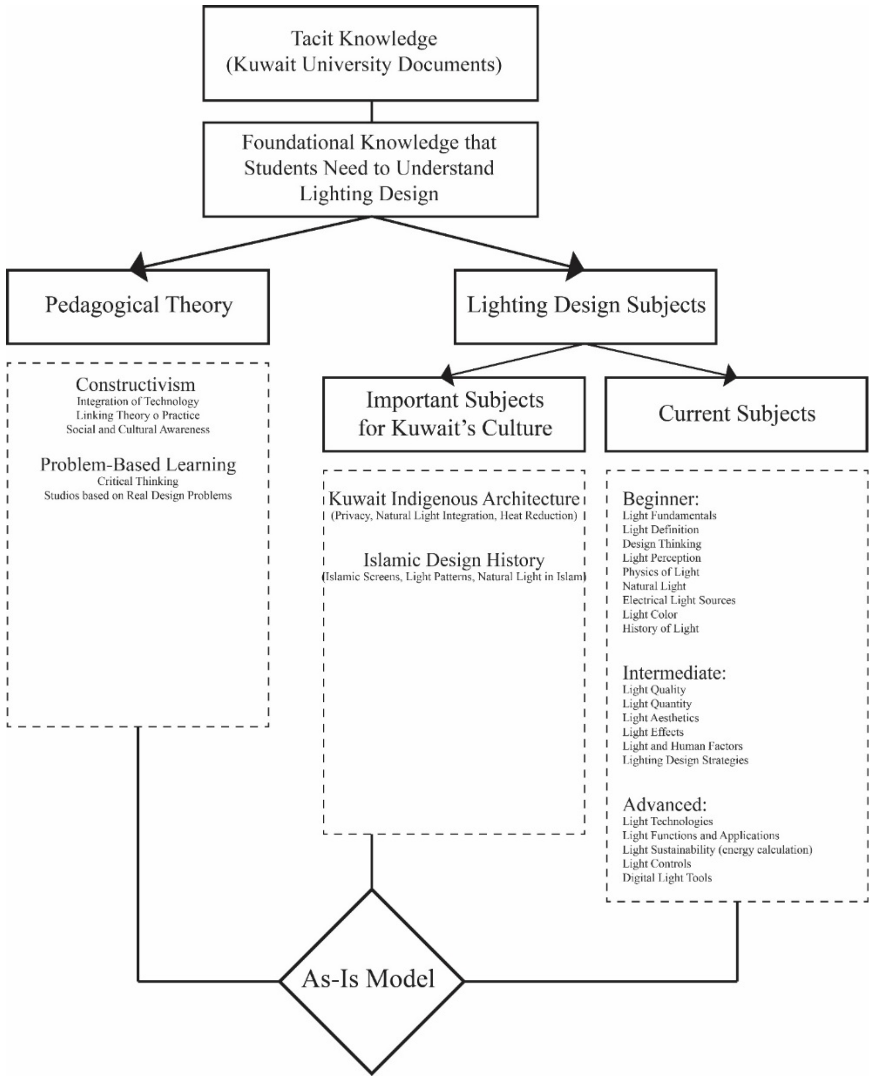


Figure 5-4. Kuwait University Lighting Documents' Tacit Knowledge Domain

5.8.2 - Lighting Design foundational knowledge at Kuwait University Based on Interview Responses

Each educator teaches students lighting design topics that he/she thinks are important to know before they graduate as architects or interior architects. Participant A thinks that students need to learn solar geometry, window properties, building orientation, thermal energy, electrical lighting, daylighting, light aesthetics, history of light, lighting's effects on human's mood and behavior, light measurements, manual calculation, principles of light, and light levels for each task. Participant B believes that students need to learn cultural, social, and vernacular aspects of light; light's influence on buildings' openings and human psychology; physics of light; light aesthetics; history of light evolution; and light simulation software:

> Students need to first understand the impact of light on the emotional, psychological, and physical aspects of a user in space … Also, lighting theory and cultural, social religious aspects of light in society … Placements of skylights, openings, clerestory, or lighting shelves … finally, most importantly, learning to work on a light simulation software.

Participant C asserted that light history, quality of light, the direction of light, light calculation, light concept generation, light sources and styles, light psychology, light energy, and light perception Are important foundational lighting topics. He/she also thinks that theatrical lighting is beneficial, even as an elective, because it teaches students a lot about light. Participant D identified the following key lighting-related topics: light's effects on human mood, task light, light energy, light specs, light distribution, light presentation, lighting-related environmental qualities, light efficiency and efficacy, physics of light, light color, light technologies, and light sources. Last, Participant E asserted that students need to learn lighting terminology, light sources and types, codes and systems, light calculation, light's quality and effects on human emotions, light quantity, and light design strategies.

5.8.3- Knowledge Needed Before Lighting Design Based on Interview Responses

Students need to understand some concepts and topics before they learn lighting design. Participant A thinks that students need math and basic knowledge about natural light. He/she believes that the Solar Energy class is a good introduction course. Participant B believes that students need interior design and design basics before lighting design knowledge: “Introduction to interior design because the lighting is part of design elements … I think Studio spatialization … It’s one of the basic first-year studios.” Participant C agreed with Participant B that students need the basics of interior design and architecture. Participant D indicates that educators need to develop students’ interest in lighting first. He feels that sight, vision, and color are good topics before focusing on lighting design knowledge: “We have to raise awareness first and then the interest will develop from the students themselves … the anatomy of the eye... human factor … how do we see colors, all the colors would be affected by light.”

In summary and based on the NVivo word count, students need to learn basic calculations, human perception and vision, design basics, design thinking, modeling and drafting skills, and solar geometry before they are introduced to lighting design knowledge.

5.8.4- Lighting Design Topics that are Related to Kuwait’s Culture Based on Interview Responses

Participant A emphasizes solar energy, daylight, and heat reduction strategies to respond to Kuwait’s hot and sunny climate. He/she also thinks that students need to learn how to control glare. Participant C thinks that light perception is an important topic for Kuwait to help people feel cooler in hot spaces: “It’s perception, because we have a very hot, arid, climate, and you can change the perception of the space and how cool it feels by lighting.” Participant D agreed with participant A that natural lighting strategies with heat reduction and energy-saving techniques are important.

> We have an abundance of light all year long, so I think with lighting designs, students should know how to utilize natural lighting … some of the advanced techniques such as light sensors … with artificial lighting, we in Kuwait, we have a very wasteful behavior with energy. Consumption is one of the highest in the world here. Sustainability and efficiency are important factors.

5.8.5 - Foundational Knowledge That Students Need Before Building Digital Light Simulation Tools Based on Interview Responses

Design thinking, light foundational knowledge, calculations, and modeling basics are important topics that students need to learn before they begin learning to use digital light simulation tools. Participant A thinks that students need to learn basic digital modeling skills, the sun's movement, building orientation, natural light control systems, types of electric light sources, light color, and light distribution before they begin learning to use digital light simulation tools.

Participant B thinks that students need to learn the foundations of design, calculations, modeling skills, and light principles. Participant D believes that students need to learn manual drafting skills, design basics, light qualities, light types, light properties, critical lighting issues, and light functions before they begin learning to use digital light simulation tools:

> Well, without having some drafting skills, and you know that the line for a wall is thicker than the line for a door, you wouldn't know how to draft it in the computer software, so the same thing applies with lighting without understanding the task needed, the quality of light needed … you wouldn't be able to use the software …

I think they need to have the basic knowledge of design and learn about the basics of lighting types through theory classes.

Figure 5-5 summarizes the foundational lighting design knowledge at Kuwait University based on the interview responses. The most emphasized topics, according to the NVivo word count, are lighting design and lighting concept generation, light quality, sustainability, and energy efficiency, levels of lighting (brightness and intensity), and light uses.

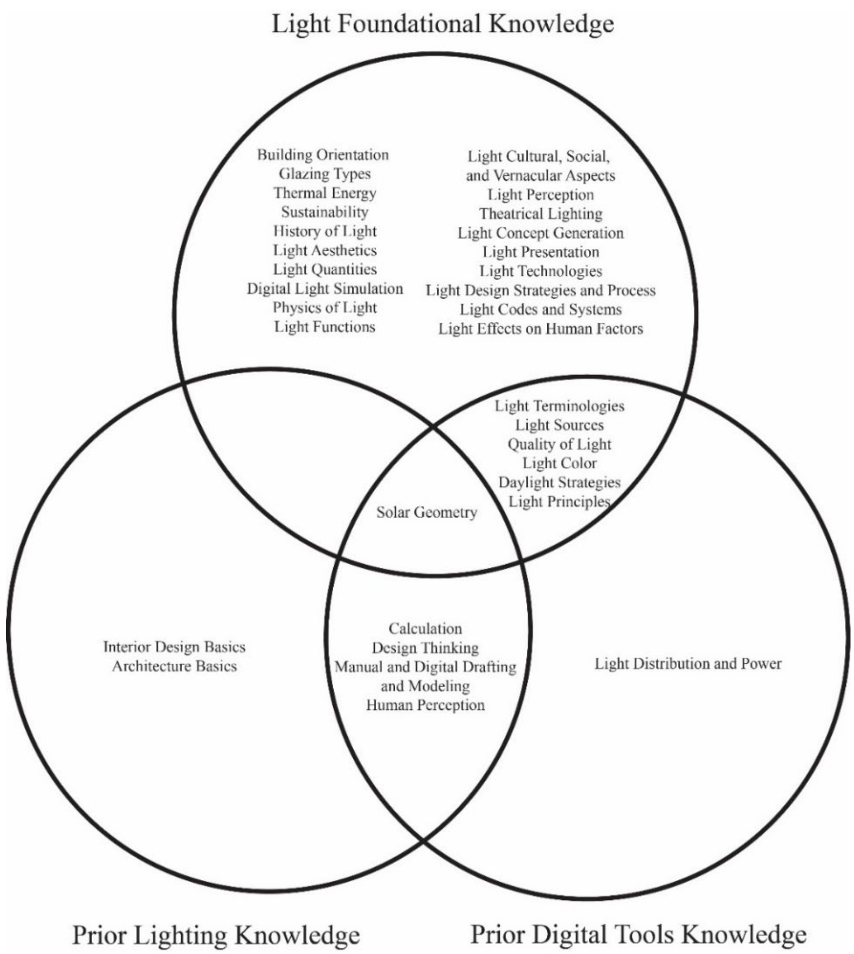


Figure 5-5. Lighting Design Foundational Knowledge at Kuwait University

5.9- Lighting Design Knowledge Delivery Methods at Kuwait University

Educators use different tools to enhance students' understanding of lighting design.

5.9.1- Lighting Design Knowledge Delivery Methods from the Documents

The educator of the Luminous and Sonic Environment course in the Architecture Department uses textbooks and PowerPoint lectures to deliver lighting design knowledge. He/she uses a book called *Architectural Lighting* by David Eagan and Vector Olgyay. He/she gives students two projects, two exams, homework, and quizzes. The exams and quizzes evaluate students' understanding of the given knowledge, whereas the projects help them apply and present the knowledge both visually and verbally.

The educators of the Environmental Building Systems I course in the Interior Architecture Department also use textbooks, lectures, and readings to deliver lighting knowledge. Participant B uses two books: *Light for Art and Culture* by Agentur Die and *The Architecture of Light* by Sage Russell. Participant E uses two books: *Lighting Design Basics* by Karlen and Benya and called *Mechanical and Electrical Equipment for Buildings* by Grondzik, Kwok, Stein, and Reynolds. Participants B and E give their students exercises and assignments to broaden their lighting knowledge, projects to apply the obtained knowledge and evaluate students' understanding of the materials, papers and presentations to present their lighting design thinking effectively, and exams to evaluate their performance.

Participant B gives his/her students in the Environmental Building Systems I course assignments on how to illuminate and change forms, how to change the mood and focus on objects, how to choose the lighting setting (e.g., indoor versus outdoor lighting), and how to create movement using light. He/she also gives the students activities to understand light's intensity, color, texture, angle, shape, and movement.

The educator of the Sustainable Interiors class uses textbooks, lectures, audio-visual materials, exercises, assignments, class readings, literature research, and market analysis to deliver the course's materials. He/she uses a book called *Sustainable Construction Green Building Design and Delivery* by Kibert. He/she gives students assignments, group presentations, quizzes, a final project, and exams to evaluate their performance and understanding of the class's materials.

5.9.2- Lighting Design Knowledge Delivery Methods Based on Interview Responses

Participant A uses lectures, case studies, projects, readings, renderings, and exams to deliver lighting design knowledge. He/she thinks that lectures are useful for teaching lighting principles, and projects are important for knowledge application and student evaluation, along with exams. He/she encourages his/her students to read extra articles and to go on site visits to learn more about lighting:

> PowerPoint presentations are a tool to educate the students and explain concepts and all the formulas. The project is to implement a way of knowing if the students understand the concept or not. That's our only way, besides the exams, of course.

Participant B uses lectures, projects, and case studies to deliver lighting design knowledge. He/she tries to link lighting theoretical knowledge to students' studio projects. He/she also encourages his/her students to read and research about new light technologies to keep up to date with the lighting industry. He/she thinks that both manual and digital tools help students in design decision making, but also believes that physical models are more beneficial to make decisions whereas digital tools are added skills: "Decision-making models. Physical models more than digital … Tools that allow them to gain skills, computer-aided designs … Computer-aided softwares help them to use the tools to come up with ideas and design better solutions."

Participant C uses lectures to teach light theory, projects to help students apply the theory, and real samples to show them light behavior with different surfaces and materials:

> Theory is very important. They cannot design something without understanding why. So, they have to understand what are the main rules of lighting, and then they start to apply them to whatever project ... You should have real samples … especially with materials. You cannot say, "Oh I want to do this," if you don't know how it interacts with the materials.

Participant D uses lectures, site visits, and exercises to deliver lighting design knowledge. He/she thinks that hand sketches and manual tools help students in design decision making more than digital tools, yet he/she believes that the latter aids in light analysis:

> I'm again from the old fashion style that you need to use your hand and sketch and trace paper … if they built their model in Revit or so on, they can transfer it to other programs to put in a certain time of the year and they do some shading or lighting analysis …That helps to a certain degree in the decision.

Participant E uses lectures to teach students light terminology and principles, gives them a problem to apply the knowledge, and uses videos and real samples. He/she thinks that educators need to expose students to different design tools to aid their design decision-making process: "I believe even if they did it with hand and with a pen is good as long as they understand what they are doing and why … They should use any tool to support their design argument."

Figure 5-6 presents a summary of the teaching methods at Kuwait University. All participants believe that both digital and analog tools are important for design decision-making, yet they feel that manual tools are more beneficial. According to the NVivo word count, the most used methods are hands-on applications in design projects; model making (using both digital and analog tools); and using visuals such as renderings, site visits, pictures, and case studies.

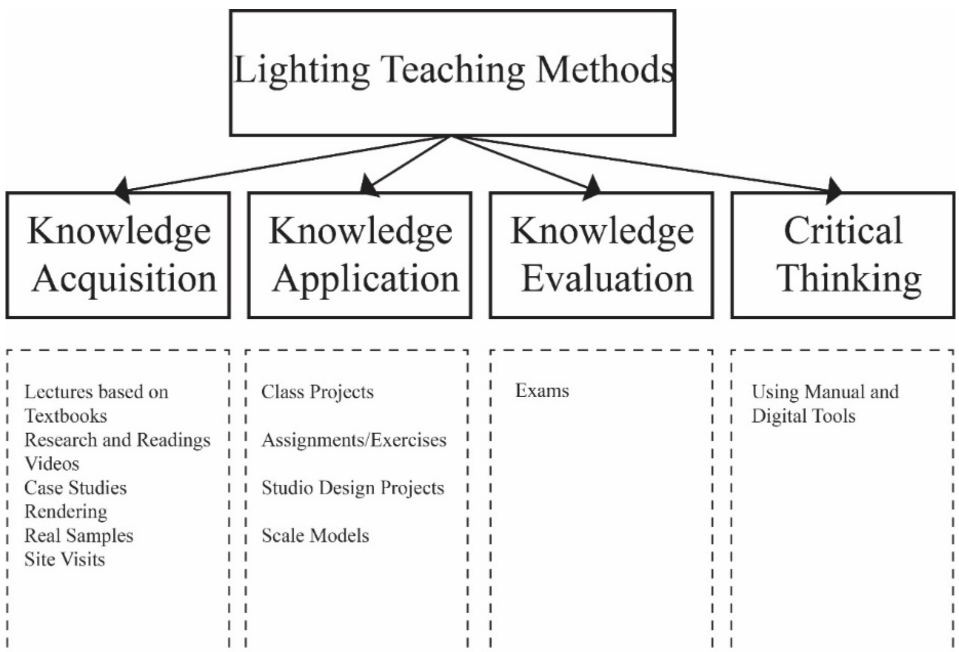


Figure 5-6. Lighting Teaching Methods at Kuwait University

5.9.3- Lighting Design Exercises from Kuwait's Interviews

Lighting design exercises help students apply theoretical lighting design knowledge. Participant A invites his/her students to stimulate and compare a lighted space using both physical and digital models in groups. Each team models a room with different window sizes and orientations to test various natural light distributions and ways to better introduce daylight in interior spaces: “they have to do certain strategies to better distribute the light. Maybe they put a light shelf. Maybe they put reflectors. Maybe they put some shading device, whatever strategy that they have learned in the class.”

Participant B encourages his/her students to fix a bad lighting scenario, test light behavior in interior spaces, and use light simulation softwares to enhance lighting design decisions and presentation. In addition, he/she believes that it is useful for students to use a sun dome to analyze natural light on a physical model:

> It’s nice to use a sun dome … If they want to explore a physical model with a relationship with sunlight … they go and take images every hour during the day, so they study shadow patterns and light inside a building.

Participant D introduces some technical light exercises like calculating light using light sensors or meters. He/she also encourages his/her students to draw light perspectives and plans to show light types and distribution.

5-10- Students’ Perceptions of Lighting Design and Digital Light Simulation Tools Based on Interview Responses

Students’ perceptions of lighting design and digital light simulation tools affect the integration of lighting design knowledge in the curriculum.

5.10.1- Students’ Perceptions of Lighting Design Knowledge

Students’ interests in lighting design vary. Some find it interesting to focus on whereas others prefer to concentrate on other design elements, as Participant B indicated:

> I can say 50% of students care or realize the importance of lighting in their projects, both natural and artificial. That is because they are interested more, as I said, in design concepts and the aesthetics of space and architectural styles more

than lighting. To them, lighting is considered as an accessory, not a function … so they think of it at the final stage."

In addition, if the lighting is a critical design element of a certain project type—like an office, a mosque, a museum, a healthcare facility, or a school—students would need to think about. As Participants B implied: "It depends on the type of project. For example, if we're designing a mosque. The mosque is about light. The school also is about light. Healthcare also ties to light." Participant D added, "If we say it's a museum, or it's a gallery, I think the lighting would be a much important factor." Participant C concurred with Participant B that some students think about lighting design in their projects, yet not from the beginning of the design process because they have more important things to focus on such as the architectural form, style, and circulation: "they cannot think about it in the beginning. It's too much … Honestly, like for architecture, massing is more important. What else? Style. How people circulate within a space." Some students follow their educators' lead; if their instructors or jury do not focus on lighting, they will not consider it in their projects, as Participant D indicated: "It all depends on the jury how much they focus on the lighting aspect, and it's rarely one of the topics they talk about in the design."

5.10.2- Students' Perceptions of Digital Light Simulation Tools

Students are attracted to digital tools due to their convenience, speed, appealing results, and ease of modeling, as Participant A explained:

> I think the students love digital. This is what I notice because the scale model requires labor, it is time-consuming … The digital model is more convenient. You can stay in your home … and it can give you all kinds of interesting results.

Students also have the drive to learn digital tools on their own. They can even surpass their educators' knowledge in such areas, as Participant A indicated:

> The students are smart. They are smarter than me. In many cases there are sometimes things that I don't know how to do, they tell me how to do it. You know they have their ways. I don't know, through YouTube or Google.

Participant B believes that the digital tools' renderings attract students: "it gives them dramatic interiors. It feels realistic, and it feels professional. So, they automatically feel proud of their work." Participant E concurred with Participant B that students love realistic images. Participant D indicated that students are eager to use digital tools from the first year to keep up with professional demands: "well, we see students are trying to jump into building information modeling from the early year with how the market has functioned." Some students, however, prefer working with hand models because they fear digital tools, as Participant B explained: "I always work parallel between digital and physical because ... Some are good at physical models and excellent model makers, but they're afraid to use computer-aided design."

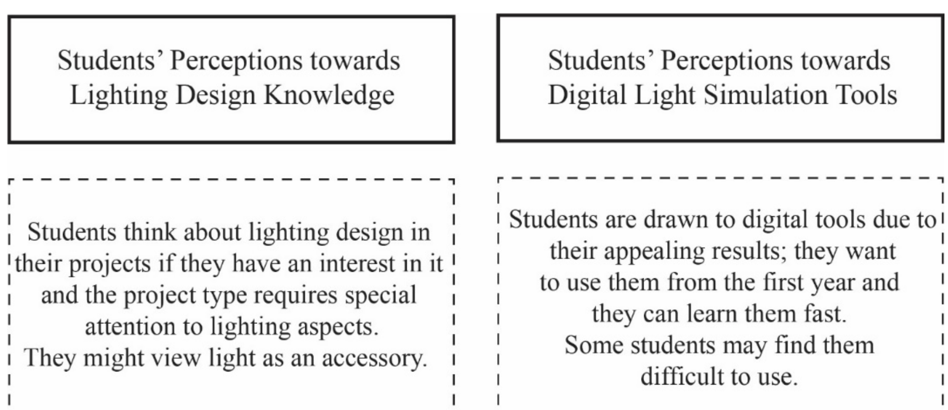


Figure 5-7. Students' Perceptions of Lighting Design and Digital Light Simulation Tools at Kuwait University

5.11- Digital Tools at Kuwait University

5.11.1- Digital Tools at Kuwait University from the Documents

Digital design tools are only introduced in the Computer Application class in the Architecture department, in the second year. The Interior Architecture department, in contrast, offers three digital-focused classes; two are mandatory given in the second and third year, and one is an elective. The three classes are Computer-Aided Design I and II and Advanced Computer Application, respectively.

In addition to the syllabi and curricula analysis, the researcher asked the educators to mark features that they think are suitable for an educational digital light simulation tool on a handout. The features that three or more educators marked were: CAD or Revit compatibility, simple rendering controls, accurate results, easy user interface, flexibility, in-program materials and objects library, and variety in image outputs.

Figure 5-8 summarizes the explicit knowledge derived from Kuwait University documents.

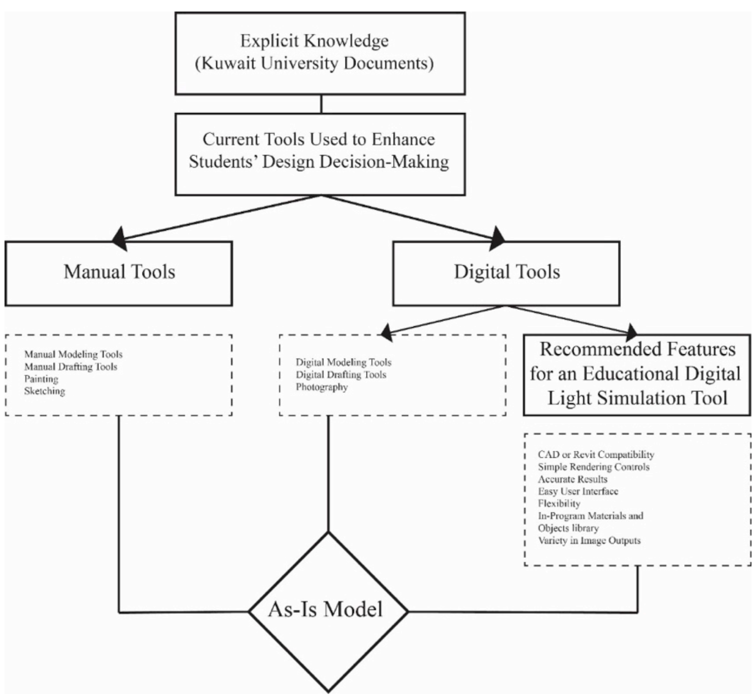


Figure 5-8. Kuwait University Lighting Documents' Explicit Knowledge Domain

5.11.2- Digital Tools at Kuwait University Based on Interview Responses

Only a few educators use digital light simulation tools at Kuwait University. Participant A uses DIALux and VELUX because they are free, quick, easy to use and learn, accurate, and compatible with SketchUp. Additionally, they have in-program light sources from famous lighting companies. He/she does not use AGi32 due to its complexity and expensive price:

> VELUX, and DIALux …These two softwares, from the same company. I think one is only for daylighting, and the other one is for daylighting and electrical lighting. It has been proven to be accurate and very easy to use … Now, there are some other softwares. I think AGi32. I think it's complicated and it's costly. VELUX and DIALux are both free … it has a library of many lights from famous lighting companies … When I teach them, believe it or not, in one class they know VELUX.

Participant C uses AGi32 and DIALux, however, he/she stopped using AGi32 due to its complexity: "I experienced AGi32. DIALux … and I think now with AGi, modeling windows become very hard. I stopped because it's complex."

The researcher asked the interviewees to add to the handout's recommended features of an educational digital light simulation tool. Participant B recommends a tool that demonstrates light dynamic effects in animations and has a drop-down menu of manufacturers' light products:

> [A feature that would] allow students to see lighting behaviors like animation or kind of video clips … Also, provide lighting maybe brands of current retailers ...

> It’s like a drop-down menu. I can pick the type or manufacturer, and then it gives me spec sheets.

Participant D recommends a tool that supports regional light files and calculates light energy consumption. Participant E suggests a tool that integrates natural lighting with artificial light in interior spaces: “it would be great if we can connect daylighting to artificial lighting somehow. I’d like to see a transition between day and night in an indoor environment. So, we link between the daylight and the manmade light.”

5.11.2.1- Positive and Negative Implications of Digital Light Simulation Tools

Digital light simulation tools have both positive and negative implications in design education. Figure 5-9 presents the digital tools’ positive and negative traits with ways to overcome the negative implications. The most emphasized positive implications based on the NVivo word count are improved design decision making, good visualization and renderings, accuracy in calculations, and help in analyzing light at different times of the year. The most emphasized negative implications, in contrast, are difficult user interface and inaccurate depiction of reality.

Participant A suggested that students compare the results from a digital tool to a physical model to understand the limitations of each tool: “I think maybe at one point we have to compare ... We compensate for the accuracy when they compare it with the physical.” He/she also suggested using physical models in the ideation phase to overcome the complexity of digital tools: “For the early stages, I think maybe it’s not good to do digital.” Participant C proposed using actual light samples and products to test light behavior: “I always go by experiencing the product itself. Send me a sample. Let’s see how the light interacts.”

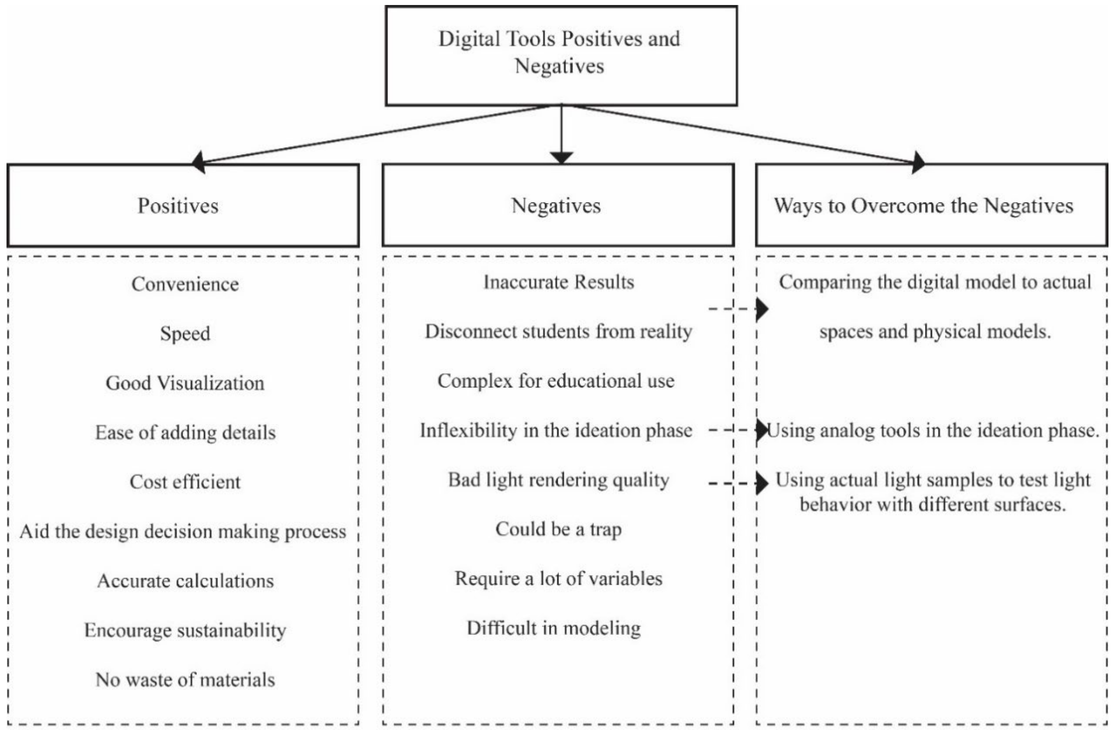


Figure 5-8. Digital Tools' Negatives and Positives

The following diagram summarizes the explicit knowledge domain at Kuwait University based on the interview responses.

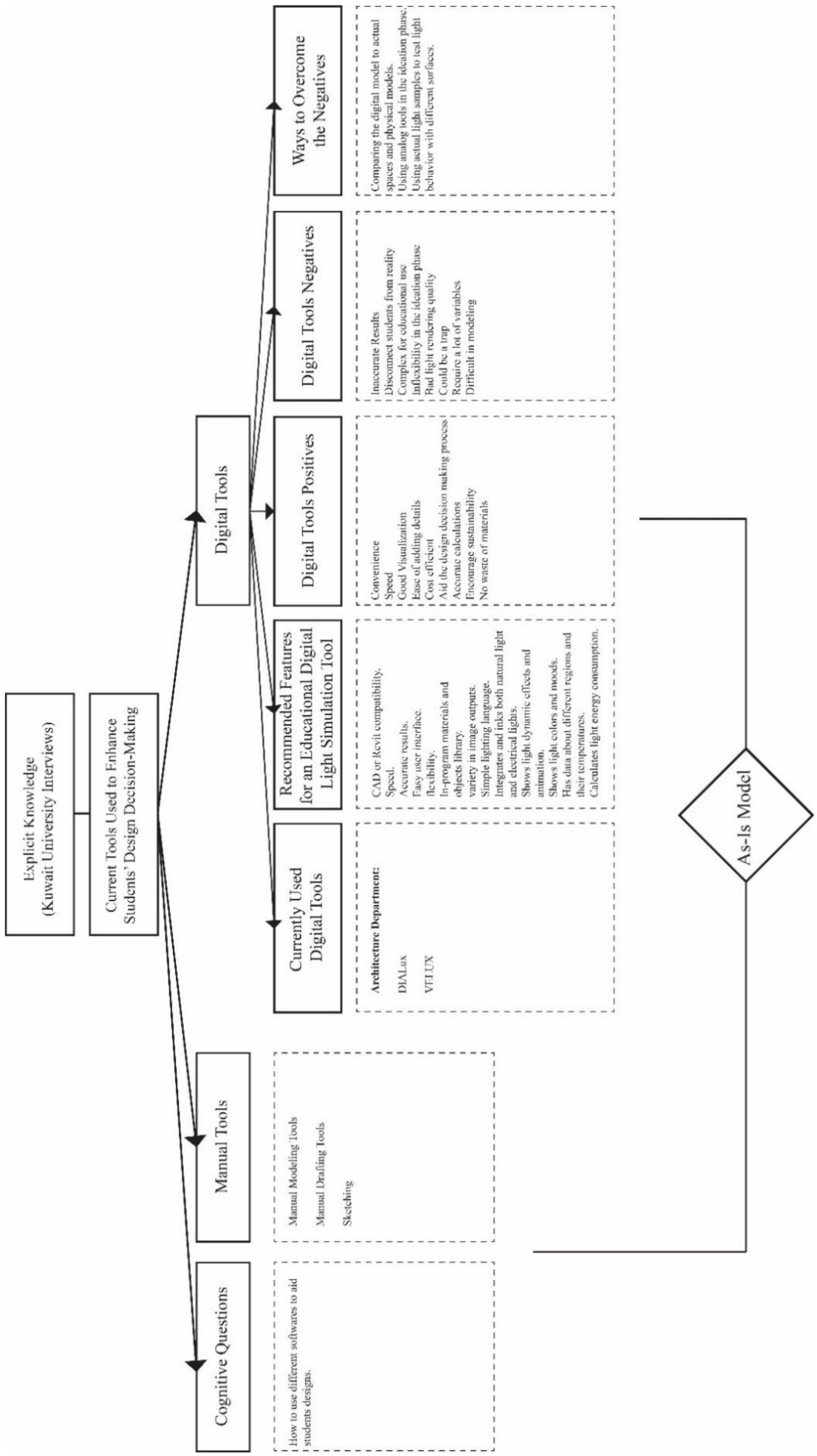


Figure 5-9. Lighting Design Explicit Knowledge Domain at Kuwait University

6.12- Future Considerations for Lighting Design Education Based on Interview Responses

To improve lighting design pedagogy at Kuwait University, Participant A suggested integrating more lighting topics in design studios: "Focus more on the role of lighting in design studios." He/she also suggested offering more lighting design electives and to separate lighting from acoustics in two different classes: "I think at one point we have to introduce advanced classes as electives … Maybe we have to dedicate a full course for lighting and a full course for acoustics."

Participant B recommended introducing lighting design topics from the very first year. He/she thinks that it is better to introduce light qualities first:

> Students are coming with no background on lighting, and they enjoy lighting and the moods and color … I think if they take a core course, not an elective, about lighting, exploration of light, and the importance of light, not as a function, but as I said, human factors and psychological level.

In addition, he/she proposed a lighting design focused studio to engage students in hands-on lighting projects, and to take them on-site visits:

> One thing that I was thinking of is finding a specific studio just for lighting and that's it. And when I say lighting, not just architectural lighting. It could be light designing, lighting fixtures, innovative lighting techniques that actually students put hands-on, and then they come up with creative ideas. … It will be really beneficial to focus on lighting design pedagogically through real site visits.

Participant C suggested offering more workshops about lighting design and more lighting design degrees. He/she agreed with Participant B that a lighting focused design studio and more lighting topics are important to raise students' awareness about lighting design: "We need to stress on lighting way more in terms maybe of degrees, in terms of workshops. We have to integrate it more into our curriculum … we have to stress on it in studios." He/she implied that architects and interior designers tend to create nice drawings and use excess lights that are unnecessary. Thus, they need to understand light hierarchy to respect light and darkness and create more interesting spaces:

> Architects and interior designers … They always think of order … you need to do something off-grid, to place it off-grid, but the effect of it will be on-grid ... They think about it in terms of the order, alignment, 'we want it to look nice in the drawing'. It's not necessary. It will look ugly on drawing, but very nice on-site. And architects and interior designers, have the urge to fill every point with light. In order to achieve good lighting, you have to respect also darkness and shadow, because you want to make contrast … and you have to also keep some room for light coming from a side lamp, or a table lamp, floor lamp … Keep the ceiling clean. No light. Depend more on table lamps, floor lamps. These are actually better sources, more flexible.

Participant D recommended offering a lighting design minor or a graduate lighting design degree in the Interior Architecture department to prepare design students for the market: "at the interior architecture program, we really want to have this to a more advanced level that can be developed into a certificate, or a minor, or even a Master's program … We need to prepare specialists, local specialists." He/she proposed integrating advanced lighting design classes in the curriculum and using the existing special topics classes to introduce more lighting design knowledge: "we need to introduce new classes to the curriculum or use the special topics classes that we have already and can be tailored based on the instructor." He/she also proposed linking quantitative and qualitative lighting knowledge to achieve a successful marriage between the science and artistry of strong lighting design.

Participant E suggested offering a design studio that is focused on building systems like lighting, cooling, and heating: "I'd recommend offering a design studio that focuses only on building system, that is lighting, electrical, HVAC system and working drawings. It's very important!" He/she agreed with Participant D that the Interior Architecture department needs more advanced lighting design classes to introduce sustainable aspects of lighting: "We can offer advanced special topics and lighting could be one of them … Covering the sustainability approach of lighting design is great too!" Additionally, he/she proposed offering more site visits and creating a lighting lab to engage students in lighting experiences: "Site visits are helpful as well, seeing things in action or having a lighting lab in the school will be great."

As for digital light simulation tools, Participant B proposed crash courses to teach students lighting design software to overcome time constraints and the faculty shortage:

> Workshops, maybe … to introduce crash courses apart from their design studios because we don't have time. Students need to explore these kinds of softwares … Without stress … So, that's why crash courses are important if we don't have available faculty.

He/she thinks that the best time to introduce digital light simulation tools in the Interior Architecture curriculum is in the second year, in order to encourage students to use them from the beginning: "It fits in the second part of the second year ... so they'll become confident in the third year." Participant D thinks that the third year in the Architecture department and the second year in the Interior Architecture department are the best times to introduce digital light simulation tools because students need to learn design basics and light principles first. Participant E thinks that the best time to introduce digital tools in the Interior Architecture department is in the third year because he/she thinks that traditional tools are more useful in the beginning: "It should start on their third year I believe. I'm more with traditional methods as a foundation."

Figure 5-10 presents a summary of the participants' suggestions. The most emphasized recommendations based on the NVivo word count are introducing more lighting design classes, hiring specialized lighting faculty, and introducing a design studio that is focused on lighting design with an emphasis on sustainability.

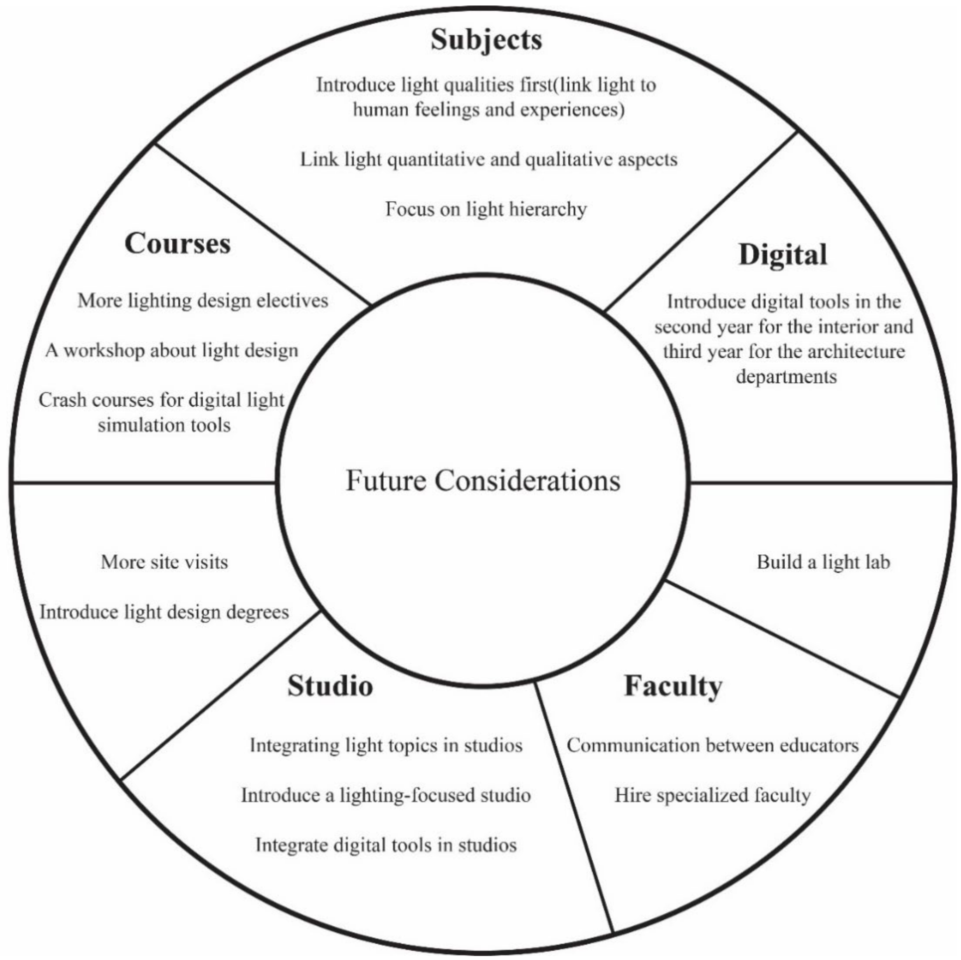


Figure 5-10. Suggestions to Advance Lighting Design Education at Kuwait University

5-13- Conclusion

The As-Is model presents the current lighting design knowledge sequence, topics, teaching methods, cultural factors, and cognitive tools at Kuwait University's College of Architecture according to the tacit, procedural, and explicit knowledge domains, as shown in Figures 5-11, 5-12, and 5-13. The researcher created the model based on Kuwait University's document analysis and interviews with current lighting design educators. Unfortunately, light is only taught briefly in the Architecture and Interior Architecture departments. Thus, both departments need better integration of lighting and digital lighting tools in the curriculum.

Current Sequence of Lighting Design Knowledge and Decision Making Tools in the Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1				
2	Light, shade, and shadow in the Architectural Communication class			
3		Solar geometry and energy in the Solar Energy elective class		
4		Mandatory lighting class: Design of the Luminous and Sonic Environments (can be in the third year as well)		
5				Advanced Lighting and Acoustics class for the master level

Current Sequence of Lighting Design Knowledge and Decision Making Tools in the Interior Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design (some lighting aspects)			
2	Building Environmental Systems class (technical, digital, fundamental, and general knowledge of light)	Human Factors class (qualitative aspects)		
3			Environmental Sustainability class (environmental, vernacular, and cultural aspects of light)	
4	Innovative Interiors Class Comprehensive application of light			

Table 13. Lighting Design Knowledge and Decision-Making Tools' Sequence at Kuwait University

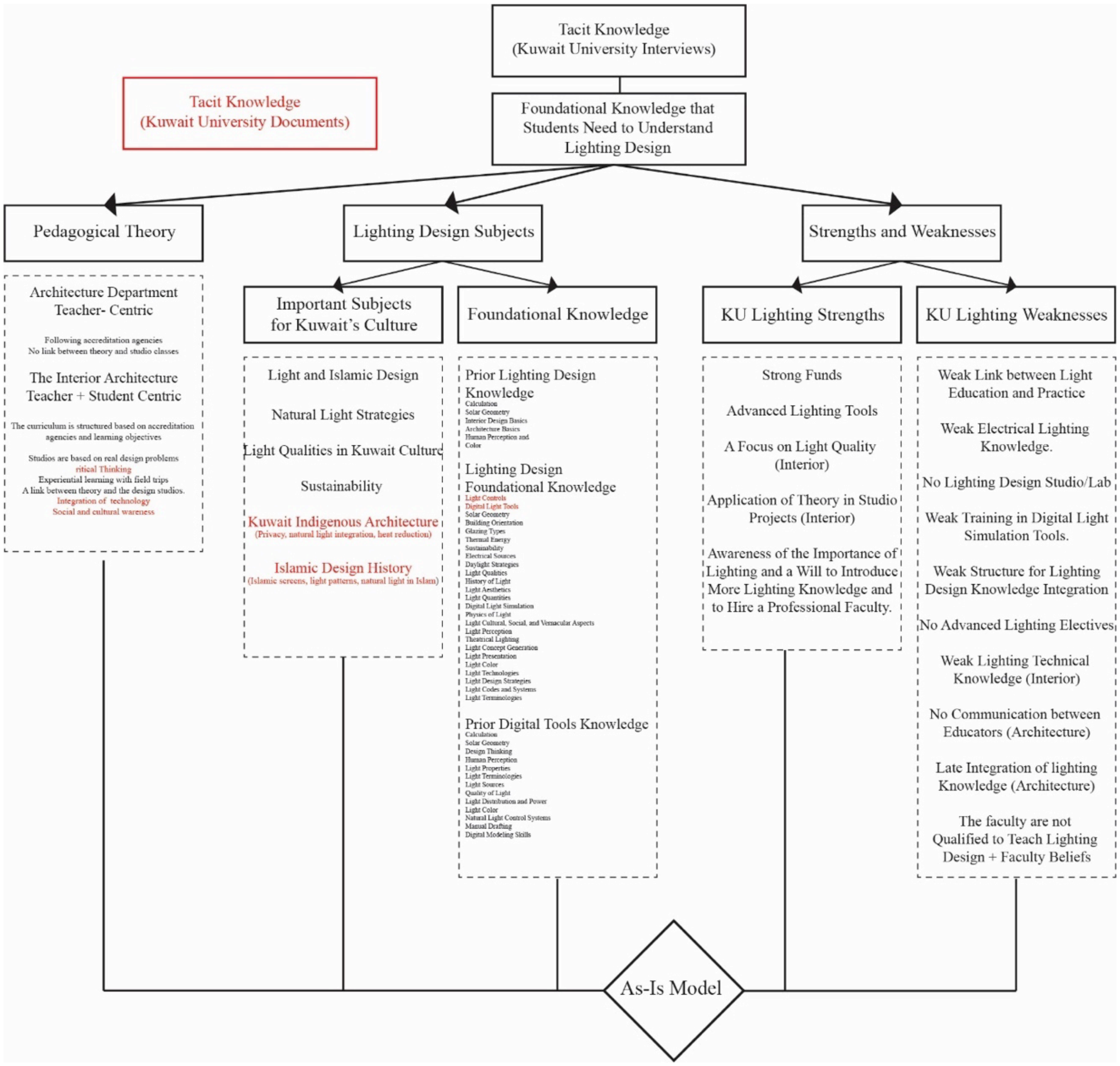


Figure 5-11. The As-Is Model Tacit Knowledge Domain

Note: the red text is added information from the documents analysis

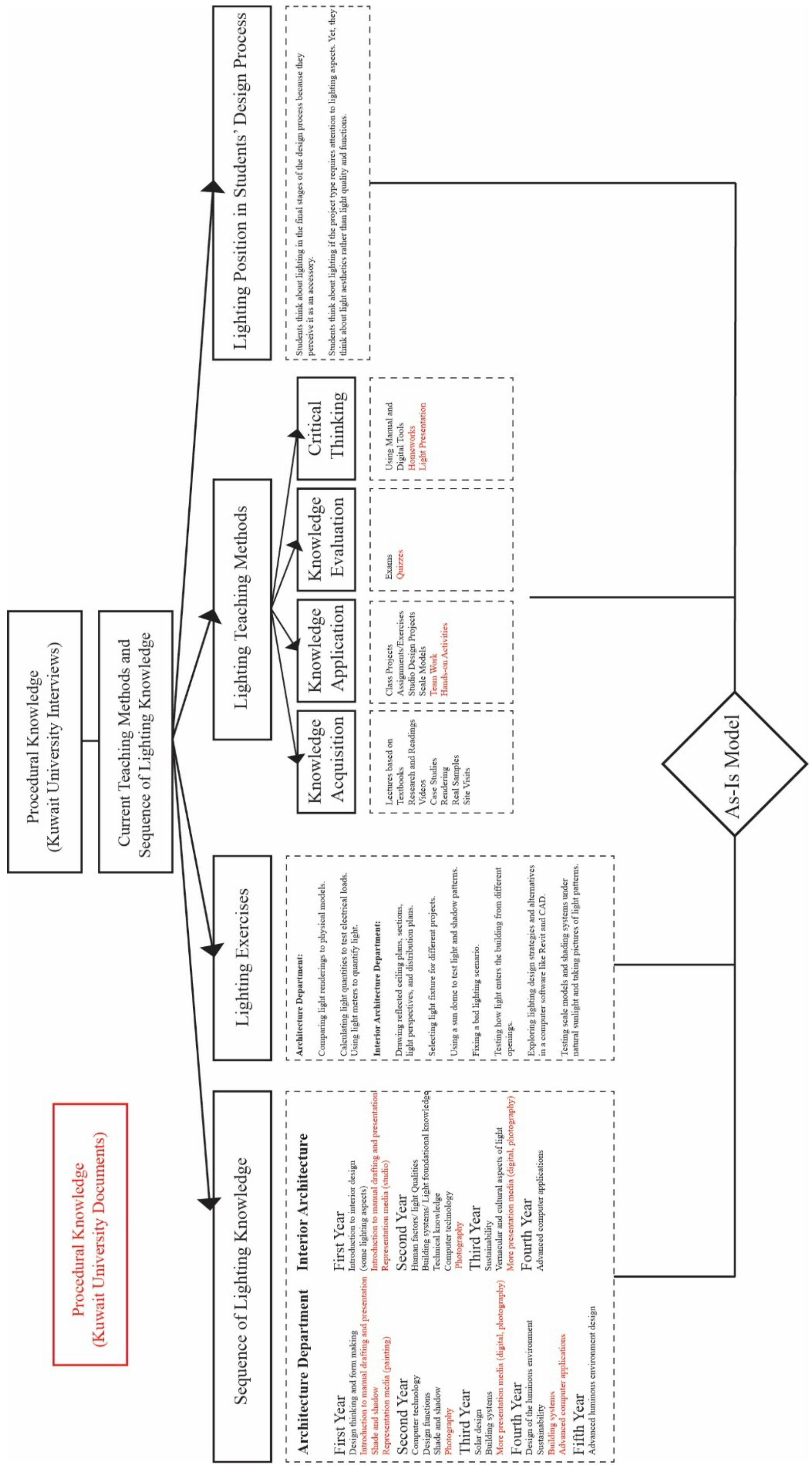


Figure 5-12. The As-Is Model Procedural Knowledge Domain

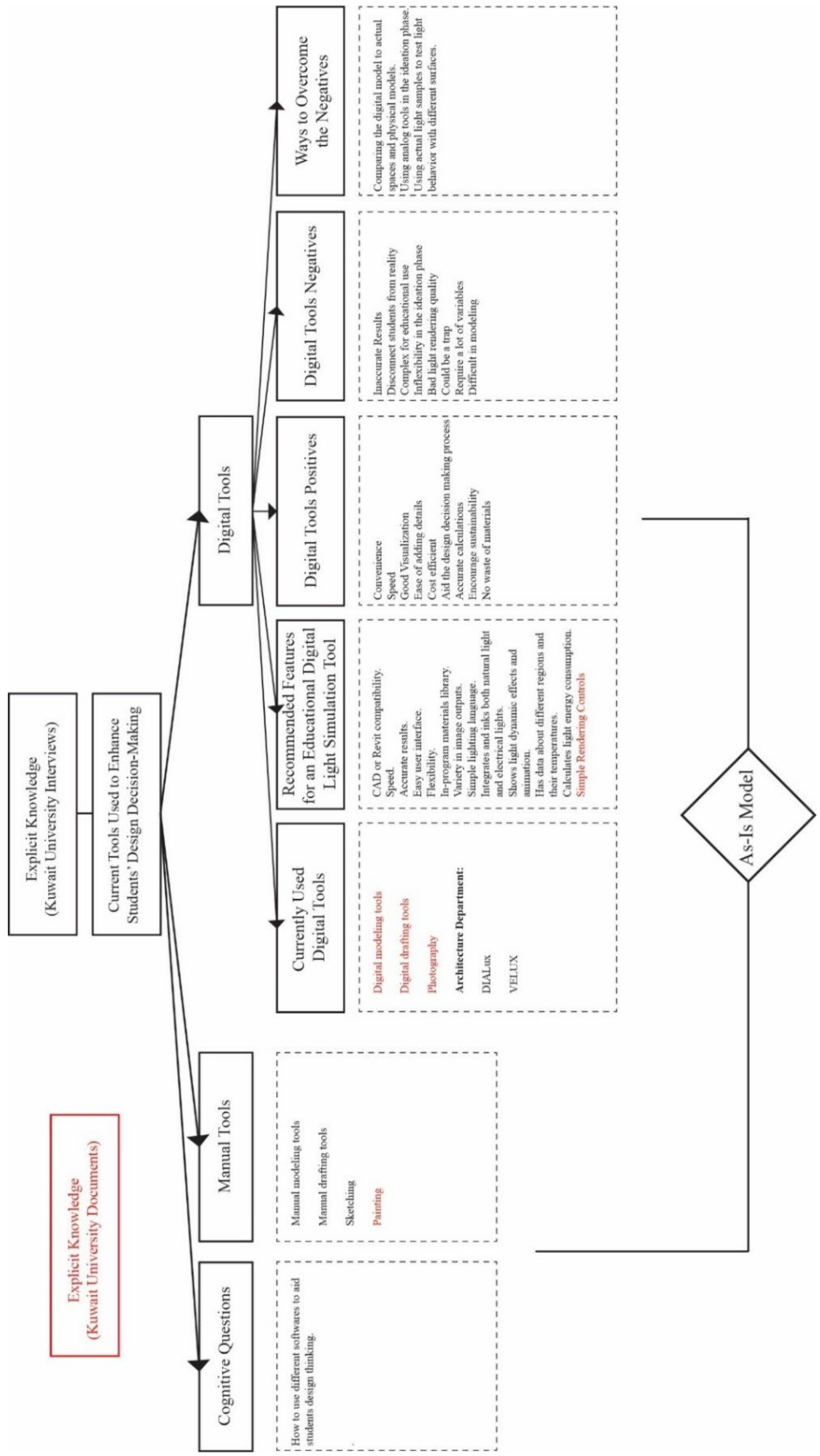


Figure 5-13. The As-Is Model Explicit Knowledge Domain

Chapter VI

6 – The United States "To-Be" Model

The researcher developed the "To-Be" model, which is the developed lighting design pedagogical model from the United States, by analyzing documents (eight curricula and syllabi) and interviewing six lighting design educators and specialists from developed lighting design programs in the United States. The To-Be model presents established lighting design topics, structure, sequence, pedagogical approaches, teaching methods, cognitive tools, and a lighting design studio.

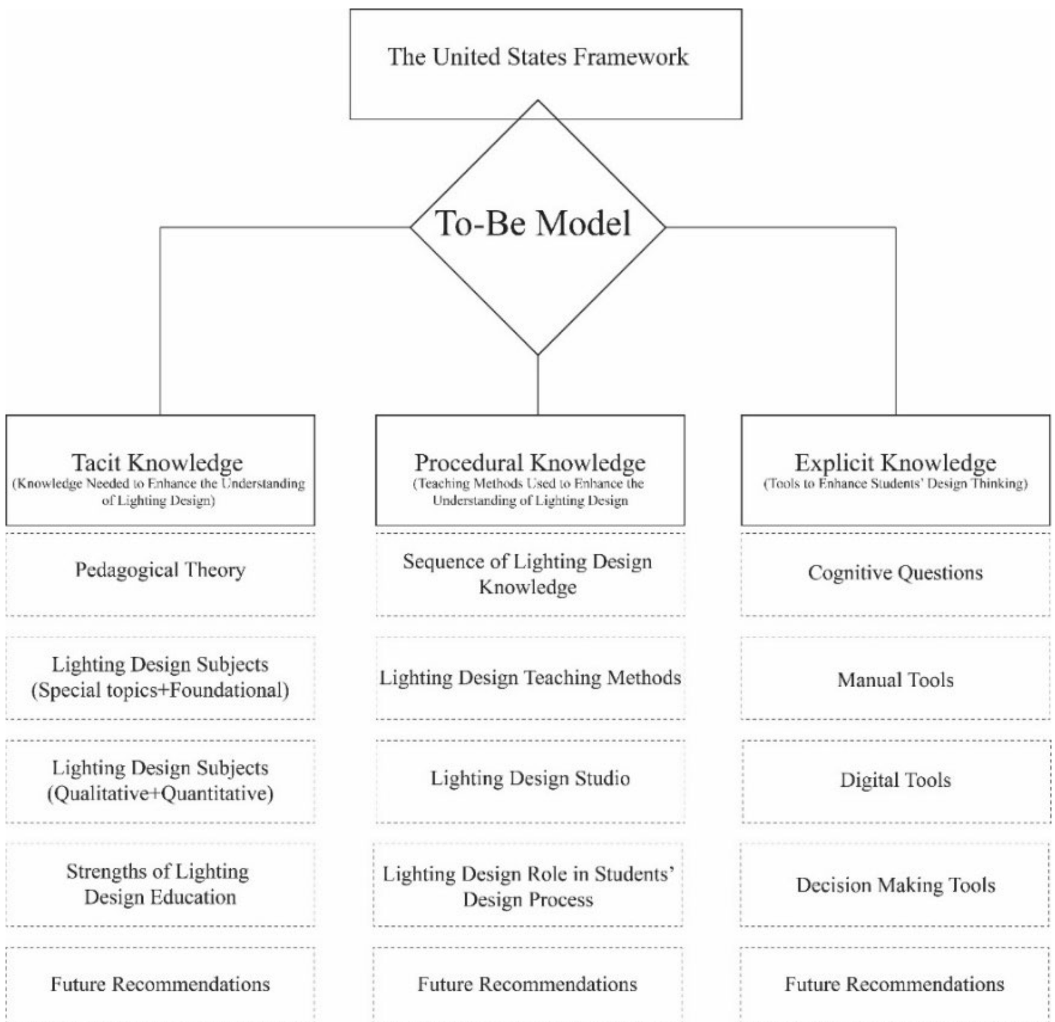


Figure 6-1. The United States To-Be Model

6.1- The United States Interviews

The objectives of the United States interviews were to understand lighting design foundational knowledge, special topics, teaching methods, knowledge delivery sequence, ways to integrate qualitative and quantitative lighting knowledge, ways to integrate digital lighting simulation tools in design curricula, recommended features of an educational digital lighting simulation tool, and tools needed to improve students' lighting design cognitive thinking and decision making.

Initially, the research targeted IALD educators but due to the educators' busy schedules, the researcher was able to only interview three IALD educators from the New York School of Interior Design, Parsons, and the University of Colorado. She also interviewed two lighting design educators from two developed theater programs, Boston University and the University of California at Irvine, as well as a lighting design enthusiast from Appalachian State University.

The New York School of Interior Design offers a graduate degree focused on lighting design called the Master of Professional Studies in Lighting Design. It also offers lighting design courses for the undergraduate Interior Design degree. Parsons has a Master of Fine Arts in Lighting Design and a dual graduate degree in Fine Arts and Interior Design with lighting design courses. The University of Colorado offers a Bachelor's and a Master's in Architectural Engineering with a focus on Lighting Design, and a certificate in lighting design for the Environmental Studies department. Boston University has graduate and undergraduate fine arts degrees focused on lighting design. The University of California at Irvine and Appalachian State University offer undergraduate degrees with some lighting design courses.

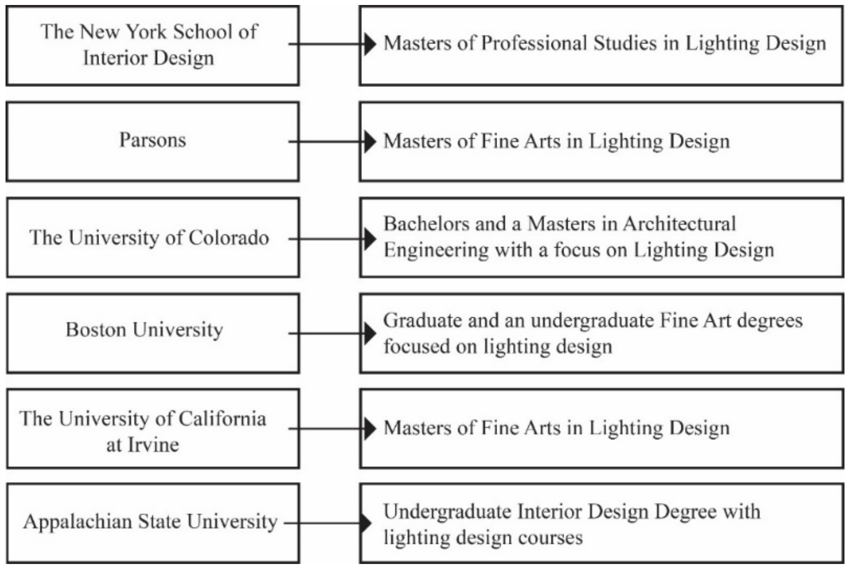


Figure 6-2. The United States Lighting Design-Focused Programs

6.2 – The United States Interviewees' Demographic Information

Interviewee A has a Bachelor of Fine Arts from Kansas City Art Institute. He/she has 20 years of experience in teaching lighting design. He/she teaches a Collaborative Design Studio (architecture, lighting, and interior design majors); Daylighting Studio; a Light, Space, and Art class that explores the poetic, perceptual, aesthetics, and phenomenological aspects of light; and a light fixture design elective that is called The Luminous Object at Parsons University. Professionally, Interviewee A offers architectural lighting consultations and has an architectural design firm.

Interviewee B has a Bachelor of Fine Arts from Iowa State University and a Master of Arts from Cornell University. He/she has 14 years of experience in teaching lighting design. He/she teaches the Interior Design Studio IV (a global hospitality studio), Interior Design Systems II (lighting and acoustics), Interior Design Studio I, and Interior Design Systems I (materials and finishes) at Appalachian State University.

Interviewee C has a Bachelor's degree in Drama and a Master of Fine Arts in Lighting Design from the University of California at Irvine. He/she has 18 years of experience in teaching lighting design. He/she teaches the Graduate Composition class, the Musical Class; a Choreography Composition; a class of Light, Sound, and Scenic Design; a Beginner's Lighting Class; and a class for Theme Park Lighting and Event Lighting at UC Irvine. Interviewee C is a professional theatrical lighting designer with a background in the theme park and event lighting.

Interviewee D has a Bachelor of Arts in Theater and Asian Studies from the College of William and Mary and a Master of Fine Arts in Lighting Design from the University of Wisconsin-Madison. He/she has 15 years of experience in teaching lighting design. He/she teaches Lighting Design 1 and 2; Lighting Design Studio 5 and 6; Lighting Design Colloquium; Production, Light and Movement; Design for Opera; and Color Interaction at Boston University. Interviewee D specializes in lighting design for live performance.

Interviewee E has a Master of Science in Lighting from the Lighting Research Center, Rensselaer Polytechnic Institute, and a Master's degree in Art History, Museum Studies from the University of Denver. He/she has 15 years of experience in teaching lighting. He/she teaches Illumination 2, an Advanced Lighting Design class, a Fundamental Design class in lighting, and the Senior Capstone Project at the University of Colorado at Boulder.

Interviewee F has a Bachelor of Fine Arts in Theatrical Arts, Mathematics, and Computer Science from New York University and a Master of Fine Arts in Lighting Design and Integrated Media from the California Institute of the Arts. He/she has 8 years of experience in teaching lighting. He/she is the head of the lighting program at the New York School of Interior Design. He/she teaches Lighting 1 and 2 for the Interior Design Degree, Studio 1 for graduate students, a Lighting Laboratory class, History of Lighting, Lighting Controls, and the Luminaire Design Competition. Professionally, Interviewee F is a theatrical lighting designer and a lighting design studio manager for a lighting manufacturer company in New Jersey.

6.3 – The United States Design Pedagogical Philosophy

6.3.1 – The United States Design Pedagogical Philosophy from the Documents

The document analysis (websites and curricula) of the eight developed lighting design programs in the United States (listed in Chapter II) indicates that the programs follow student-centered pedagogical models. They utilize constructivism, experiential learning, and PBL approaches. They try to link light theoretical knowledge to its practice, connect qualitative and quantitative aspects of lighting, emphasize hands-on activities and experimentation, involve students in environmental and social contexts, emphasize human factors, utilize technological developments, provide a multidisciplinary learning environment, offer a flexible curriculum, and integrate lighting knowledge in design studios or labs where students solve real-world problems using different problem-solving and critical thinking skills.

6.3.2 – The United States Design Pedagogical Philosophy Based on Interview Responses

Educators at Parsons meet certain learning objectives and combine both theory and hands-on learning. Each semester, students take theoretical and technical lighting design knowledge and apply that knowledge in their studio projects. Appalachian State

University tries to combine both theory and practical knowledge to prepare students for their professional careers. The curriculum is teacher-centric but within each course, teachers have the freedom to change the syllabus based on students' feedback.

The University of California at Irvine (UCI) focuses on hands-on learning. The school provides workplaces for practical learning, internships, and mentorship opportunities. The School of Drama at Boston University combines professional, theoretical, and practical knowledge. Students learn about different theater elements, apply their knowledge in design studios and productions, and develop professional skills. The curriculum of Boston University is teacher-centric; it is structured based on what educators think is important to learn.

The University of Colorado at Boulder follows a content-driven pedagogical theory where the classes and the curriculum are set, but in each class, educators meet students' interests, as interviewee E indicated:

> First of all, it cannot be teacher-centric, but it has to be content-centric in the sense that it has to involve principles of how people live in a building and how a building should function for people. Once you have that as your current fundamental point of departure, then you adjust it to the students' ways of learning.

The design classes combine theoretical knowledge with practical exercises in the lighting lab. Interviewee E believes that theory is as important as hands-on activities because it helps students realize the potential and success of their designs: "you could do lighting by feeling … There has to be a fundamental knowledge that tells you whether what you're doing is appropriate. That's where the theory comes in."

The New York School of Interior Design combines both theory and hands-on activities with field trips and internship opportunities. The curriculum is student-centric; educators structure it and adjust their teaching approaches based on students' feedback, as Interviewee F asserted:

> It's definitely student-centered … we use a lot of feedback from student, surveys as well as kind of voice of the student meetings to get a sense of how things have gone … So, there's flexibility in terms of no professor really has leverage to say this is how I'm going to do it.

In conclusion, developed lighting design programs in the United States combine both teacher-centric and student-centric pedagogical approaches; the curriculum is usually set with specific learning outcomes and objectives, but the classes and syllabi are framed around students' needs and feedback. All programs link theoretical knowledge of lighting design to practical exercises, applications, and experiences either in lighting labs, field trips, or studio projects. Most programs equip students with different design tools, professional knowledge, and internship opportunities.

6.4 - Intentions of Each Design Year from the United States Interviews

At parsons, the first year of the master's in Lighting Design degree focuses on light foundations, principles, applications, and presentation tools both digital and manual. The second-year focuses on the final project and thesis. Thus, it is more theoretical with research and applications in more complex interdisciplinary design projects. Students also take different electives in the second year.

The undergraduate Interior Design program at Appalachian State University focuses on design foundational knowledge, design presentation tools both manual and digital, and small scale design projects with social, environmental, behavioral, and pragmatic research in the first year. The second year focuses on residential and workspace studio projects, interior design codes, materials and finishes, building systems, and design history. The third year focuses on cultural issues, internships, building systems (including lighting), and a collaborative design studio project. The fourth year focuses on retail design projects, design competitions, and a final graduation project where students apply all the knowledge they gained.

The undergraduate drama program at UCI is very flexible and student-oriented. Students decide what they want to take each semester, yet educators encourage them to take the foundational topics within the first 2 years. The first year of the undergraduate drama program at Boston University, in contrast, is a foundation year where students experience different theater elements and design skills in order to be able to choose their concentration at the end of the year. The students who choose lighting as a concentration learn the following in the second year: light vocabulary, functions, art, qualities, and pragmatic production with some hardware knowledge. In the third year, they learn visual aspects of light and light design thinking and crafts. In the fourth year, they learn professional lighting knowledge, light philosophies, and light history. Finally, they work on their final project and show it in their last year.

The first 2 years of the undergraduate Architectural Engineering program at the University of Colorado at Boulder focus on engineering fundamentals like math, physics, chemistry, and science. In the third year, students learn about building construction, structures, and systems like mechanical, electrical, lighting, after which they choose their concentration. In the fourth year, they learn the principles of design and focus on lighting design if they choose it as a concentration. The BFA and MFA curricula at the New York School of Interior Design transition from theoretical and historical knowledge in the first 2 years to more practical and professional knowledge in the third and fourth years with lots of hands-on activities, projects, and professional site visits and training.

In conclusion, most of the programs focus on foundational knowledge in the first 2 years, including aspects of theory, history, visual presentation tools, human factors, applications, and light qualities. In the third year, students learn about building systems, lighting, and professional knowledge. The last year is a comprehensive year where they apply the knowledge they gained in a graduation project. Table 6-1 sums up the yearly design intentions of each program.

Yearly Design Intentions of Different Design Programs

Year	Parsons	The Appalachian State University	The University of California at Irvine	Boston University	The University of Colorado at Boulder	The New York School of Interior Design
1	Light foundations, applications, history, theory, physics of light, luminaires, natural light, human factors, and analysis and presentation tools.	Design foundational knowledge drafting and presentation tools, design projects with social issues, sustainability, behavioral research, and pragmatic design	Flexible Curriculum with a focus on foundational knowledge the first two years	Foundation year with design skills	Engineering fundamentals	Theoretical and historical knowledge.
2	Final project and thesis, electives, research and Theory.	Residential and workspaces projects, interior design codes, materials and finishes, building systems and design history.		Light vocabulary, functions, art, qualities, and pragmatic production with some hardware knowledge	Math, physics, chemistry, and science	Theoretical and historical knowledge.
3		Cultural issues, internships, building systems including lighting, and a collaboration design project.		Visual aspects of light and light design thinking and crafts.	Building construction, structures, and systems like mechanical, electrical, lighting.	Practical and professional knowledge.
4		Retail design projects, design competitions, and a final graduation project.		Professional lighting knowledge, light philosophies, history, and a final project	Principals of design and they focus on lighting design if they choose it as a concentration	Hands-on activities, projects, and professional site visits and training

Table 6-1. The Yearly Design Intentions of the United States Lighting-Focused Programs

6.5 – The Sequence of Lighting Design Knowledge Based on the United States Interviews

The first year of the Master's degree in Lighting Design at Parsons covers principles and physics of light, theory of light, history of light, types of electric lighting, daylight methods and technology, and both digital and analog light representation tools. In the second year, students select different electives and focus on their thesis.

Educators at Appalachian State University, in the Bachelor's of Interior Design Program, introduce lighting design topics from the third year in the Building Systems two class. Students learn about fixture selections and reflected ceiling plans from the first year and natural light in the second year's building services class, yet they go deeply into lighting design in the third year and then apply the knowledge in the following studio project.

Students in the undergraduate drama degree at UCI take lighting classes at any time from the first year onward. Some students can even graduate without any lighting design knowledge; however, if they want an honors degree, they have to take the lighting course. Students of the Lighting Design Masters at Boston University take lighting classes from the first year, but they focus on it in the second year. Students start with light as an art form, light functions, and qualities, ending the year with light production. In the third year, they learn about visual light presentation and design. In the final year, they take light professional knowledge and build large-scale light mockups.

Educators at the undergraduate Architectural Engineering program at the University of Colorado at Boulder program teach lighting in the third year, but they encourage students to take it in the second year in the Illumination One class, which focuses on light physics, technology, and metrics. Students then take Illumination Two to learn about lighting design and application. Illumination One and Two are mandatory classes. In addition to the mandatory classes, students have five lighting electives: natural light, radiative transfer, controls class, advanced lighting design, and optical design. Students can also take electives from outside the department like light psychology, light perception, and theatrical lighting.

Students at the New York School of Interior Design take two mandatory lighting courses in the undergraduate Interior Design degree in the second and third year; these courses combine both daylight and electrical light topics. Students of the master's degree, on the other hand, take both daylighting and electrical light subjects from the first and second year and they can take electives in light history and light for retail and artwork, as interviewee F implied:

> I'd say our 3- and 4-year degrees, you get lighting in years 2 or 3. The first year is more about understanding history in general and interior design theory. If it's an accelerated one-year degree, then you get the lighting right away … In our three and four years, the interior designers take daylighting and lighting combined. The lighting design students that post professionals take a separate daylighting course from the lighting course … There are a few courses such as the history of lighting and lighting for retail and artwork, which are open as electives for some of the master students. For undergraduates, lighting courses are mandatory. We don't have electives at that level.

That being said, Interviewee F indicated that students think about light composition and quality in reflected ceiling plans from the first year, before they take the mandatory lighting courses: "many of their other courses involve lighting as part of the scope … they have to do RCPs, come up with ideas for the lights." The first mandatory light class tackles aspects of physics and science of light, qualities of light, and lighting design. The second mandatory class is studio-based with knowledge about light controls and digital light simulation tools like AGi32 and DiaLUX.

In sum, programs that are focused on lighting design introduce lighting knowledge from the beginning, whereas other programs introduce lighting knowledge in the second or third year. That does not mean that lighting design knowledge is not evident in earlier years, but the main lighting design course is in the second or third year. Most schools have two mandatory lighting courses; in the first course, they introduce the light theory, qualities, principals, technology, and representation tools, whereas the second course is mostly studio projects and applications. In addition to the mandatory classes, some programs offer a variety of lighting design electives to meet students' interests. Table 6-2 summarizes the sequence of lighting design knowledge.

Lighting Design Knowledge Sequence

Year	Parsons	The Appalachian State University	The University of California at Irvine	Boston University	The University of Colorado at Boulder	The New York School of Interior Design
1	Light foundations, applications, history, theory, physics of light, luminaries, natural light, human factors, and analysis and presentation tools.	Fixtures selection and reflected ceiling plans	A Flexible Curriculum they can take a lighting class at any time and they can escape the topic too.	An exposure to light	Electives can be taken in any year	Light composition, quality, and reflected ceiling plans
2	Final project and thesis, electives, research and Theory.	Natural Light		Light vocabulary, functions, art, qualities, and pragmatic production	Light physics, metrics, energy, and light technology	Daylight and electrical light topics Electives in light history and light for retail and artwork (masters) physics and science of light, qualities of light, and lighting design
3		Building Systems 2 class with applications in design studio projects		Light presentation and light design thinking	Light design and applications	light controls, digital light simulation tools like AGi32 and DiaLUX, and light design studio projects
4				Professional lighting knowledge, light philosophies, history, and a final project	Electives: natural light, radiative transfer, controls class, advanced lighting design, optical design, light psychology, light perception, and theatrical lighting .	

Table 6-2. Lighting Design Sequence in the United States Lighting-Focused Programs

6.6 – Sequence of Digital Simulation Tools from the United States Interviews

Interviewee A introduces digital light simulation tools from the first semester because he/she believes that students need to understand the intention of the tool to use it creatively in the ideation phase: "it's a vital tool in the early conception of a design … Introduce it early in the student's education so that they can learn the idiosyncrasies and get past that and understand how to manipulate the tool." Appalachian State University introduces digital design software programs from the first year as well to encourage students to sketch with them in the ideation phase. Nevertheless, they do not teach students digital software programs that are specific to lighting design analysis.

Interviewee C presents design and drafting tools like Vectorworks from the first year, but students learn analog tools first: "in our curriculum, it's all introduced within their first year. That said, we're on quarter so we have about 10 weeks per quarter. Our first quarter is analog, for lighting designers." Interviewee E stated that students in the University of Colorado learn digital technology like Microsoft Excel spreadsheets from the first year, but they learn light simulation software like AGi32 in the third year in the Illumination Two class: "Excel sheet is introduced at the very first year."

The New York School of Interior Design introduces a digital light simulation tool in the third year for 3- or 4-year degrees and in the second year for a 2-year degree.

In sum, four programs introduce digital tools from the very first year to encourage students to use them creatively in the ideation phase. Nevertheless, most schools introduce analog tools first, after which they integrate digital light simulation tools in the third year for the 3- or 4-year programs and in the second year for shorter programs.

Digital Tools Sequence						
Year	Parsons	The Appalachian State University	The University of California at Irvine	Boston University	The University of Colorado at Boulder	The New York School of Interior Design
1	Digital tools	Digital tools	Digital tools		Digital tools	
2						Digital tools
3					Digital light simulation tools	Digital tools Digital light simulation tools
4						

Table 6-3. Digital Tools Sequence at the United States Lighting-Focused Programs

6.7 - Strengths of Lighting Design Pedagogy in the United States Based on Interview Responses

Developed lighting design programs in the United States have different strengths. For example, Parsons has a great location in New York City, it provides the school with lots of design sources, the faculty are part-time practicing professionals who bring in strong design expertise, the students are international (which brings a lot of cultural diversity into the program), the program balances well between qualitative and quantitative lighting knowledge, and it has multidisciplinary studios and collaborative learning between different disciplines. The school has a lighting lab that is equipped with unique lighting tools like a defused sky simulator, the educators communicate with one another, and the program offers a dual degree that combines lighting design with interior design, architecture, or industrial design. Interviewee A stated:

> I think being in New York City offers access to a lot of design resources and we have a lot of part-time faculty that come from the professional community that teaches. So, they bring their expertise into the program. It's a highly international program … So, it's very diverse, which is interesting from a cultural and geographic standpoint. And I think how we integrate multi-disciplinary teaching

> and the balance between the poetic and the technical is quite unique … we have shared studio environments where students across the school of constructed environments, architecture, interior design, and industrial design share spaces. Then we have a light lab that has tools in it that we use in reference … some of the unique tools includes a helipad for solar shadow alignments and geometry study and then a diffuse sky simulator … we have dual degrees and double majors, where you can get a combined degree in interior design and lighting or architecture and lighting, … a double major between industrial design and lighting design as well. So, I think that will help to complete some of the interest in technology and lighting like fixture design specifically and give students the ability maybe to broaden their choices with how they desire to focus their education.

The strengths of Appalachian State University are the application of theoretical lighting knowledge in practical studios, faculty who specialize in lighting, and the lighting lab with different lighting demonstration kits and applications, as Interviewee B noted:

> I'm an LC and I'm very involved in lighting and have been for ages … also the lighting lab … I honestly saw right after the integration of that … I saw test scores improve. I saw that's right when we started winning our Source awards.

The strengths of the lighting design pedagogy at UCI are collaborative learning and teamwork, an emphasis on digital technology, and the availability of seven performance spaces for application and demonstration. Boston University's strengths are the student-centric pedagogical approach where educators shape the learning process based on each individual's needs, the mentorship approach, hands-on learning, professional practicing faculty, and a state-of-the-art lighting lab.

The strengths of the lighting design pedagogy at the University of Colorado at Boulder, as Interviewee E described, are the emphasis on cognitive thinking and professional knowledge, the collaborative learning environment between architectural engineering and environmental design students, and the lighting lab with its unique and flexible lighting technologies:

> Professionally, our students are super well-equipped. That's what the employers tell us … I have environmental students and architectural engineering students in that class co-mingling. It's so interesting to see how stiff the engineering thought is and how fluid the other one and how they're clashing. That's what I love about it because suddenly the engineering students are saying, "Wait for a second, I can stretch my arms a little further and it's okay." … We have our lighting laboratory … We are enjoying right now things like a new gonio, a photometer, lighting sphere, for example. We've created a bunch of demonstrations for lighting design for students to deal with materials, to be able to see the difference between, say, beam angles and directionality against textured walls and a very flexible system.

Other strengths are the nine different lighting classes that the program offers and strong communication between instructors. The school also brings in adjunct faculty and digital lighting software specialist to teach students advanced lighting design knowledge and technology:

> We do use adjunct professors or faculty when we need, for example, the optical design class is taught by an adjunct … We have been very fortunate because

Lighting Analyst is a local. Their company is here in Colorado. We bring people from them and … they're teaching them deeper things about the software that they didn't know before.

Lastly, the strengths of the New York School of Interior Design include technical lighting knowledge (which prepares students for their professional careers), professional practicing faculty with different lighting design backgrounds, evening classes that allow students to work in professional lighting firms during the day, the application of light theory in students' projects, and an updated lighting lab with different lighting samples and technologies. Interviewee F explained: "We have a unique lighting laboratory… we have the first installation that lets you look at Metta, MERS, and color compositions."

In sum, the shared lighting design pedagogy strengths are professional knowledge that prepares students for their future careers, lighting labs with different lighting technology, the professional practicing faculty, the application of theoretical lighting knowledge in studio projects, collaborative and multidisciplinary learning, and effective communication between lighting educators. The NVivo word count emphasizes the lighting lab, professional faculty, and having a multidisciplinary studio environment.

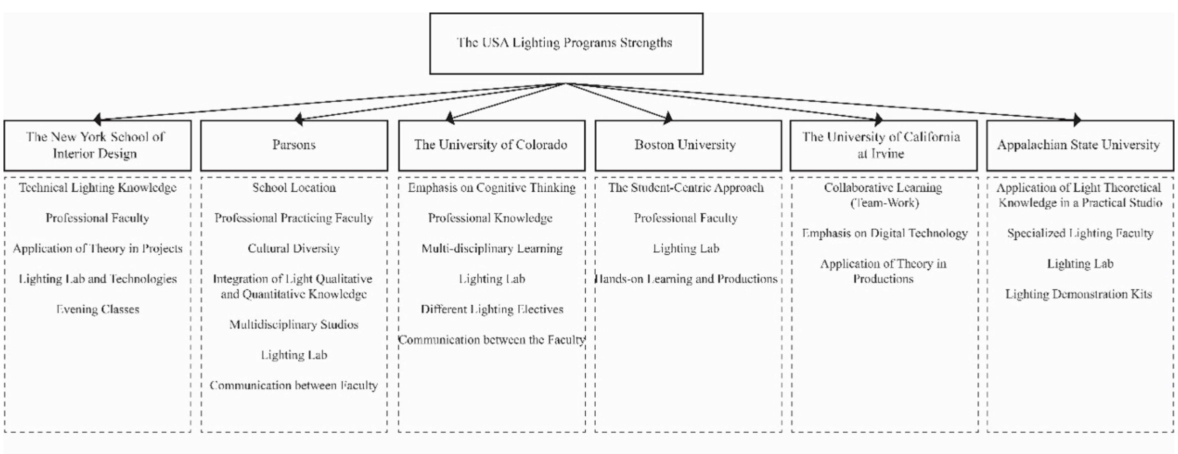


Figure 6-3. Strengths of the United States Lighting-Focused Programs

6.8 – Foundational Lighting Design Knowledge in the United States

The researcher analyzed syllabi and exercise sheets from five interviewees and asked them about light foundational knowledge that students need to learn before they graduate as designers, the knowledge they need before they learn lighting design and digital tools, and special lighting design knowledge. The following sections present the results from both the document review and the interviews.

6.8.1 – Lighting Design Foundational Knowledge Based on the Document Analysis

The Light Space, Art course at Parsons includes lighting topics such as light properties and effects, light color, electric light sources, natural light factors, light art and poetics (light installations), light's effects on visual perception and experience (light's effects on human factors), light technologies, environmental psychology, and light applications. The Allied Studio, in contrast, offers the following topics: natural light, light sensorial effects, light presentation and documentation, social justice, codes and regulations, solar geometry, light quality, light and sustainability, electric light sources, light design process, quantitative light measures, light controls, luminaire design, environmental psychology, and design thinking.

Light principles, light sources, light analysis, light calculation, light presentation and documentation, light terminologies, light and color, light applications and strategies, light's effects on human factors, codes and standards, light technology, light sources history, light effects (theatrical lighting), and light controls are lighting subjects offered in the Interior Design Systems II course at Appalachian State University

The Digital Design: 2D/3D modeling, Digital Design: Lighting Graphics, and Lighting Design /Digital Modeling courses at the University of California at Irvine include lighting design digital modeling and light presentation. The Lighting Design Studios 1, 2, 3, 4, 5, and 6 at Boston University include various topics. Studio 1 includes light art, the lighting design process and vocabulary, lighting design thinking, light perception, light functions and qualities, light angles and intensities, light composition, light color, and light movement. Studio 2 covers light techniques (technology) and light qualities. Studio 3 focuses on the lighting design process, light presentation, and color theory. Studio 4 tackles light communication (expression of feelings using light) and light quality (mood and textures). Studio 5 emphasizes light functions, light applications, and light qualities. Last, Studio 6 covers professional lighting practice, art history, light communication, and light presentation tools.

As for the Lighting I course at the New York School of Interior Design, the following lighting design topics are presented: light and shadow, light perception, light's effects on human factors (light psychological and physiological effects), light terminology, luminaires and applications, light sources, daylight, light design process, lighting design documentation, light calculations (quantitative metrics), light codes and regulations, light presentation, light controls, key players in lighting, color theory, environmental concerns related to lighting (sustainability), design thinking and principles, and professional lighting knowledge.

In sum, the topics that four or more programs cover are light effects on human factors and health, light properties and principles, light and color, light technology and controls, light applications and strategies, light presentation and documentation, and quantitative lighting measures. Other topics that only three or fewer programs mentioned are: design thinking, light sources, natural light and solar geometry, light art, light qualities and effects, light and sustainability, environmental psychology, lighting design process, light codes and regulations, luminaire history, art history, theatrical lighting, light digital modeling, light perception, light and movement, and professional lighting practice. xx

In addition to the syllabi, the researcher gave the interviewees a handout with lighting design topics to sort from beginner level to advanced levels. Table 6-4 presents the results from the handout.

USA Interviewees Categorization of Lighting Design Topics (Tacit Knowledge)

Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
Light Definition and Purpose Light Perception Layers of Lighting Design Electrical Light Sources Light Color Brightness and Glare General Knowledge about Electricity Design Thinking	Light Measurements and Calculations Luminaries Types and Operation Human Factors Light to Enhance Architecture and Interior Spaces Lighting Design Process, Tools, and Deliverables Safety and Security (way-finding and communication) Light Art and Inspirational Mediums Light Theory and Philosophy	Fixture Design Lighting Design Digital Computation and Technologies Theatrical Lighting	Light Art and Inspirational Mediums (Example: installations and photography)
Physics of Light + Light Behavior with Surfaces Lighting Design Tactics and Qualities Energy and the Environment History of Light Outdoor Lighting Lighting Design Profession (professional Practice) Color Theory	Daylight Integration and Influence (daylight strategies) Energy and the Environment Outdoor Lighting Design Studio Focused on Lighting Design Light Applications and Case Studies (Activity Needs)		

Table 6-4. USA Lighting Design Subjects Categorization

Figure 6-4 presents the lighting design topics from the United States documents.

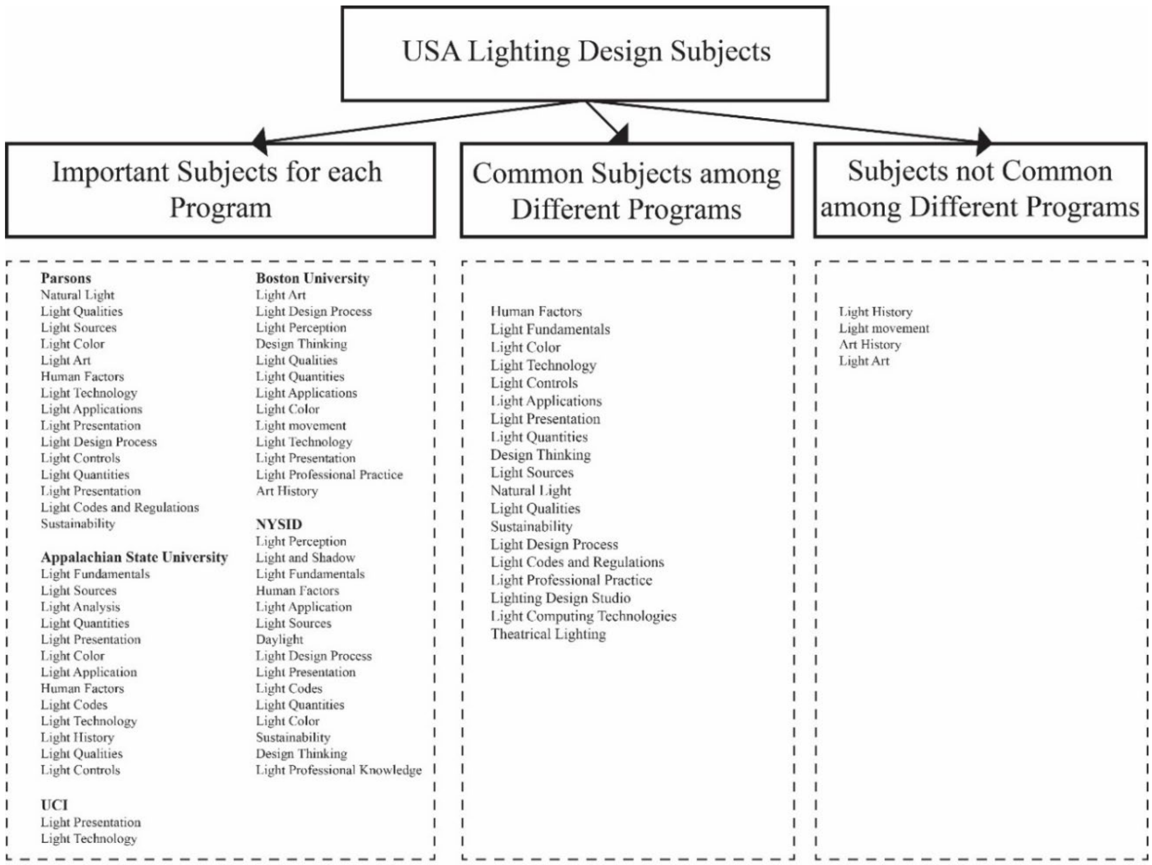


Figure 6-4. USA Lighting Design Subjects

Figure 6-5 summarizes the tacit knowledge from the United States documents.

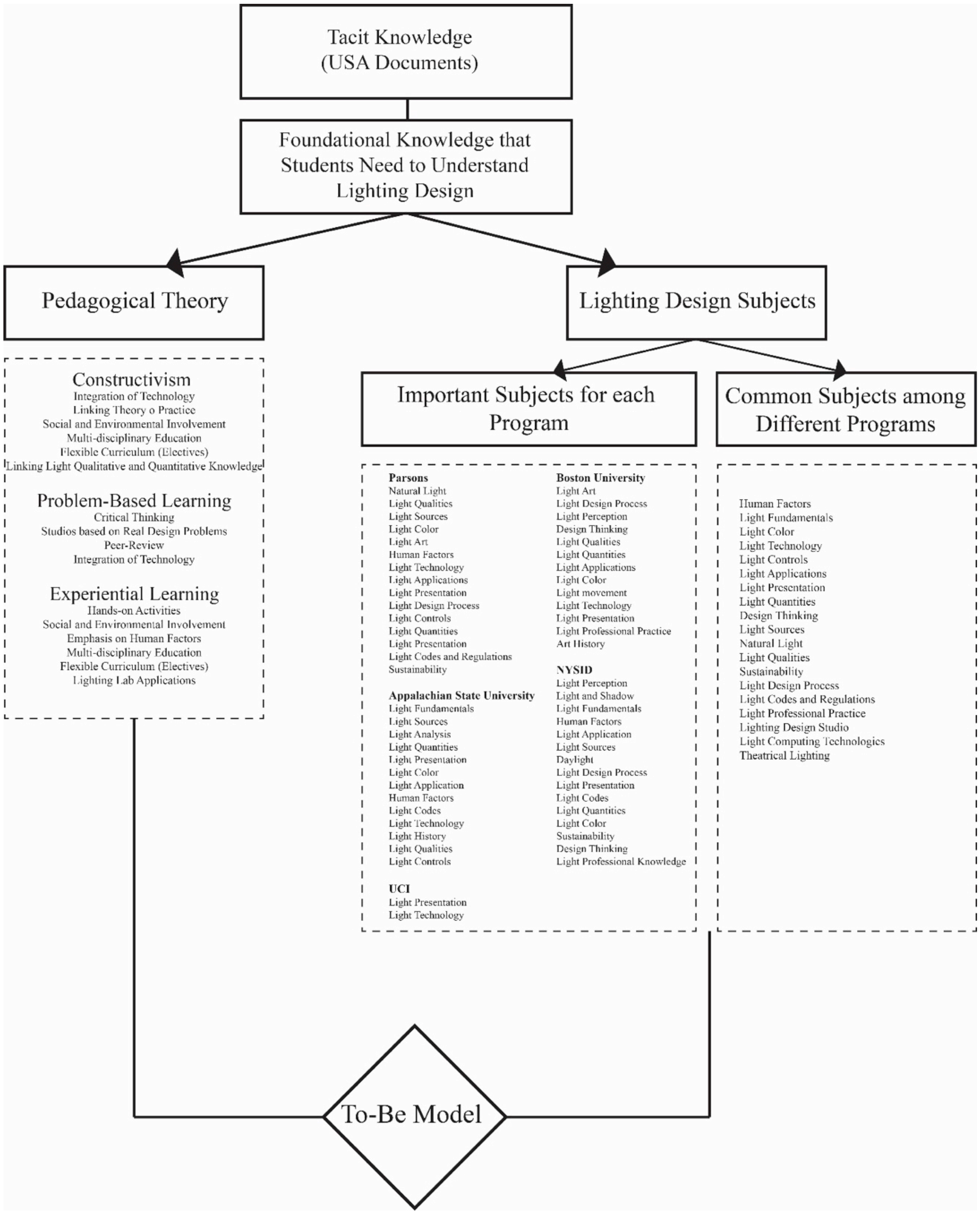


Figure 6-5. The United States Lighting Documents' Tacit Knowledge Domain

6.8.2 – Lighting Design Foundational Knowledge Based on Interview Responses

Interviewee A thinks that light's effects on human and social behavior, light psychological effects, light color, light perception, light quantity, light composition, light context, and light functions are all foundational knowledge that students need to learn before they graduate as designers:

> You have to understand the human perspective within all of this. How does the human inhabitant respond to and react to certain aspects of the light? That includes color, composition, quantity, the context of the activity, the task activity, the social activity, urban, rural, interior, exterior … It's just understanding human beings as a species; how it sees? How it senses? How it psychologically digests and translates this information is critically important.

Interviewee B believes that light's effects on human health and indoor air quality, light's interaction with materials and finishes, environmental sensibilities, sustainability, and light's relationship to acoustics are all foundational knowledge. Interviewee C indicates that color theory, light history, light theory, light application, light art, light fixture specification, light technologies, light effects on human behavior, and storytelling with light are important foundational knowledge: "They need to understand how lighting moment to moment affects a guest or an audience member … no matter what discipline of lighting you're doing, you're trying to tell a story." Interviewee D thinks that light functions, light qualities, light properties, light art, art history, light technologies, and light design thinking are important foundational knowledge:

> I think it's very important that at the beginning we are talking about our ideas … The functions and qualities. You have to understand what the intent of the light … And then you have to understand the individual properties or qualities of light and how they relate to what you want it to do.

Light energy, light metrics, light physics, light culture, light perception, and light design thinking and evaluation are important foundational knowledge based on Interviewee E's point of view:

> They need to know the metrics … your eye is not the same as my eye. The way I perceive light culturally is not the way you perceive it culturally. A true understanding of the fundamentals of the medium is really very important. I think, more than understanding physiology and psychology.

Interviewee F believes that light design thinking and evaluation, light metrics, lighting controls and sensors, light composition, light hierarchy and layers, light's interaction with materials, lighting codes, light qualities, and light design presentation are important:

> In terms of quality of light I think … where to put lights to create different moods and effects … I want my students to start out thinking where do we want our eyes to go in this space? What's the hierarchy of things? And so, whether it's sketching or using Photoshop or even just writing out, being able to describe it to us in pin-ups and presentations and a mixture of showing inspiration images, why they like them. I look for that as a primary driver at the beginning.

In sum, lighting foundational topics that design students need before they graduate are physics of light, light properties (metrics), light energy and effects on the indoor air quality (light quality), light types, light technologies (controls and sensors), light functions and applications, light design thinking and evaluation, light's effects on human health and behavior, light color theory, light perception, light art, light composition, light hierarchy and layers, light presentation tools, light design context, light and art history, light theory, light culture, and lighting codes. The NVivo word count indicated that the most emphasized topics are light quality, metrics, history, theory, color, art, and functions.

6.8.3 - Knowledge Needed before Lighting Design from the United States Interviews

Students need foundational design knowledge before they learn lighting design or digital light simulation tools. Interviewee A believes that the design process, drawing techniques, critical thinking, spatial reasoning, physical modeling, and design modeling software are important topics to learn before lighting design knowledge. Interviewee B thinks that design thinking, building construction, building technology, building services (plumbing, electrical, and HVAC), codes, architectural representation, and digital modeling are important. Interviewee C believes that building basics for architecture is important, whereas Interviewee D thinks that technical knowledge, art history, and architecture design are basic topics. Interviewee E asserted that introduction to architectural engineering, building materials and systems, building design, math, and computing technology are important foundational topics. Last, Interviewee F thinks that math, color theory, representation tools, computing technology, and rendering are important prior lighting knowledge.

In sum, the prior lighting subjects that design students need to learn are design thinking, the design process, math, building construction, materials, design presentation, spatial reasoning, critical thinking, computing technology, physical modeling, drawing techniques, design technology, building services, building codes, art history, and color theory. The most emphasized topics based on the NVivo word count are modeling skills (both physical and digital), drawing techniques, the design process, design thinking, and building science and technology.

6.8.4 - Knowledge Needed Before Learning to Use Digital Light Simulation Tools Based on Interview Responses

Interviewee A believes that students need to learn design theory, human factors, physics of light, history of lighting design, and design thinking before learning to use digital light simulation tools. Interviewee B thinks that students need to learn manual drafting and design graphics: "understanding the graphics of it, understanding when do you get onto digital after the sketching? … The understanding of line weights … How to title the drawing, how to take a section." He/she also thinks they need building science foundations and basic digital modeling skills. Interviewee C agreed with Interviewee B that students need to learn analog presentation and drafting tools:

> Analog first, I think it is important to tactically touch something. Hand drafting, and knowing what it feels like to use a thicker pencil versus a thinner pencil and apply more pressure and less pressure, lightweight line type all this … Having that experience makes you think about it more in the computer.

Interviewee D thinks that students need to learn design thinking, design vocabulary, art, and design foundations before digital light simulation tools: "you have to have a strong basis in concept, vocabulary, intent, and art. All the art part has to be solid before you move into the technology part."

Interviewee E implies that students need to learn manual drafting tools, design and lighting design fundamentals, lighting design reasoning, light metrics and behavior, human perception, materials characteristics, technology, and lighting software's capabilities and limitations:

> This thought of brain, hand, paper at the beginning of the thought process is very important … Teaching the students to be able to question suspect numbers, to be able to backtrack why is that those numbers came out the way they are, and not taking those numbers for granted … understanding how light behaves within a space and materials and all of those things are very important … They have to know how the eye works … They need to know technology.

Lastly, Interviewee F seconded the previous interviewees' feedback in that students need to learn physics of light, light metrics, light measurements, light technology, luminaires, the science of light, and physical modeling tools.

In conclusion, the topics that design students need before learning digital light simulation tools are physics of light, lighting fundamentals, manual drafting and analog design presentation tools, design thinking and reasoning, design theory, design vocabulary, human factors and perception, light technology, history of lighting design, art, design foundations, materials characteristics, lighting software's capabilities and limitation, digital modeling, building science, light measurements, and types of luminaires. The most emphasized topics based on the NVivo word count are analog drafting and modeling techniques, design thinking, and fundamental lighting knowledge like physics and theory of light.

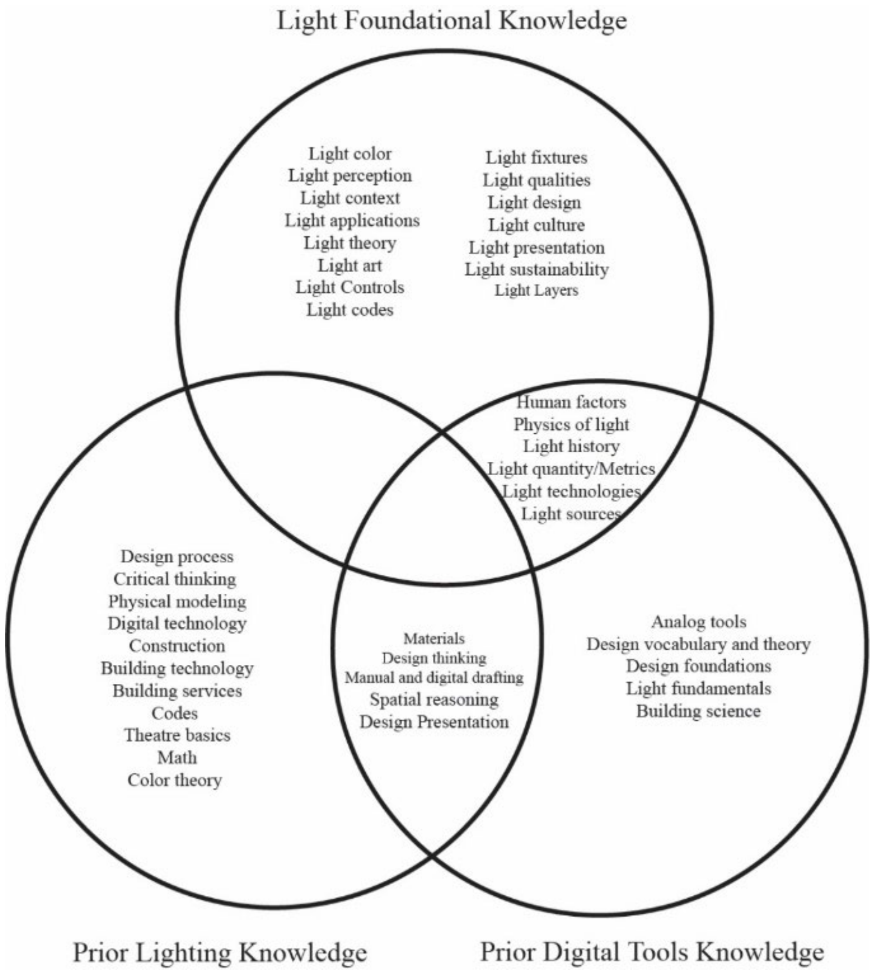


Figure 6-6. Lighting Design Foundational Knowledge in the United States Lighting-Focused Programs

6.8.5 –Qualitative and Quantitative Lighting Design Knowledge from the United States Interviews

Lighting design has both qualitative and quantitative aspects. Interviewee A thinks that it is important to integrate both from the beginning to help students translate light measurements into human experiences:

> The two are in constant dialogue and the students are reading theory. They are exploring the poetics of light and then looking at the measured outcomes through digital software and analytical software … Because light is so abstract and so

ephemeral and conditional on so many levels, being able to measure it is super important. But more importantly, understanding how to interpret the data. The outcome of the measurement to reality … we're not interested in the data for the sake of data or meeting a quantitative requirement. We're interested in the data to understand experientially how the space is performing.

Interviewee B prefers to begin with qualitative lighting knowledge to touch upon students' feelings and get them excited about studying lighting design. For example, he/she begins with daylight's effects on human health, and how light influences people's mood and perception: "The very first week when we talk about daylight, we talk about seasonal affective disorder, we talk about mood, we talk about how most people are phototropic." After qualitative knowledge, he/she introduces luminaires and then light photometrics, calculations, controls, applications, and presentation. Interviewee C believes that qualitative lighting knowledge is more important in theater. Interviewee D agreed with Interviewee C that they do not measure light in theater; they only measure light angles to create highlights and shadows.

Interviewee E introduces quantitative lighting knowledge and its fundamentals first because the engineering mindset looks for light physics, numbers, measurements, and fundamentals:

> They're engineers. They're coming out of 2 years of very heavy engineering … it makes sense that they really deep dive into the fundamentals of lighting. Once they understand what they're dealing with, then we put it in perspective and say, What does it mean for us? How does it relate to us as people and in materials and the interaction … students coming out of engineering in this heavy mindset …

> you introduce the softer part and the students really see it as the softer part, right? While they're learning all this heat transfer and all of these things we're talking about psychology and the students are really thinking that this is just fluff.

The New York School of Interior Design (NYSID) program starts with light theory, principles, history, and light qualities, then proceeding to more quantitative aspects and applications of light, as Interviewee F explained:

> We touch on some of the principles, like Richard Kelley's three tenants of lighting. … The application of lighting follows that. I would say that the curriculum of the school starts a little more theoretical and research and history and then goes into more quantitative. And yeah, lighting starts qualitative and gets quantitative.

He/she tries to focus on quantitative lighting knowledge in terms of calculations because interior designers usually emphasize light ideas, concepts, and renderings: "the quantitative research really comes in with lighting, the lighting courses are considered math courses in terms of we get into foot-candle levels and calculating targets."

In sum, most programs start with qualitative lighting knowledge followed by quantitative knowledge except for the architectural engineering degree, which starts with quantitative knowledge to respond to the engineering mindset. Parsons stands out because they combine both from the very beginning.

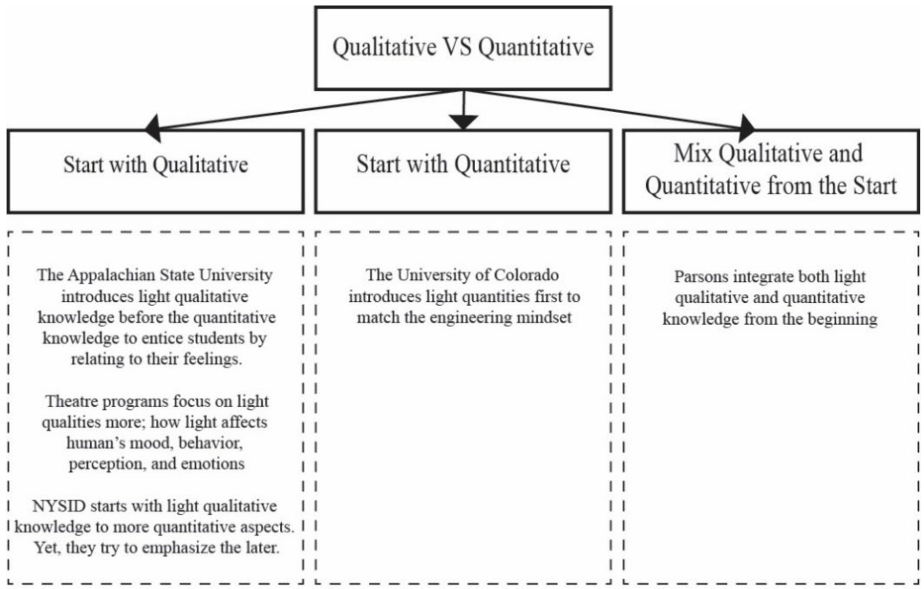


Figure 6-7. Lighting Design Qualitative and Quantitative Knowledge in the United States Lighting-Focused Programs

6.8.6 – Lighting Design Special Topics Based on the United States Interviews

Developed lighting design programs in the United States have special topics that distinguish each program from the others. For instance, Interviewee B emphasizes the cultural aspects of lighting at Appalachian State University. Interviewee C focuses on event lighting and park lighting at the University of California at Irvine. Interviewee D has a unique class called light and movement at Boston University. He/she collaborates with dancers and choreographers to teach students how light affects human movement and vice versa. He/she also concentrates on light and color. Interviewee E thinks that what distinguishes the University of Colorado is the technical aspects of light like luminaire design, radiative transfer, controls, and outdoor lighting. Quantitative aspects of light like lighting loads and schedules, and the large-scale lighting mock-ups are unique topics at the New York School of Interior Design.

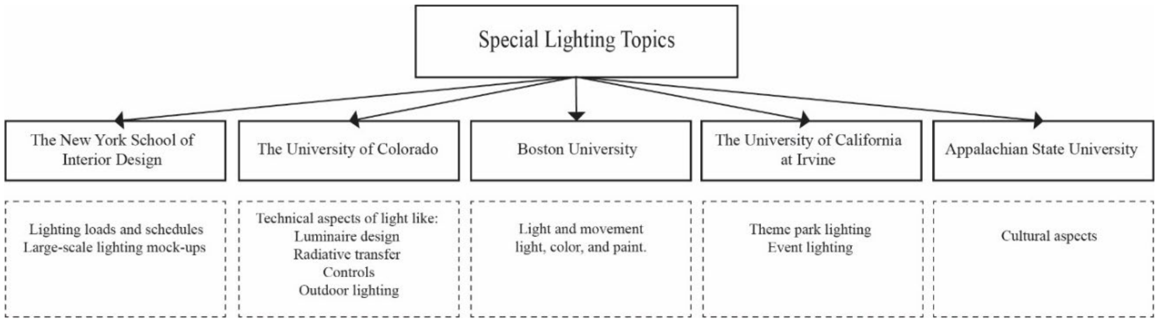


Figure 6-8. Lighting Design Special Topics in the United States Lighting-Focused Programs

6.9- Lighting Design Knowledge Delivery Methods in the United States

The researcher interviewed and analyzed syllabi and exercises sheets from five interviewees to understand the lighting design teaching methods.

6.9.1- Lighting Design Knowledge Delivery Methods from the Documents

Educators from developed lighting design programs in the United States use different methods to deliver lighting design knowledge. Interviewee A uses cognitive questions like why and how questions to ignite students' cognitive thinking. He/she uses hands-on activities/exercises in the light lab, weekly pin-ups, peer review, lectures, readings, field trips, large-scale projects, journal writing, group critiques, seminar discussions, and individual research (precedents, observations, recordings, and diagrams). He/she encourages teamwork, time organization, and leadership. He/she uses multidisciplinary group exercises to promote cross-disciplinary thinking and teamwork. He/she exposes his/her students to different lighting digital tools like Rhino with Diva plug-in, Sketch-Up with Light Stanza plug-in, Ecotect, AGi32, Sun Surveyor (App), and Sun Seeker (App). He/she believes that students need to learn different light presentation tools like diagrams, photographs, drafts, material displays, perspectives, models (both physical and digital), and light sources specifications to better present their designs.

He/she uses different readings and books such as *The Private Life of Modern Architecture* by Colomina, and Beatriz *The Art of Light and Space* by Butterfield; *Sun, Wind & Light, Architectural Design Strategies* by Brown and DeKay; *The Lighting Handbook* by the Illuminating Engineering Society; *Questions of Perception: Phenomenology of Architecture* by Holl, Pallasmaa, and Perez-Gomez; *Between Silence and Light: Spirit in the Architecture of Louis I. Kahn* by Lobell; *The Architecture of Natural Light* by Plummer; *Daylight & Architecture: Light to Life* (Spring 2015) by Velux Group; and *Daylight & Architecture: Forward Through Feedback* (Spring 2018).

Figure 6-9. Parsons Lighting Lab

Interviewee B uses lectures, teamwork exercises, technological-based learning and collaboration, demonstrations in the light lab, field trips, exams, and hands-on exercises to deliver lighting design knowledge. He/she exposes his/her students to lighting manufacturers' competitions and encourages them to display their lighting design to the public in light expositions. As for books and readings, he/she uses *Fundamentals of Lighting* by Winchip and *The Architecture of Light* by Russell. Interviewee C uses video tutorials, quizzes, projects, and teamwork exercises to deliver lighting design knowledge in his/her digital lighting graphics courses.

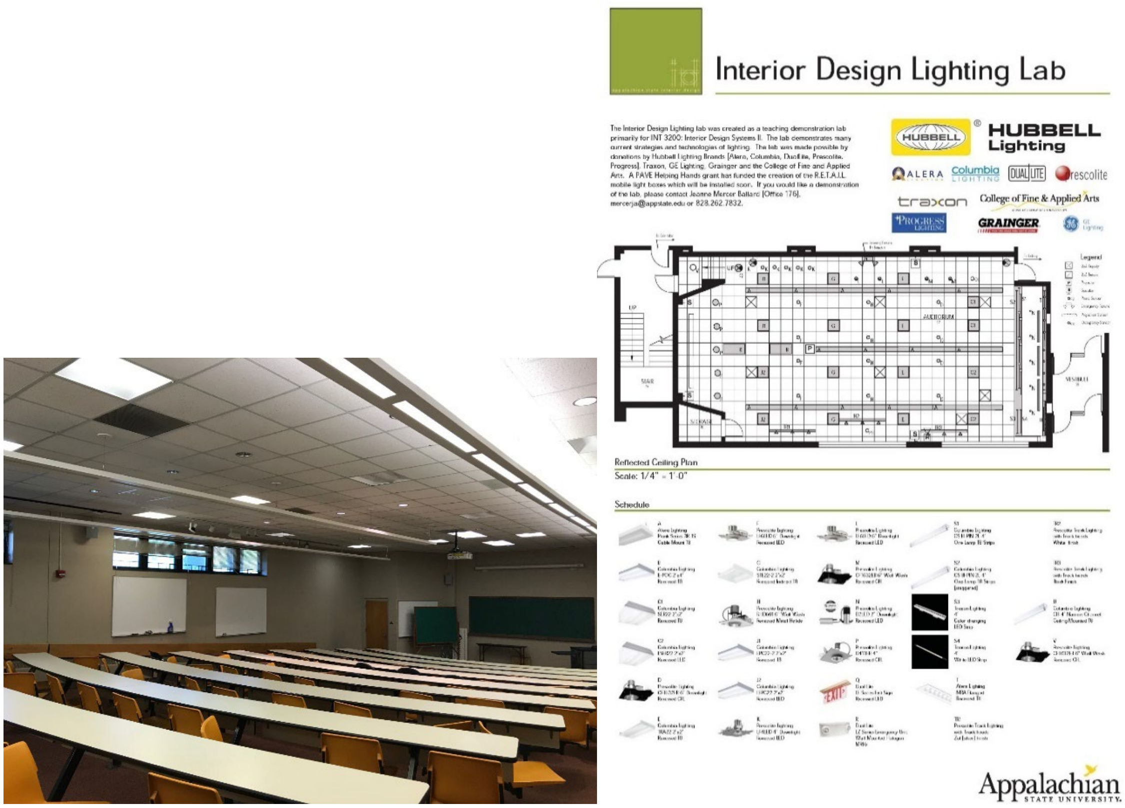


Figure 6-10. Appalachian State University Light Lab

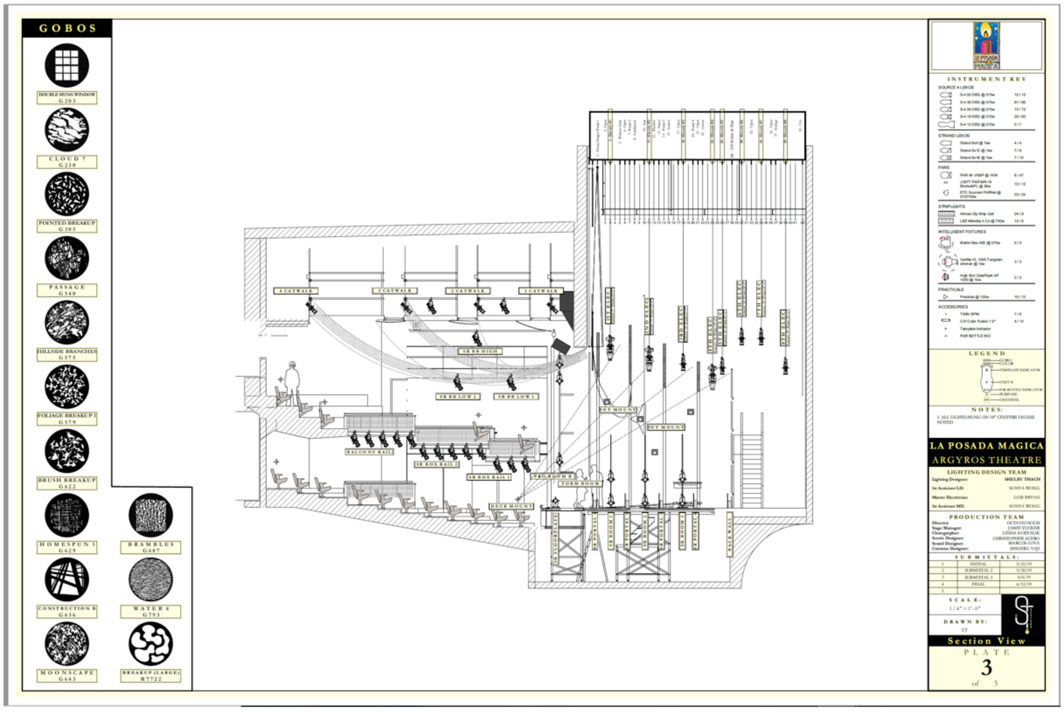
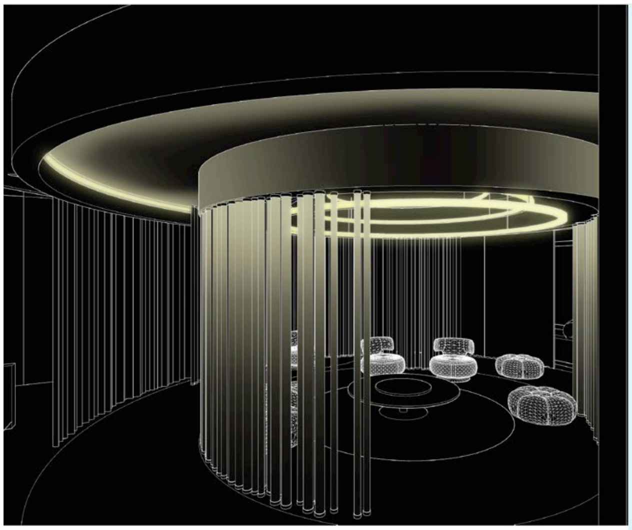


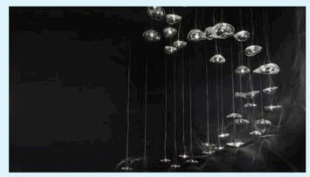
Figure 6-11. Example of a Student Work from the Digital Lighting Graphics Class at Appalachian State University

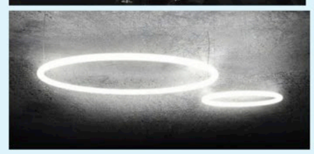
Interviewee D uses hands-on activities, demonstrations in the lighting lab, field trips, assignments, peer-review, full-scale projects, and teamwork exercises to deliver lighting design knowledge in his/her lighting studios. He/she encourages independent design decision-making to emphasize design critical thinking. Interviewee F uses readings, assignments, props and demonstrations, projects, research, field trips, lectures, exams, journal writing, and theoretical knowledge application to deliver lighting design knowledge. He/she uses the following books: *The Illuminating Engineering Society Handbook*, *Interior Lighting for Designers* by Gordon; *The Architecture of Light: Architectural Lighting Design Concepts and Techniques* by Russell; and *Fundamentals of Lighting* by Winchip.

Figure 6-12. NYSID Light Lab

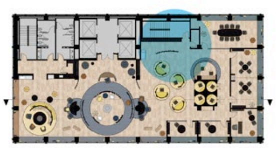


TREATMENTS	METHODS
Decorative clustered illumination for seating area and reception desk	Series of crystal pendants, in three different dimensions (8", 10", 12") Dimmable LED lamp.
Indirect lighting emanated from architectural frame reveal	Cove lighting. LED tape
Direct downlight to accentuate the texture of the glass columns creating a waterfall effect	Downlight LED lamps over each column
Direct-indirect light in the center of the room for decoration.	Circular LED direct light polycarbonate pendant lamp.





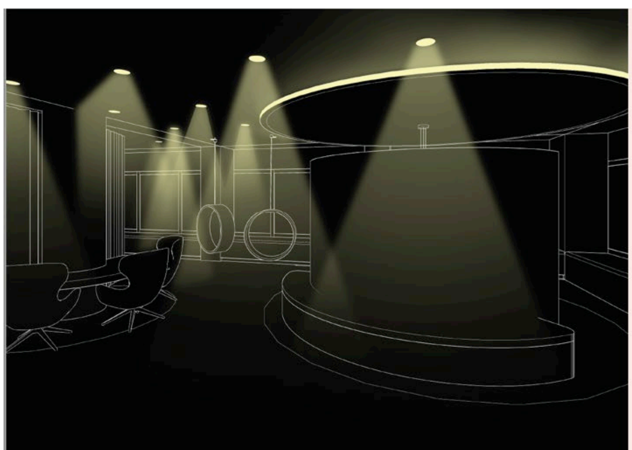
Diagrammatic perspective sketch



PUBLIC AREA

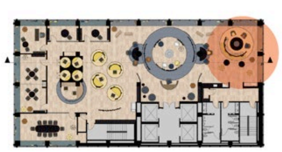
"THE WELL"

charity: water



TREATMENTS	METHODS
General illumination for circulation.	Recessed trim-less downlight. 3" diameter. Recessed and 360° adjustable bulb. White painted metal finish.
Indirect lighting emanated from architectural frame reveal	Cove lighting. LED tape
Decorative suspended lighting over the table of the gathering area.	Pendant with acrylic diffuser, white matte lacquer finish. 2700K LED bulb. Dimmable.

Diagrammatic perspective sketch



PUBLIC AREA

PANTRY AND MULTIPURPOSE

charity: water

Figure 6-13. A Graduate Student's Work from the NYSID

6.9.2- Lighting Design Knowledge Delivery Methods Based on Interview Responses

Educators use different knowledge delivery methods that comply with their overarching pedagogical philosophy. Interviewee A uses lectures with practical applications, hands-on modeling, drawing, field trips, and demonstrations in the light lab to deliver lighting design knowledge. The program at Parsons offers faculty-led workshops and technicians' assistance to teach students digital light software programs as well. Interviewee B uses lectures, physical demonstrations, case studies, research ideas, examples, exercises, site visits, and hands-on studio applications:

> We do a lot of lectures, but I try not to keep it too boring. So, I have a lot of props. So, when I'm talking about lamps, I'm passing lamps around the room. When I'm talking about fixtures and luminaires, I'm pointing up in that ceiling and showing demos in that room … Case studies or even just smaller, little ideas, like theoretical ideas … we did a luminaire scavenger hunt, and then we did a photometric exercise … like they can learn from it over here and then apply it over in the studio.

Interviewee C uses projects, site visits (to projects and shows), exercises, manufacturers visits, light demonstrations in a real theater, and peer review:

> We do the field trip class … we go visit manufacturers, visit lighting design firms … Then they have to pick a store that does that well and a store that does that badly … We bring manufacturers out to show their products … we physically light in real-time on the stage.

Interviewee D uses site visits, scavenger hunts, manufacturers' visits, professional guest lectures, research projects, sketching exercises, examples, written projects, light lab applications, and hands-on activities and projects:

> I have a scavenger hunt that they go to a museum and I give them a list of things that they have to find in paintings about light. We have a lot of visits from manufacturers and other lighting professionals who come and talk about their work. We do research projects in which they have to present a concept and it's supported through visual research. We sketch … projects that they do in the light lab about a specific topic … So, our primary teaching tool is project-based.

Interviewee E uses textbooks, lectures, readings, research, demonstrations both in the light labs and as props in the class, assignments, hands-on exercises, visualizations, and a final project. He/she encourages his/her students to read before each class to cover more information within a short time:

> There are reading responses that the students have to complete before the class … It provides some background to where I can come in in my classes and start either diving deep or widening the knowledge to be able to cover more material in more depth.

Interviewee F uses presentations, site visits, light animation, light schedules, light controls, narratives, spec sheets, hands-on activities, applications in the design studio project, exams, peer review, inspirations, computer research, light lab demonstrations, portable demonstration cases with light props and fixtures, digital renderings, and physical mock-ups to deliver lighting design knowledge:

They're doing studio projects, but they also have a few exams that are more lecture-based … we look at either doing basic animation or at least creating multiple versions of a room and then cross-feeding in PowerPoint. Things that can show how light is a dynamic element … I teach the foundation of light while showing digital tools …The first course they can pick between a retail space and office or a residence … That way they are looking at their peers. Even if you choose residence, you're giving your peer feedback on their office concepts and ideas. So, over the one-year course, we're exposing them to lots of project types.

Figure 6-14 summarizes the different teaching methods. The most used tools based on the NVivo word count are lighting lab demonstrations, field trips, manufacturers visits, design projects, assignments, visualizing light using analog and digital tools, lectures, and hands-on activities.

Lighting Design Knowledge Delivery Methods

Parsons	Appalachian State	UCI	Boston University	University of Colorado	NYSID
Lectures Hands-on modeling Drawing Analysis Light-lab demos Field trips Workshops	Lectures Physical demonstrations Case studies Research ideas Examples Exercises like luminaire hunt Site visits Studio applications Exams Teamwork	Projects Site visits Exercises: comparing a good and a bad lighting scenario Manufacturers visit Light demonstrations Peer review Visualization using manual and digital tools	Site visits Scavenger hunts Manufacturers visits Guests' lectures, Research projects Sketching exercises Examples Written projects Lab applications Hands-on activities	Textbooks Lectures Readings Research Light labs demos Props in the class Assignments Hands-on exercises Visualizations A final project	Presentations Site visits Light animation Light schedules Controls narratives Spec sheets Hands-on activities Studio applications Exams Peer review Inspirations Computer research Light lab demos Portable props Digital renderings Physical mock-ups

Lectures, presentations, site visits and scavenger hunts, hands-on activities, projects, assignments, exams, lighting lab demonstrations, physical props, manufacturers visits, professional guest lectures, workshops, case studies, inspirations, team projects and peer review, application of light theory in the design studio project, digital renderings, readings, visualization tools both manual and digital, and dynamic animations.

Figure 6-14. Lighting Design Knowledge Delivery Methods at the United States Lighting-Focused Programs

Figure 6-15 shows the researcher's categorization of the teaching methods.

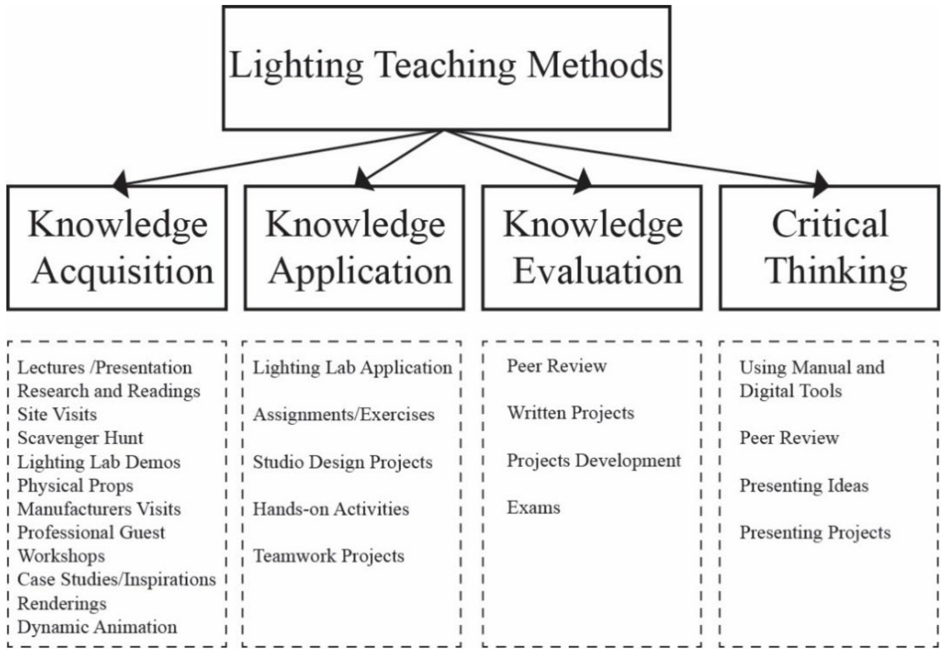


Figure 6-15. Lighting Design Teaching Methods Categories in the United States Lighting-Focused Programs

6.9.3- Lighting Design Exercises Based on the United States Documents

Lighting design exercises are important for translating theoretical lighting knowledge into practical applications. Each educator provides his/her students with some exercises to help them better understand different aspects of lighting design. Interviewee A encourages his/her students to create a light installation, as a group, to understand light as a phenomenon and evoke different human senses. The installation teaches students how to construct things with special attention to materials, proportion, details, and form. In this exercise, students also form a question about light, write about the light phenomena, and document the installation using video and printable media. Interviewee A also encourages his/her students to readapt an existing building to a new purpose or an activity with a focus on human sensorial experiences.

Interviewee B introduces his/her students to light source scavenger hunts, an office space design, and a cultural restaurant design to meet IES recommendations in order to understand light qualities and calculate light levels. He/she encourages them to present their lighting designs using different media (including digital) and document their design process both in visual (plans, drawings, sketches, schedules) and narrative formats. Another exercise is a site survey where students draw an existing ceiling, create a light schedule for the light sources, and provide cut sheets.

Interviewee C invites his/her students to draft a light plot with sections and different views, write a narrative about their lighting design concepts, identify lighting controls, and create light renderings. Interviewee D invites his/her students to create a performance in a lighting lab, write a critical comparison paper between different plays, translate text into an expressive light play, create a light collage, and find light sources in a scavenger hunt.

Interviewee F introduces his/her students to an office project to teach them about task lighting and ambient lighting and encourages them to design a multi-story retail project to learn about accent lighting and light documentation. He/she also encourages them to write about a light experience, to measure light levels in different spaces, to sketch different light treatments, to research about IESNA standards, to create illumination hierarchy diagrams, and produce light fixtures schedules and cut sheets.

Figure 6-16 summarizes the procedural knowledge from the United States documents.

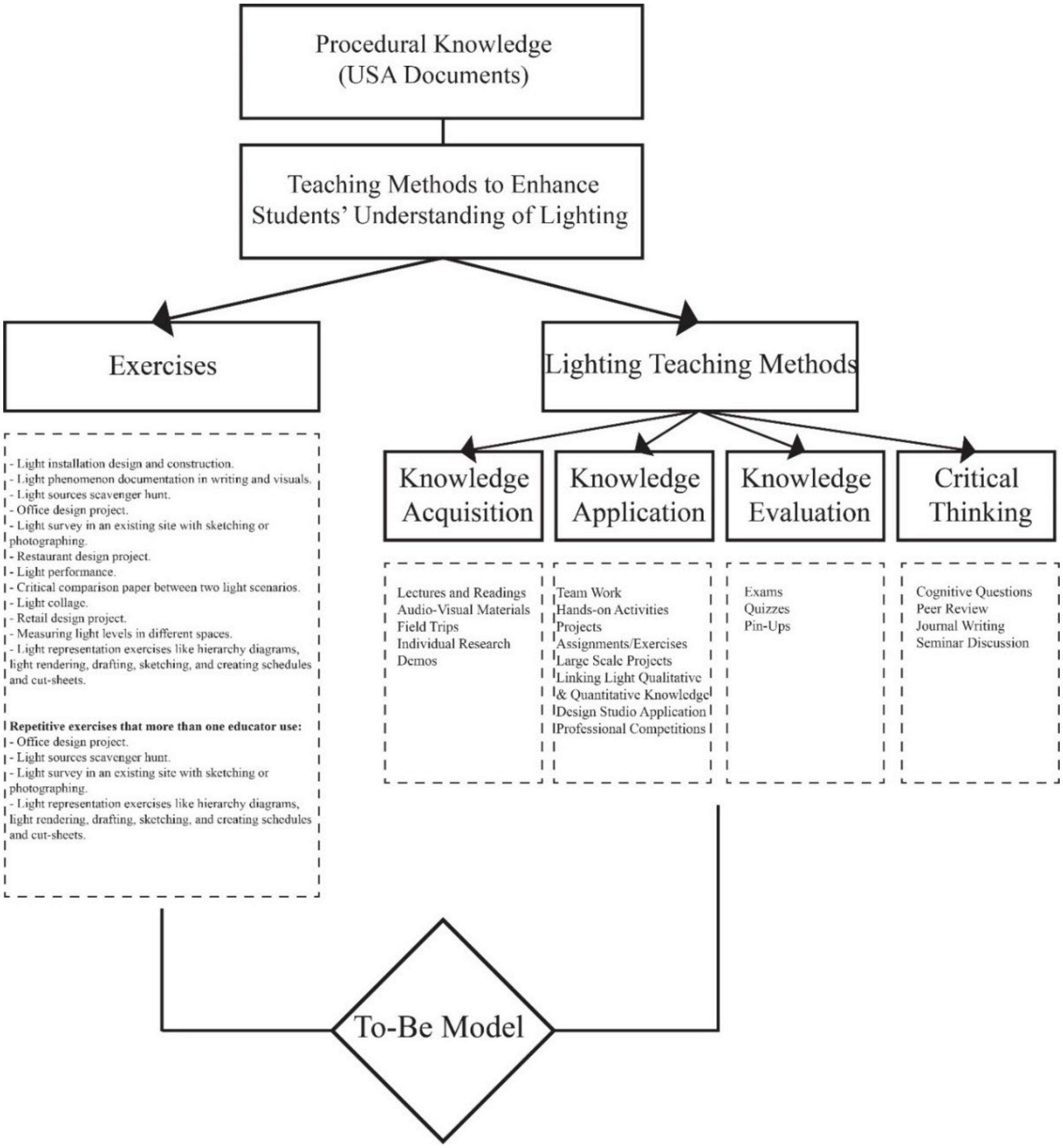


Figure 6-16. The United States Lighting Documents' Procedural Knowledge Domain

6.10 - Lighting Design Cognitive, Presentation, and Analysis Tools

This section explains the cognitive and presentation tools that educators believe are useful in the design process.

6.10.1 - Lighting Design Presentation, and Analysis Tools Based on Interview Responses

Interviewee A thinks that drafting, diagramming, and modeling tools, both digital and manual, are important. He/she believes that AGi32 and programs that offer gray scale and pseudo color renderings are good lighting analytical tools:

> Analytical tools that measure and offer some kind of spatial modeling of lighting effects like AGi32 that we use I think is really important … I think the quantitative is part of it. But then the rendering modeling that gives gray scale and pseudocolor images is super important. The other kinds of representational tools, computer modeling and just diagramming and drawing tools are super important.

Interviewee B thinks that sketching is a great way to initially present design ideas to clients. As for details, his/her students use both digital tools and sketches. Interviewee C believes that, first and foremost, students should be able to speak and write about light in a simple language like in scripts and narratives: “They need to know how to talk about it. Lighting more than any other discipline is harder to talk about … If you start talking in technical terms … they’re going to tune out.” He/she thinks that both digital and analog tools are useful in the ideation phase; however, some students may find digital tools more beneficial toward the middle of the design process where they have more details and a concrete understanding of how the design will look. He/she also thinks that research images help students communicate their initial ideas and concepts. Interviewee D agreed with Interviewee C that talking about lighting design ideas with supporting images helps in communicating design thoughts, especially to non-designers. He/she thinks that digital drafting, diagramming, and paperwork management software like Vectorworks, Photoshop, and Lightwright are really important, in addition to sketches, built models, and manual tools.

Interviewee E recommended charettes, PowerPoint presentations, research images, renderings, lightmaps, and digital diagrams. He/she believes that monochromatic renderings are important in the ideation phase to deliver concepts and that realistic renderings are only useful to show the final design. Nevertheless, he/she supports using both hand sketches and digital diagrams to show ideas in the ideation phase: "learning to do lightmaps, whether it's by hand with a colored pencil, using Photoshop or using Illustrator or whatever, whatever software it is, it's really very important."

Interviewee F stated that students present their lighting designs with different media such as SketchUp, Vray, hand drawings, hand sketches, digital renderings, digital plans, luminaire images, or PowerPoint presentations. They present their concepts and initial design ideas in a sketch format and they use digital tools towards the end: "I will say all students generally will start in the sketching … And I will say they are not required to do digital by the end, but many of them do."

In sum, most educators encourage students to present their initial design ideas and concepts in a sketch format, whether it is sketched by hand or via computer software like Photoshop, Illustrator, or SketchUp. Students then develop their designs in detail and produce renderings using a digital analysis tool like AGi32 or DiaLUX. Educators do not force their students to use one tool over the other; they give their students the freedom to use whatever tool they are most comfortable with and that they think is most effective to communicate their ideas.

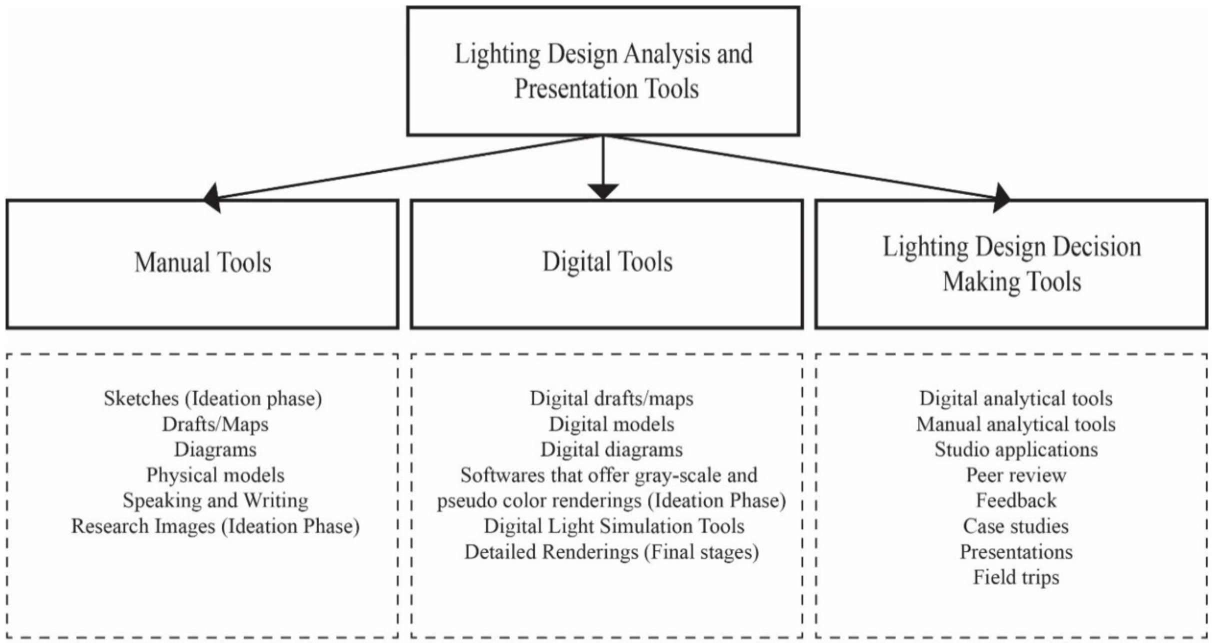


Figure 6-17. Lighting Design Analysis and Presentation Tools in the United States Lighting-Focused Programs

6.10.2 - Digital Light Simulation Tools that Educators Teach

Digital light simulation tools are analytical tools that students use in the design process. These tools are taught either within the lighting class or in an external workshop. The approach differs from one school to another. Parsons teaches students AGi32 to prepare them for their professional careers, especially because it is free for students and it is the most used lighting design software in the United States as Interviewee A implies: "AGi32 is the most widely used software in the United States. It's independent of any manufacturers. So, we want to teach the students how to use that software with the interest of preparing them for work."

Interviewee B teaches his/her students a simple program with a very easy interface called Flash ZC. Nevertheless, this software has many limitations. For example, it only analyzes rectangular spaces with uniform lighting; hence, students cannot use it to analyze their complex projects. Interviewee C introduces different digital tools like Photoshop, Illustrator, and Vectorworks. He/she integrates Vectorworks in his/her classes because it is the most used program in theater and it allows students to draft, render, and model light in one place. UCI also introduces Vision and AutoCAD. Vision helps students control theater lighting and it is free, whereas AutoCAD helps them create detailed 2D maps.

Educators at the University of Colorado and NYSID are similar to Parsons. They train students in AGi32 to prepare them for their professional careers. The University of Colorado also plans to introduce the AGi32 Revit plugin to students as Interviewee E implies: “Obviously, AGi through Revit, that’s becoming more and more popular. That’s something that we’re learning as well.” Interviewee F thinks that the AGi32 plugin (ElumTools) is easier for students: “ElumTools is AGi32 inside of Revit which can be easier, but you need enough Revit knowledge.” In addition to AGi32, NYSID introduces students to Vray, Photoshop, Revit, Adobe Animation, and SketchUp.

DiaLUX is another digital light simulation tool that international students prefer because it is the standard software outside of the U.S., it is free, and it has a lot of manufacturers’ databases, as Interviewee F indicated:

> DiaLUX is free for designers to use. The manufacturers are paying to be included in the database for DiaLUX. AGI costs the designers money, but it’s not subsidized by manufacturers … And I think that’s part of why we don’t require AGI in the curriculum, but we offer them free training. They can attend instead of having to pay for a course.

In sum, lighting educators teach their students the standard software for their particular region. The standard digital light simulation software for architects and interior designers in the U.S. is AGi32, thus it is the one integrated in U.S. universities. DiaLUX, in contrast, is the most widely used tool internationally.

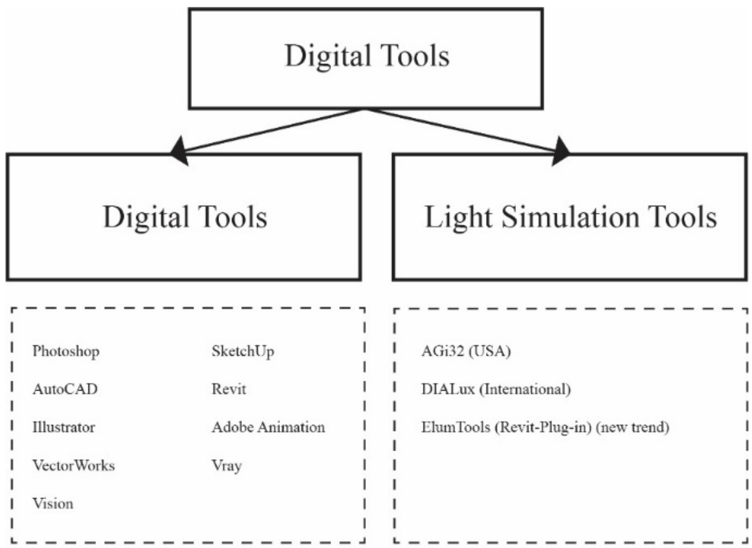


Figure 6-18. Lighting Design Digital Tools the Educators Use in the United States

6.10.3 - Lighting Design Presentation and Analysis Tools From the Documents

The researcher obtained cognitive lighting and lighting analysis tools from five interviewees' syllabi. Figure 6-19 presents the analog and digital tools described in the documents. She sorted the digital tools into tools used in architecture and interior design programs and tools used in other programs, as shown in Figure 6-20. The researcher also asked the educators to mark features that they think are appropriate for an educational digital light simulation tool on a handout. The features that three or more educators marked are CAD or Revit compatibility, simple rendering controls, accuracy, easy user interface, flexibility, variety in image outputs, speed, and simplicity in calculations.

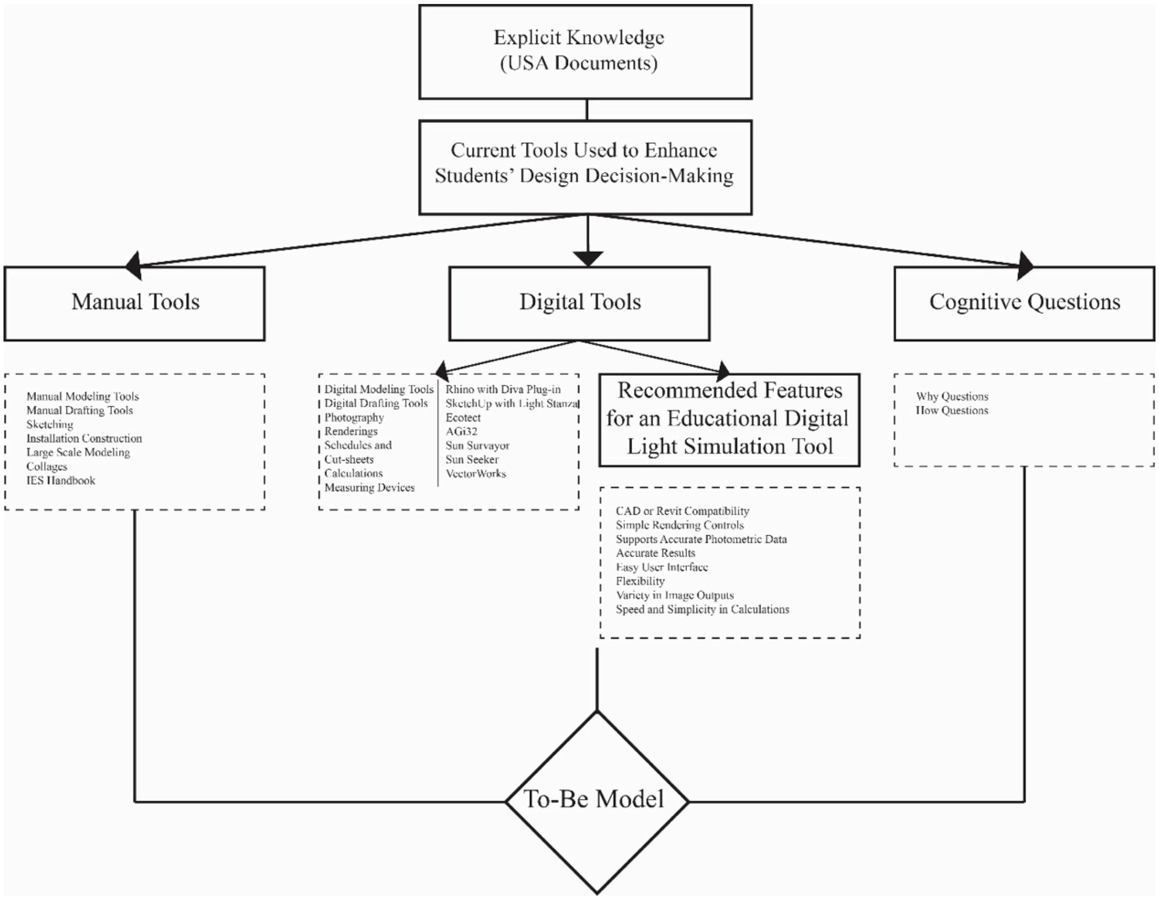


Figure 6-19. The United States Lighting Documents' Explicit Knowledge Domain

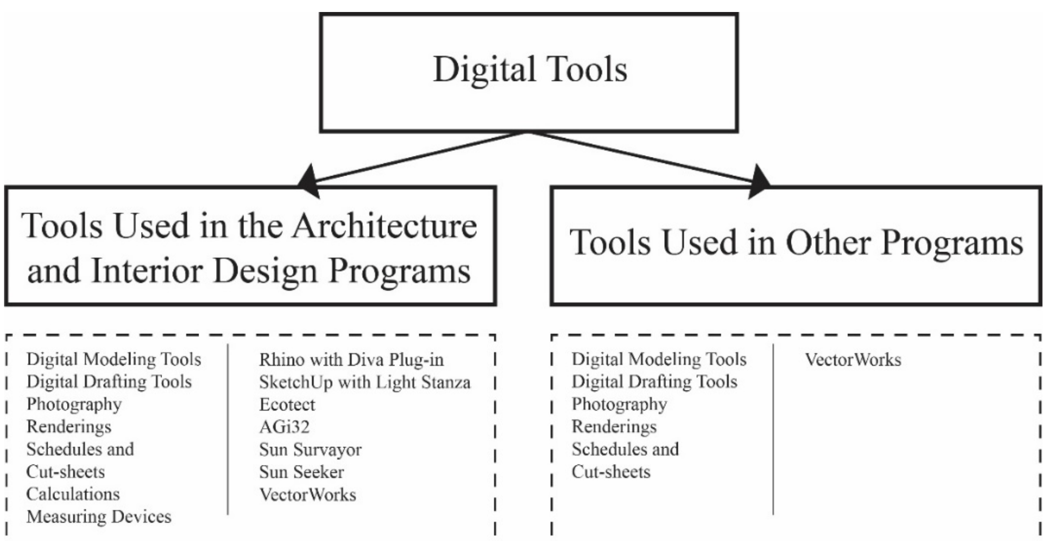


Figure 6-20. Digital Light Simulation Tools that are used in the United States Design Schools

6.11 – Students Perspectives towards Lighting Design Education and Digital Tools Based on Interview Responses

Design and engineering students tend to think about lighting late in the design process; however, the mandatory lighting classes along with the lighting lab encourage them to think about it from the conceptual stages. Interviewee E implies that people with an engineering mindset think about lighting towards the schematic or design development phases; hence, educators need to prompt engineering students to think about light creatively from the beginning.

When it comes to digital tools, there are two opposing schools of thought; some students gravitate toward them and use them from the early design stages whereas others fear them and prefer analog tools, as Interviewee D implied: “every student, of course, has a different skillset … there are some students that just struggle with Vectorworks a lot and there are others that are whiz kids and they can do it in their sleep.”

Interviewee E, in contrast, indicated that students gravitate more towards digital tools than analog. He/she finds it hard to encourage them to use analog tools: “I think this generation is a digital generation. Having them do things by hand in particular for engineering students is difficult.” Interviewee F stated that the use of digital versus analog tools depends on the students’ background:

> That becomes the point where one of the students might develop more Revit skill. One of them might be doing a lot of 3DMAX. It depends on what they want to do on their projects … it really depends on their backgrounds and how comfortable they are.

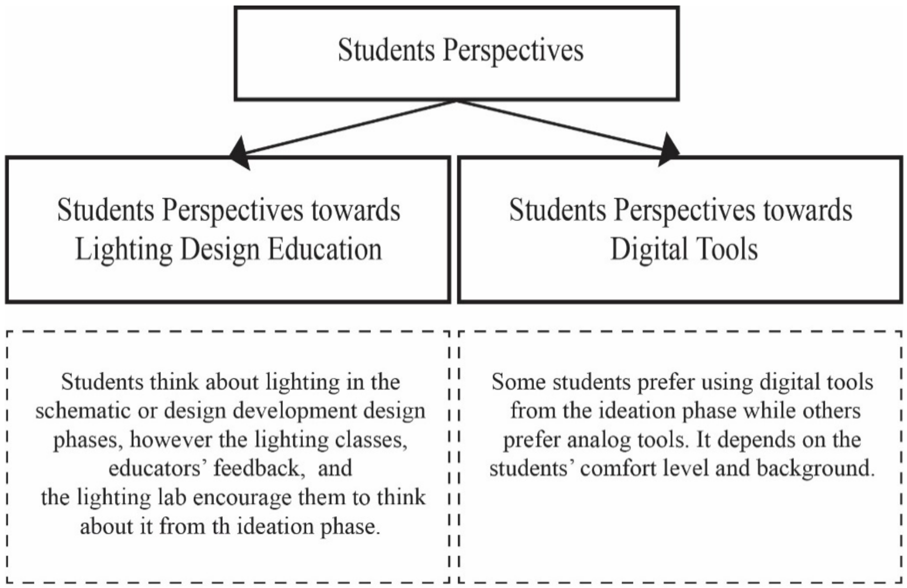


Figure 6-21. Students' Perspectives on Lighting Design and Digital Tools in the United States

6.12 - Positive Implications of Digital Light Simulation Tools

Digital simulation tools have both positive and negative implications in design education. Interviewee A thinks that digital light simulation tools are useful if students understand their purpose: "it doesn't teach you everything, but if you understand it as a tool, as a resource that is used in specific applications with very specific purposes, it's a great resource." He/she believes that digital tools provide students with amazing renderings and light representations. For lighting specifically, they help students understand light contrast, dynamic effects, composition, and how to translate numerical lighting values to human experience and social interaction:

> It's to understand compositional dynamics, contrast ratios and ultimately as I've said, transcribing the data, the numerical data that's measured into a human experience …. like how does that change the appeal or the unappealing nature of a space-based upon the context of social behavior or an event that's taking place.

Interviewee B indicates that digital light simulation tools help students calculate light and meet energy codes. Interviewee C explains that they help students design with speed, which, in return, saves them money. He/she also thinks that digital tools make online collaboration and remote alterations easier. Students update the design, fix mistakes, and share the project online with ease:

> It's easier to do that online collaboration, … I think in some ways, it takes the same amount of time to create that initial drawing by hand or by the computer. Once it's in, how quickly you can update things.

Moreover, digital tools are more practical in lighting design decision making, especially when students cannot create real scale mock-ups due to resource limitations, as Interviewee D explained: "doing a full-scale theatrical production is impossible for every project, right? … So, in that sense, digital spaces, digital teaching can be very valuable." Interviewee F asserted that there are digital light simulation tools that visualize and calculate light accurately: "I think DiaLUX and AGI … Those tools if you model correctly and have good information can be very accurate in predicting the effect. It works better in some things like getting average foot-candle levels."

6.13 - Negative Implications of Digital Light Simulation Tools

Interviewee A thinks that BIM modeling is complex to use in early design stages: "I think that there are some assets to BIM modeling later in the documentation stages, but it's incredibly cumbersome to work with early in the schematic design and DD phases." He/she also thinks that digital tools deceive students with an inaccurate representation of reality: "I also think there are liabilities with it because it can create this untruthful fabrication of a situation that is believable." In addition, he/she believes that digital tools disconnect students from how things are fabricated, which affects their cognitive processes in comparison to hands-on activities:

> The weakness of the digital tool is the displacement from any kind of hand or body cognitive understanding of how things are built and how spaces are constructed. As we're drawing, literally the hand relationships awaken different neurological and brain activity. And I see the lack in our students quite frankly.

Interviewee B feels that digital tools limit students' creativity in the ideation phase because they focus more on the digital model construction rather than brainstorm ideas. Students may even select options that are easier to build with the digital model. Additionally, some programs like AGi32 are too complex for educational use, and redundant because they require students to rebuild their models in another interface.

Interviewee C implies that some digital tools have limitations with light animation. He/she agreed with Interviewee B that such tools limit design thinking in early design stages because students may perceive the early digital model as the final one: "They say that design is 75% sketching and doodling and by jumping in the computer early, people look at it and go, 'It's done.' It might prohibit the larger conversation." In addition, he/she feels that digital models lack the feel of scale: "I think the scale was a hard thing to see … I'm working on a 3D model of a theater and the first time I walk into it, the scale always feels weird."

Interviewee D explained that digital tools are complicated and require a lot of training, which competes with design learning time. He/ she supported Interviewee B's and C's argument in that such tools deceive students in the ideation phase by providing an early result. He/she also thinks that a 2D image cannot depict an actual lighting experience: “inaccuracy … It’s a two-dimensional screen where you can’t sit back in a theater and see it live … The way the light is in the air is not the same.”

Interviewee E agreed with Interviewees C and D in that digital tools limit design thinking in the ideation phase because they direct students to the final solution, rather than helping them develop their design concepts: “it’s very difficult to pull them away from the hours and hours that they spend in investing in that model.” Interviewee F thinks that some software programs like 3DsMAX are bad for measuring light: “I’ll expand that to things like V-Ray and 3D max too, which show accurate renderings maybe, but not measurable. You’re not getting foot-candle readings.”

6.13.1 - Ways to Overcome the Negative Implications of Digital Light Simulation Tools

The interviewees suggested ways to overcome the drawbacks of digital light simulation tools such as comparing a physically built model to a digital one to understand the limitations and strengths of each tool. Interviewee A thinks that another good method is to give students exercises that target specific traits of the tool: “I also feel that just structuring exercises around the tool use in a way that students can recognize the benefits or understand positive and negative attributes of them.” He/she also suggested introducing digital tools early in design education to familiarize students with them.

Interviewee B invites his/her students to use analog tools or sketch-friendly digital tools like SketchUp and Photoshop in the ideation phase to overcome the limitations of digital tools in the early design stages. Interviewee C suggested introducing students to different digital tools to help them choose the most suitable one for the ideation phase.

He/she also recommended that students use virtual reality glasses to immerse them in a lighting design experience that is close to reality.

Interviewee E recommended that teachers mentor students, encourage them to present their designs in an unfinished look (like a gray scale rendering in the ideation phase), and invite them to experiment with light options in a ready-made digital model to overcome the digital tools' limitations:

> Let's just use it as an unfinished model, right, and this is your canvas. This is a canvas with where you're doing is painting with light in the first time, remove those luminaires, put another set of luminaires just to see how it works, and then compare it … The case that I'm making is to just use gray scale. If you're using the tool really to visualize just patterns of light, an amount of light, then I think that if your variables were fed correctly … it would be appropriate then to provide the models already to the students to go ahead and say, "Don't worry about creating the model. Just use these models to be able to start dropping in luminaires, moving them around, increasing light levels, changing reflectances and colors, and see what you get."

Interviewee F proposed a narrative format in the ideation phase with some sketches to overcome the digital tools' limitations: "I think removing any kind of visualization tool, in the beginning, is great. Adding in sketches to help express, but that narrative list helps them talk about lighting and stack their ideas for every space." He/she agreed with interviewee E regarding giving students a ready digital model to simplify their digital light experimentations.

In conclusion, Figure 6-22 presents the positive and negative implications of digital light simulation tools with some suggestions to overcome the drawbacks. The most emphasized advantages based on the NVivo word count are good light visualization, quick calculations, ease in fixing mistakes, and aid in design decision making. The most repetitive drawbacks are the inaccurate depiction of reality, being time-consuming, and causing frustration in the ideation phase. Lastly, the most emphasized recommendations are using a sketched rendering for early design stages and comparing a physical model to a digital one.

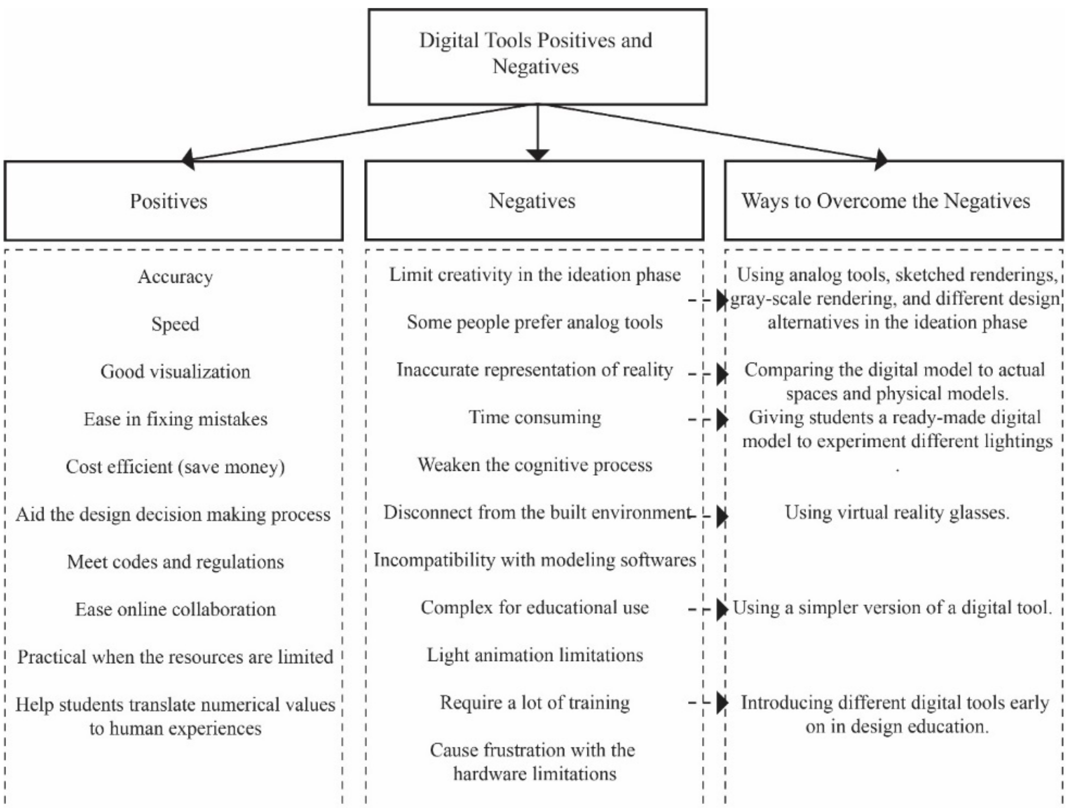


Figure 6-22. Digital Light Simulation Tools Positives and Negatives

6.14 – Future Recommendations to Enhance Lighting Design Pedagogy Based on Interview Responses

This section discusses suggestions to advance lighting design pedagogy, the integration of digital light simulation tools in design curricula, a design studio that is focused on lighting, and cognitive questions that help students in lighting design decision making.

6.14.1 –Recommendations to Advance Lighting Design Pedagogy

Interviewee A recommended an early exposure to light in design education:

> to start early in the curriculum … I can't imagine an interior design project that doesn't talk about the material, finish, color palettes, and so on. But you can't experience those without light. Right? … So, one can't talk about material and tone and color in the abstract. It has to be contextual in relationship to light.

He/she suggested introducing light in studio projects and to have more lighting classes that incorporate lighting technology, control systems, and luminaire design:

> I think looking at studio coursework and having light be just fundamentally a part of the conversation … I think expanding the knowledge of controls and digital systems would be great. Expanding the study of luminaire design would be good as well.

He/she emphasizes light's effects on human factors, positive feelings, and health: "I would say on a seminar course, talking about the subject of light beyond the technical and ensuring that human factors are included with that."

Interviewee B proposed hiring more faculty to introduce advanced lighting design subjects and to introduce multidisciplinary lighting design courses like fixture design and theatrical lighting that are open to different design students. He/she agreed with Interviewee A in focusing on qualitative aspects of light and its effects on human behavior and health. Interviewee C supported Interviewee A's argument regarding exposing students to lighting from the beginning. He/she proposed using a lighting lab for light applications: "We just recently got a light lab … that has helped us a lot to do mockups with specifically other design disciplines." Moreover, he/she suggested offering an honor award if students take certain electives including lighting to encourage the acquisition of lighting design knowledge. Interviewee D advises educators to help students develop critical thinking, team collaboration, time management, and problem-solving skills to help them pursue any design career they desire:

> I believe that we need to build the foundation... theater is still the best program for teaching you about a lot of things. It teaches you how to be a critical thinker. It teaches you how to be a problem solver. It teaches you how to collaborate with other people. It teaches you how to be good at time management. So, all of those skills are valuable, whether you're talking about being a professional lighting designer in theater, architecture, or interiors.

He/ she believes that students need both light art and technology as foundations; however, technology should not outweigh light design thinking. Educators need to find a good balance between the two in the available timeframe: "I would say my advice is don't let the technology rule the teaching of design. The design has to come first. Understanding light, understanding its properties and how to communicate yourself and your artistry through light."

Interviewee E recommended introducing lighting knowledge in a sequence because it needs time, lots of exercises, and repetition:

> It's not helpful, in my mind, to compress all this knowledge for the sake of compressing it because it's not going to stick. Lighting needs to, like any knowledge, you need time, you need repetition, you need depth, you need angles.

Interviewee F proposed the integration of more lighting design electives, quantitative lighting knowledge, an understanding of light's effects on the circadian rhythm and human health, and site visits:

> We currently don't have electives enough for sure that would target lighting. I would like to see more of them … I hope to add some of the more quantitative, what does light does with our circadian stimulus things like that. That's a goal to add to the program … at least one, maybe two classes that are more about the impact of lighting on health for occupants will be critical for the interior designers … I think getting them out more to see applications is always valuable.

He/she also recommended hiring more lighting design faculty and bringing in design specialists to attend students' design juries: "there need to be more lighting educators in general … I would love us to start bringing in lighting faculty during the jurying for the different projects in each class. Because that perspective is useful to reinforce." Last, he/she encourages other lighting designers to attend lighting design conferences and symposiums and share lighting design information and research:

> Being aware of resources available to you. So, IALD education trust … Going to the conferences and symposiums, following grants … The other thing is sharing

information. But while it seems like we're all in competition, truly there are not enough lighting designers.

Figure 6-23 summarizes the suggestions to advance lighting design education. The NVivo word count emphasizes qualitative lighting knowledge, hand-on projects and exercises, advanced lighting courses, and technical lighting knowledge.

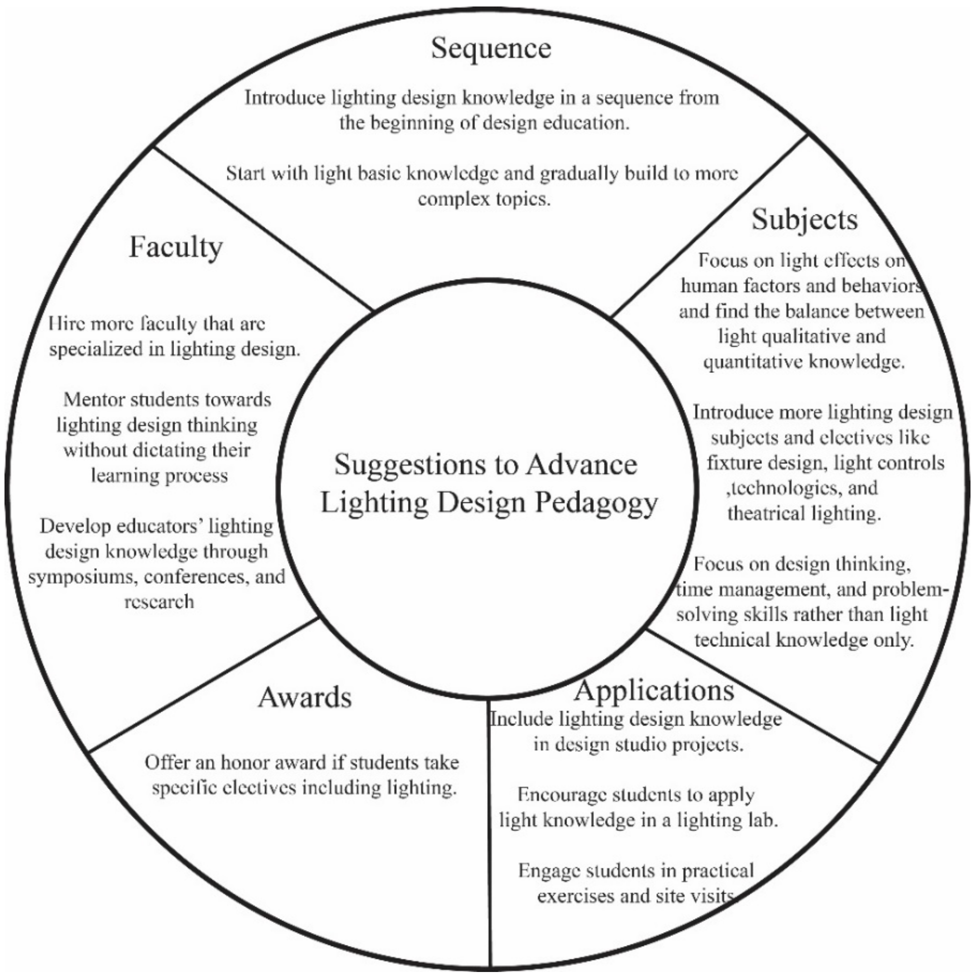


Figure 6-23. Recommendations to Advance Lighting Design Education

6.14.2 –Recommendations to Integrate Digital Light Simulation Tools

Interviewee A suggested introducing digital tools from the beginning along with analog tools to familiarize students with both and to enable them to shift between the two tools efficiently:

> I think it's critical to introduce digital tools on in day one so that there's a comfort level with the tool or maybe I should say an understanding of the process of how one toggles between analog and digital. I think it's critical, especially today given how digital tools are so dominant.

Interviewee C proposed exposing students to different digital light simulation software programs rather than mastering one because they may need to use a different software in practice:

> When it comes to technology, expose them to as much as possible, we can't make them a master of all of it, because that's a 10-year program that keeps changing, but we can expose them to all of it and let them know where to go and get the information.

He/she also suggested hiring a faculty to teach and introduce more digital technologies: "We've been talking about building the program more by bringing on more faculty that can teach those types of technology classes."

Interviewee D recommended having a virtual lighting lab:

> Our lighting program as a proposal into the university to build a virtual light lab because I think that the students, for the future, they're going to need to know that both professionally, but also it's a useful tool to teach, and it will open up a way of teaching that we can't currently do.

Nevertheless, he/she thinks it is better to integrate digital technology toward the middle or the end of design education: "I think it's better toward sort of the middle to the end. I think it's very important that at the beginning that what we are talking about our ideas." He/she believes that students need to focus on design thinking and brainstorming ideas in the foundational years: "I want to develop their thinking about light first ... I want their imaginations to be the tool. I don't want a computer simulation to be the tool." Interviewee E agreed with Interviewee D regarding introducing digital technology toward the middle or the end of design education to allow for a larger design thinking conversation. Interviewee F proposed more digital lighting design classes for the master's level, but he/she thinks that manual tools are more useful for undergraduate students.

Figure 6-24 summarizes the suggestions for integrating digital tools in design education.

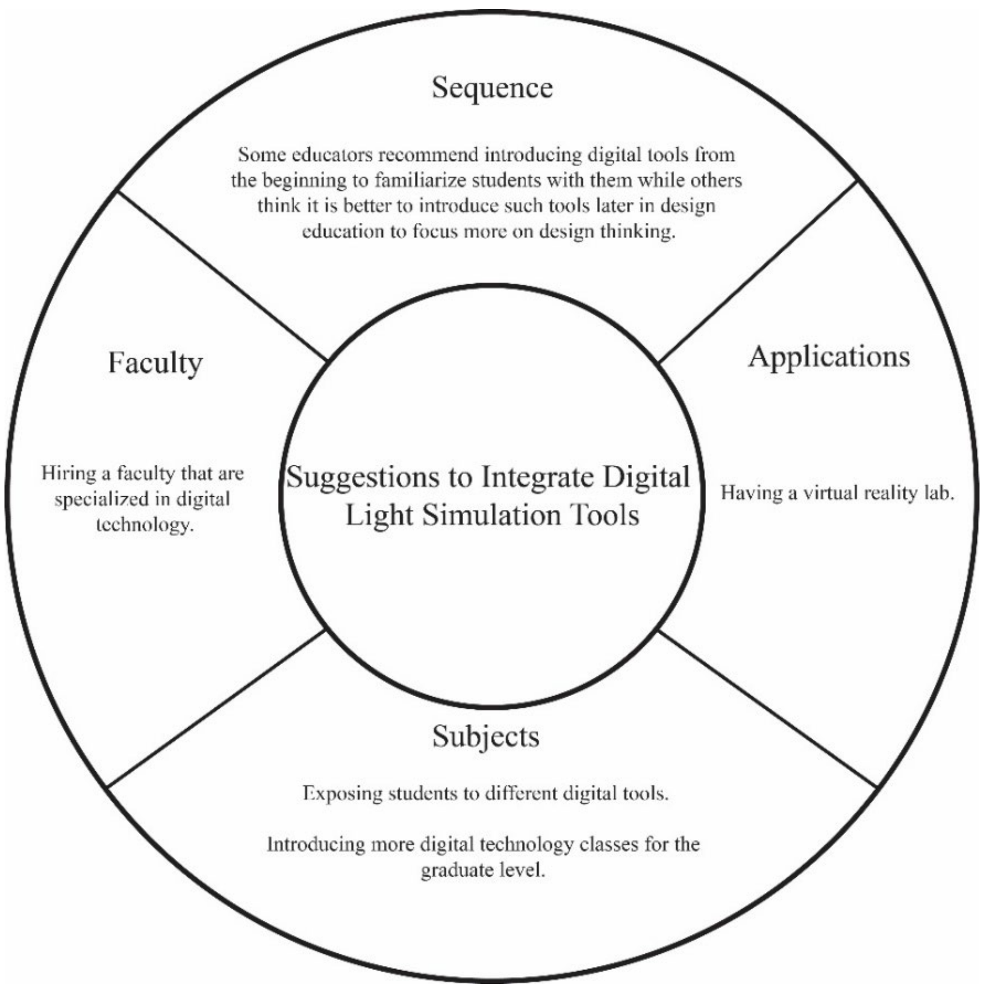


Figure 6-24. Recommendations to Advance Digital Light Simulation Tools Integration in Design Education

6.14.2.1 – Recommended Features for an Educational Digital Light Simulation Tool

This section presents a list of features that each interviewee thinks are useful in an educational digital light simulation tool. Interviewee A believes that compatibility with most digital modeling software; flexibility in adjusting materials' properties and reflectance; having different rendering outputs like gray scale and pseudo colors; the ability to render light phenomena like luminance, illuminance, and other sensorial phenomena, accuracy, and speed, especially in rendering; are important features.

Interviewee B suggested a plug-in version for students, a simple lighting language, simple rendering controls, having an in-program material and light source library, speed, and an easy user interface. Interviewee C endorses stability, ease of use (especially in adding light sources, light textures, and light intensities), powerful processing power, and a drop-down menu with light sources. Interviewee D thinks that an easy user interface, high processing power, stability, updated technology, speed, and ease of learning are important features.

Interviewee E suggested using a straightforward software program that provides realistic renderings and produces gray scale lighting maps. Interviewee F, in contrast, recommended using a professional software program that has a good glare-measuring tool:

> My point of view is I would not simplify or change the digital tool for the student. I would force the student to use it on a professional level because that's what will prep them best … I can't wait for them to have a better way to measure glare, but they're going to have to redefine IES files.

Figure 6-25 summarizes the recommended features of an educational digital light simulation tool. The most emphasized features based on the NVivo word count are speed, accuracy, compatibility, and producing different rendering outputs.

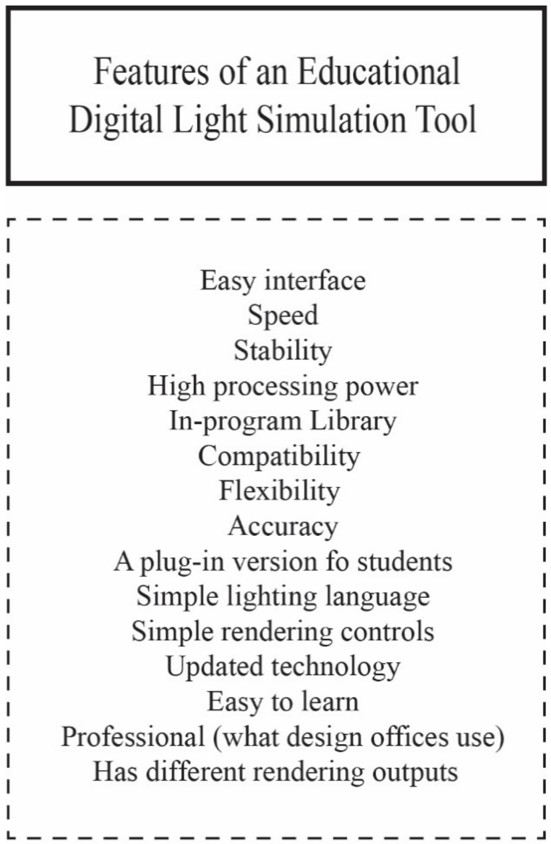


Figure 6-25. Recommended Features for an Educational Digital Light Simulation Tool

6.14.3 –A Lighting Design Studio

The lighting design studio starts with warm-up projects and develops through cognitive questions to more complex lighting design projects.

The Warm-Up Project

Interviewee A introduces an abstract lightbox exercise where his/her students simulate a light phenomenon using different light sources, materials, and controls. This exercise helps students understand light and its physical behavior as a raw substance:

> We have a project we call the box project, and we have the students go out and through just observation and take a photograph of some light phenomenon. It can be during the day, during the night, reflections, whatever. Then we have them simulate that within a contained environment. So, it forces them to look at the phenomenon carefully, understand what's causing the phenomenon, what about the phenomenon is intriguing or stands out, and then how do you craft that physically with light. So, they usually involve electric light somehow as a source, and the box is about 18 inches cubic square. Then they apply materials inside of that, and they might use refractive media to bend, shape, or distribute light in some way. I should also say they're not replicating the image of light, but they're transcribing the phenomenon, they understand the phenomenon to be in a new spatial context.

He/she refers to a book that encourages the readers to look at light in an abstract way and use it creatively within different special contexts:

> There's this book written by an artist, Jane or Robert Erwin, who uses light a great deal. The title of the book is, *Seeing Is Forgetting the Name of the Thing One Sees*. So, when you really begin to perceive the world and understand the world on an essential level, you're no longer looking at a table, or a chair, or a bookshelf, but you simply see light, material, texture on a much more raw level. … in relationship to human in-habitation, social dynamics, perception, memory, and so on.

Interviewee B suggested starting with an installation project to play with light as a raw material: "something more theoretical, like more of a James Turrell type of art installation." Interviewee C agreed with Interviewee B that a light installation is a good start-up project. Interviewee D recommended a light movement exercise where students use portable light sources to represent a play, a poem, or a painting through light:

> In the first week of their third semester, they have to read a play or read a scene from a play and they have to come in and represent that scene with three lights … create a 1-minute movement phrase with a portable light … Sometimes they have to read a poem and represent the poem in light. Sometimes they have to find a painter and represent that painting in light.

Interviewee E suggested using a charette:

> I think, it's important to do time exercise through charettes. Those charettes introduce the students to various types of projects from the point of view of the users, right? It could be a church, it could be an office, it could be a visitor center, it could be whatever. They're small enough that they can do it in three hours. The idea is to just capture the quality of their thought.

Interviewee F proposed that students hunt for a bad lighting project as a warm-up project: "a bad lighting project. So, take a photo of something that is bad lighting and tell us why it's bad."

Lighting Design Projects:

Interviewee A encourages his/her students to build large-scale mock-ups both physically and in digital software to understand light in a spatial volume. He/she then involves them in more complex light applications to understand light's relationship to social, behavioral, and dynamic contexts. Interviewee B proposed a restaurant or a museum project because it requires complex light studies: "I think the restaurant project is a really good one … then work our way towards something really complex, like a whole museum exhibit design.” Interviewee E suggested big projects like a library, whereas Interviewee F proposed a small project with different lighting treatments like a restaurant or a house where students light different tasks:

> I think a restaurant is great because it’s got a mix of specific task goals like how do you deal with a kitchen or bathroom as well as aesthetic kind of flexibility that a dining space can be so many things and it usually has some daylight integration. It’s a small scale that can capture lots of different space types. I think residences are also a pretty good starting project. It’d be interesting to give them a tiny, like a workshop project.

He/she also recommended full-scale light explorations in a light lab: “the closest thing I do is the lighting studio or the lighting laboratory … These are full-scale explorations.” He/she encourages his/her students to provide detailed light plans like reflected ceiling plans, cut sheets, light schedules, and images. Lastly, he/she endorses a one-on-one desk critique as well as peer review through regular pin-ups.

In conclusion, the warm-up project is a small project that encourages students to view light as a raw and abstract material to understand its physics and behavior. After the warm-up exercise students are encouraged to work on more complex light projects like a restaurant, a museum, a play, a library, or a house. These projects invite students to think about different lighting scenarios and concepts and ways to apply them physically, explore them, and represent them. Students present their lighting concepts using different analog and digital media. Educators use one-on-one desk critiques, peer review, and cognitive questions to ignite students’ cognitive thinking in a studio environment.

6.14.3.1 – Lighting Design Cognitive Questions

Cognitive questions ignite students' design thinking and explorations. Design educators use these questions to direct students' thinking to certain knowledge domains without dictating their learning process. Interviewee A uses pragmatic, conceptual, experiential, philosophical, hierarchical, phenomenological, functional, and quantitative questions. He/she utilizes these questions in exercises and projects. For example, he/she asks, what kind of tasks do they need? What sensorial experiences do they want to achieve? What is a light hierarchy in a space? He/she emphasizes light's effects on human factors more than light quantities:

> First and foremost, we are always talking to students about these phenomenal human perceptual dynamics. What is the ambition with the space? What do you want people to sense? Where do you want their eye gaze to go? What is the hierarchical organization of the space?

Interviewee B uses conceptual, practical, aesthetical, functional, hierarchical, execution, cultural, and experiential cognitive questions. For example, what is the main light idea? How can you create a culturally comfortable environment? What do you want to emphasize in a space? Is the design functional?

> For me everything starts from their concept … It's like once we've got that big idea … is there a good contrast? Have you accented the right things? Have you considered all the tasks? … I'm really actually extremely interested in cultural aspects and differences in lighting. What do people really prefer versus what's happening could be two different things?

Interviewee C uses problem-solving, conceptual, execution, and evaluative cognitive questions. For example, how can you solve the problem at hand? How will you implement the design? Which design alternative works best? Does the concept work? Interviewee D uses technical, procedural, why, and execution cognitive questions. For Example, how do you plan to make the design work? Why did you make a certain choice? How are you going to implement the design?

> It's hard to say it in general terms because somebody might need a very small prompt to think differently about what they're doing. Some people might need a technical prompt to think differently about what they're doing. I'm always trying to ask in some way, what's the why and the how. "Why did you make that choice? How are you going to exhibit that choice on stage or execute that choice on stage?" So it's that connection between the thought and the execution.

Interviewee E uses pragmatic, contextual, financial, technological, experiential, functional, and why questions. For example, what are the needs of the client? What is the context of the building? What technology will you use and why? How will the building operate? How will people move within the building and through its thresholds? Interviewee F uses functional, technical, experiential, hierarchical, and aesthetic questions. For example: how will you meet the codes? How will you control the light? What finishes and materials work best with your lighting concept? What kind of fixtures will you specify?

Figures 6-26 and 6-27 summarize the lighting design studio projects, methods, analytical tools, and cognitive questions. The most emphasized questions based on the

NVivo word count are qualitative (experiential and sensorial), pragmatic, functional (task questions), conceptual, and hierarchical.

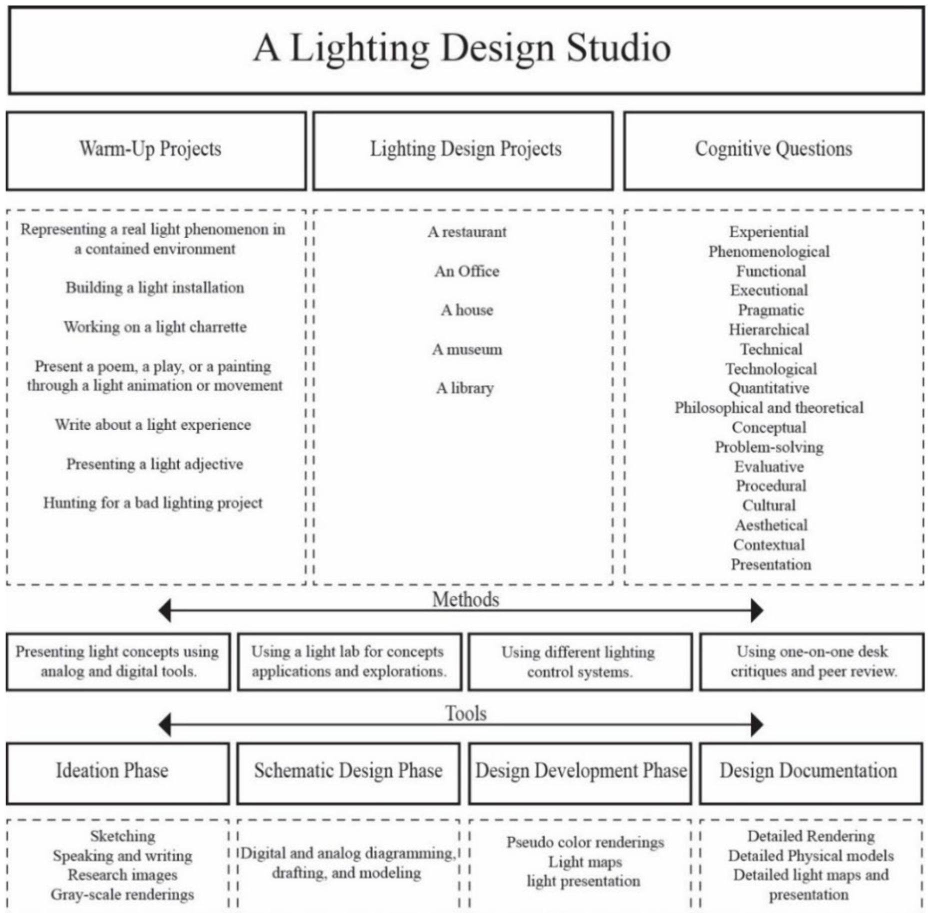


Figure 6-26. A Lighting Design Studio

Examples of the Cognitive Questions

Experiential: Wow will people move within the building and through its thresholds?
Phenomenological: What do you want people to sense?
Functional: Is there a good contrast?
Executional: How to implement the design?
Pragmatic: What are the needs of the client?
Hierarchical: Where do you want their eye gaze to go?
Technical: How will you control the light?
Technological: What technology will you use and why?
Quantitative: How will you meet codes?
Philosophical and theoretical: Why did you make that choice?
Conceptual: What is the ambition with the space? What is the main light idea?
Problem-solving: How are going to solve the problem?
Evaluative: Which design alternative works best?
Procedural: How do you plan to make the design work?
Cultural: How to create an environment that is culturally comfortable?
Aesthetical: What finishes and materials work best with your lighting concept?
Contextual: What is the context of the building?
Presentation: What tool will you use to present your design?

Figure 6-27. Cognitive Questions

6.15 – Conclusion

The To-Be model presents the established lighting design knowledge sequence, topics, teaching methods, cognitive tools, future recommendations, and a lighting design studio in relation to the tacit, procedural, and explicit knowledge domains as shown in Figures 6-28, 6-29, and 6-30. The researcher created the model based on the United States document analysis and interviews with lighting design educators. The knowledge in this model is transferred to the As-Is model (discussed in Chapter VI) to create the proposed lighting design pedagogical framework (discussed in Chapter VII).

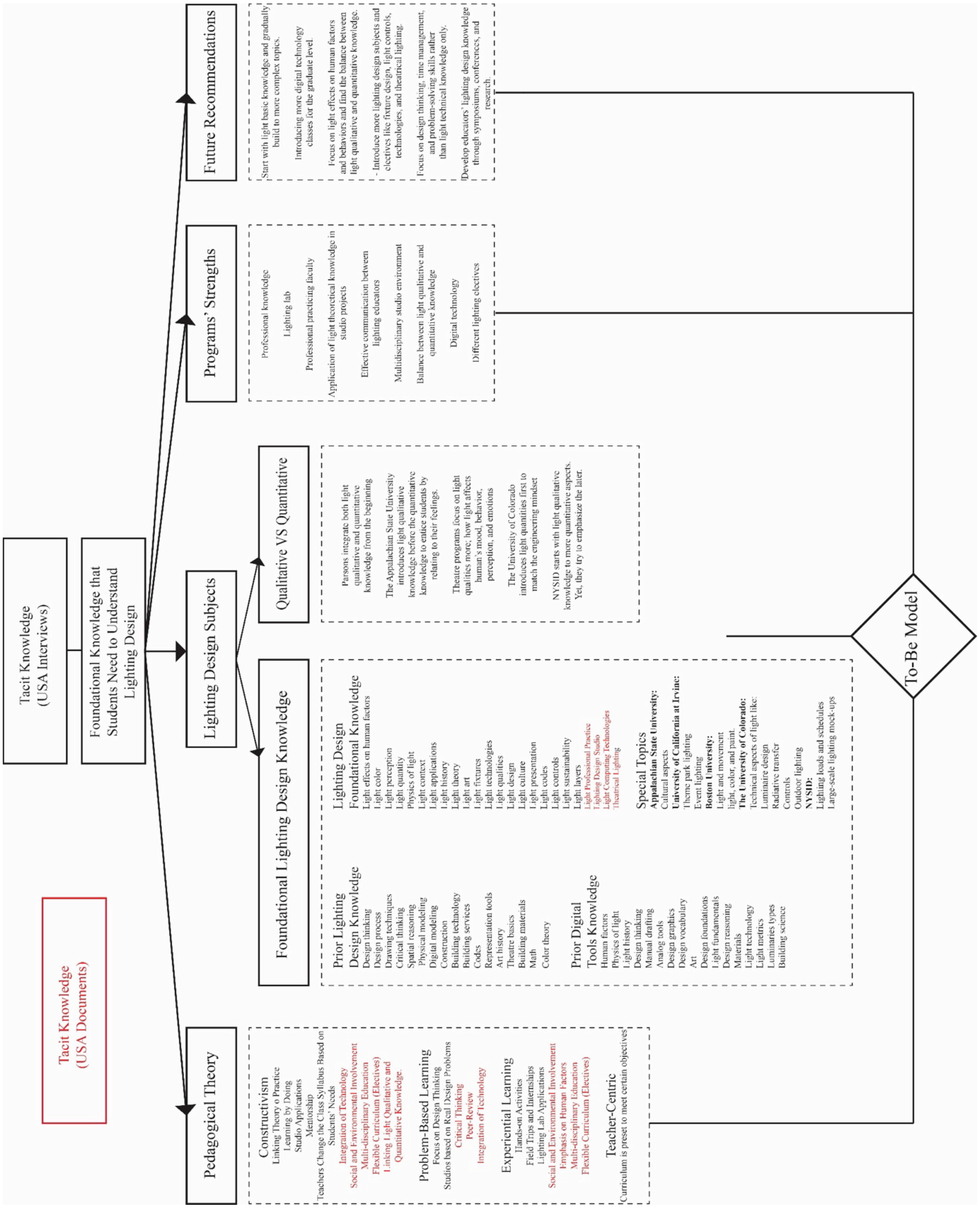


Figure 6-28. The United States To-Be Model Tacit Knowledge Domain

Note: the text highlighted in red is added from the documents analysis

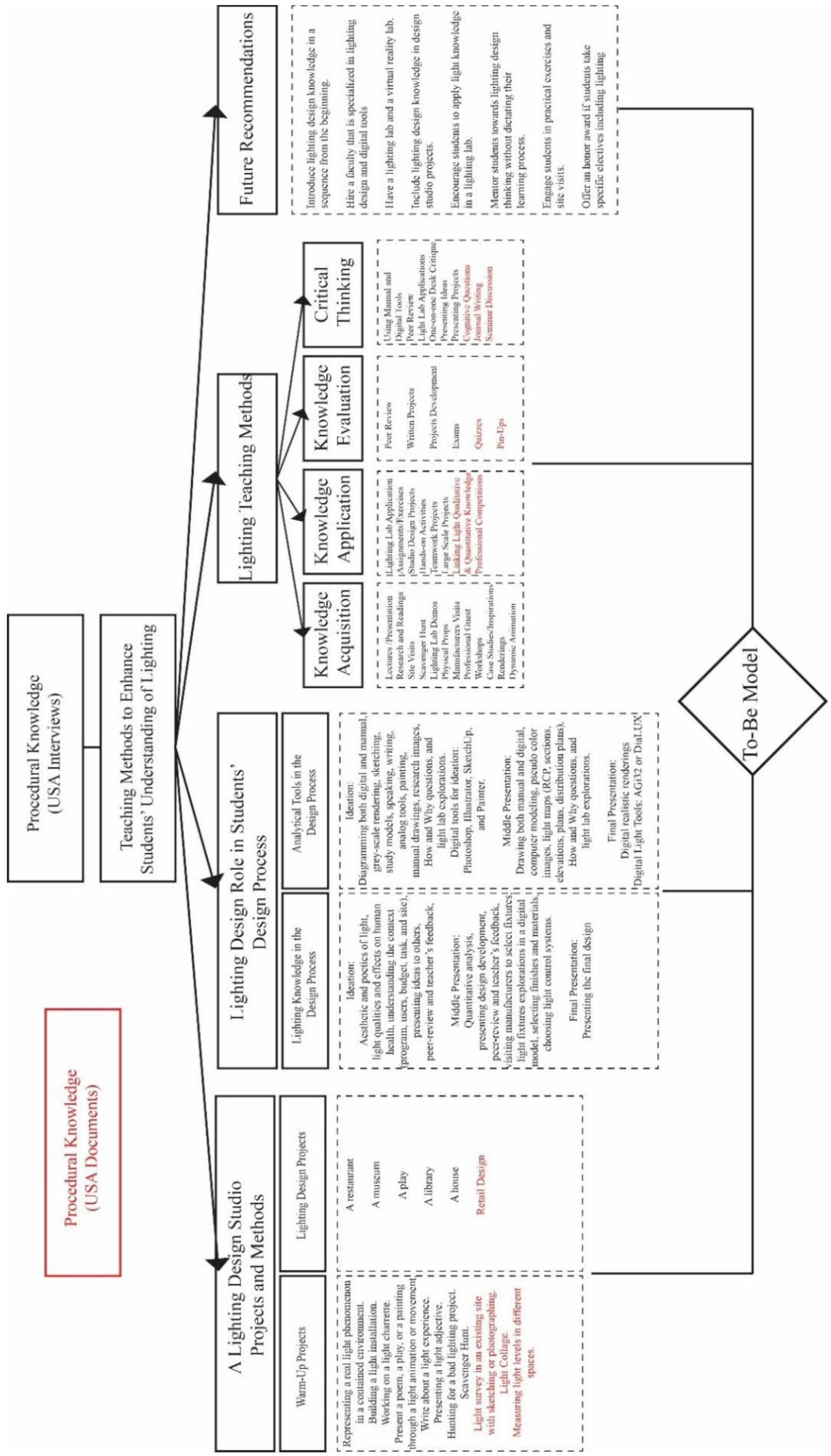


Figure 6-29. The United States To-Be Model Procedural Knowledge Domain

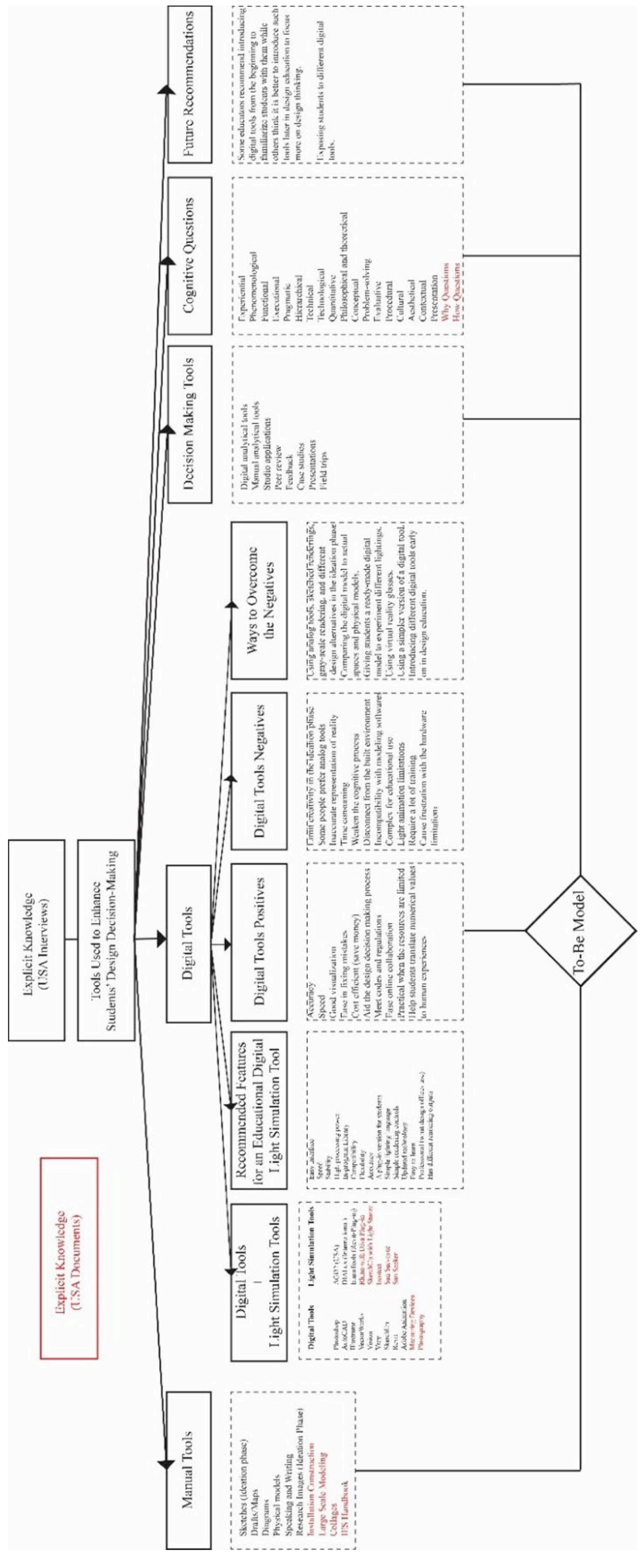


Figure 6-30. The United States To-Be Model Explicit Knowledge Domain

Chapter VII

7- Adopting the United States Lighting Design Pedagogical Framework to Kuwait's Framework

This chapter discusses the influence of the literature, the United States document analysis, and interview results on the proposed framework. It presents a learning path where lighting design knowledge is integrated into a yearly sequence based on foundational, intermediate, advanced, and future knowledge domains with a focus on tacit, procedural, and explicit knowledge. The chapter also highlights a studio scenario narrative for a practical application of the framework.

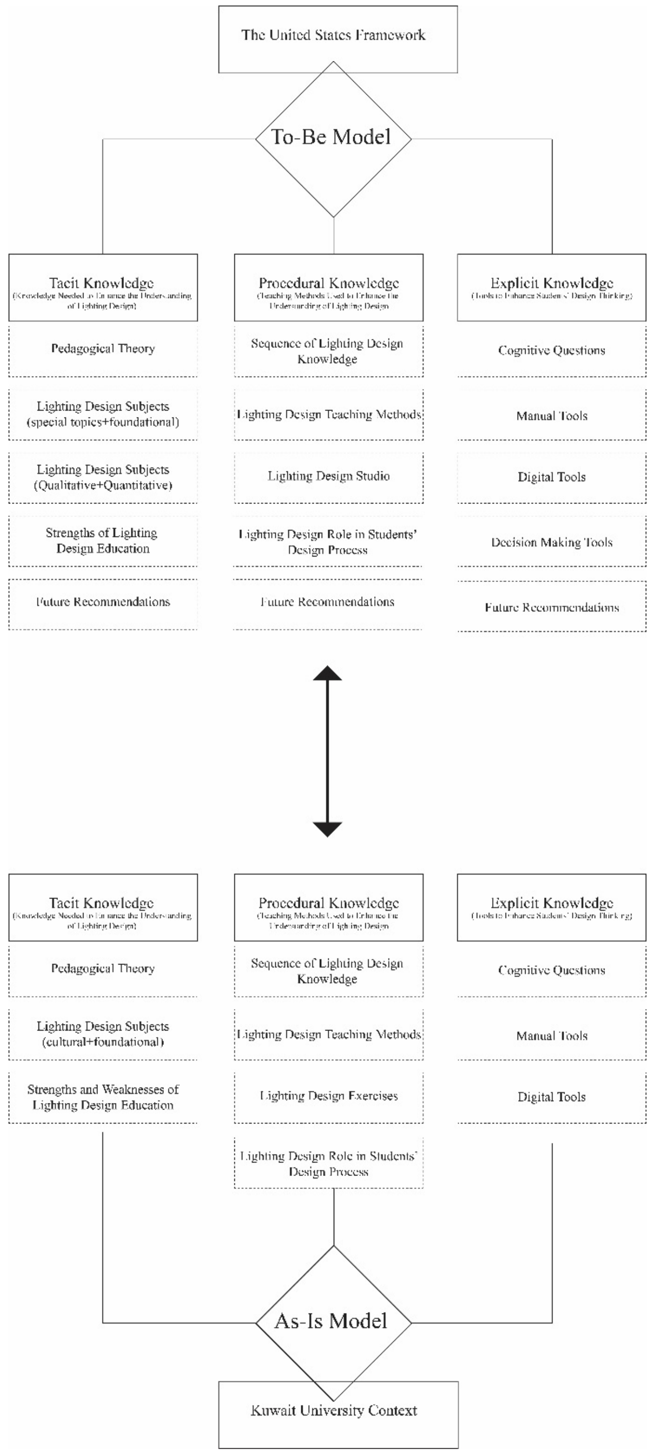


Figure 7-1. Adopting the United States To-Be Model to Kuwait's As-Is Model

7.1 – The Influence of the Literature on Kuwait's Framework

The literature influenced the framework in different knowledge domains. In the theoretical domain, it proposed extra lighting design topics such as light hierarchy and layers, light definition and importance, fixture design, outdoor lighting, lighting for safety and security, the lighting design profession, and general electricity. In the procedural knowledge domain, it suggested a multidisciplinary foundational year where students from different design majors work together. It also recommended introducing more lighting design electives, linking qualitative and quantitative lighting knowledge, and inviting students to present aspects of lighting design in the role of an educator to ignite their critical thinking, research skills, and passion for different lighting topics. Lastly, in the explicit knowledge domain, the literature suggested introducing a BIM lighting plug-in for ease of use, integrating digital tools in a sequence from the beginning to enhance the learning process, and launching an advanced digital light elective. The researcher presented the recommendations in Figures 7-2, 7-3, 7-4, and 7-5, and Table 7-1.

In addition to the knowledge domains, the literature proposed the implementation of a lighting design studio. The proposed studio starts with a warm-up project that is related to students' past knowledge and experiences. Educators are encouraged to understand students' past knowledge through questions and observations. Students are invited to use different tools to analyze and understand lighting behavior in the studio, including physical mockups, digital analysis and modeling tools, and analog tools, both for drafting and diagramming. Students are also encouraged to self-assess their projects through reflective writing and participate in group projects and peer reviews. Educators are invited to take students on cultural field trips and give them feedback without dictating their learning process. Educators are also encouraged to use different cognitive questions to guide students' design thinking. Figure 7-6 shows examples of possible questions.

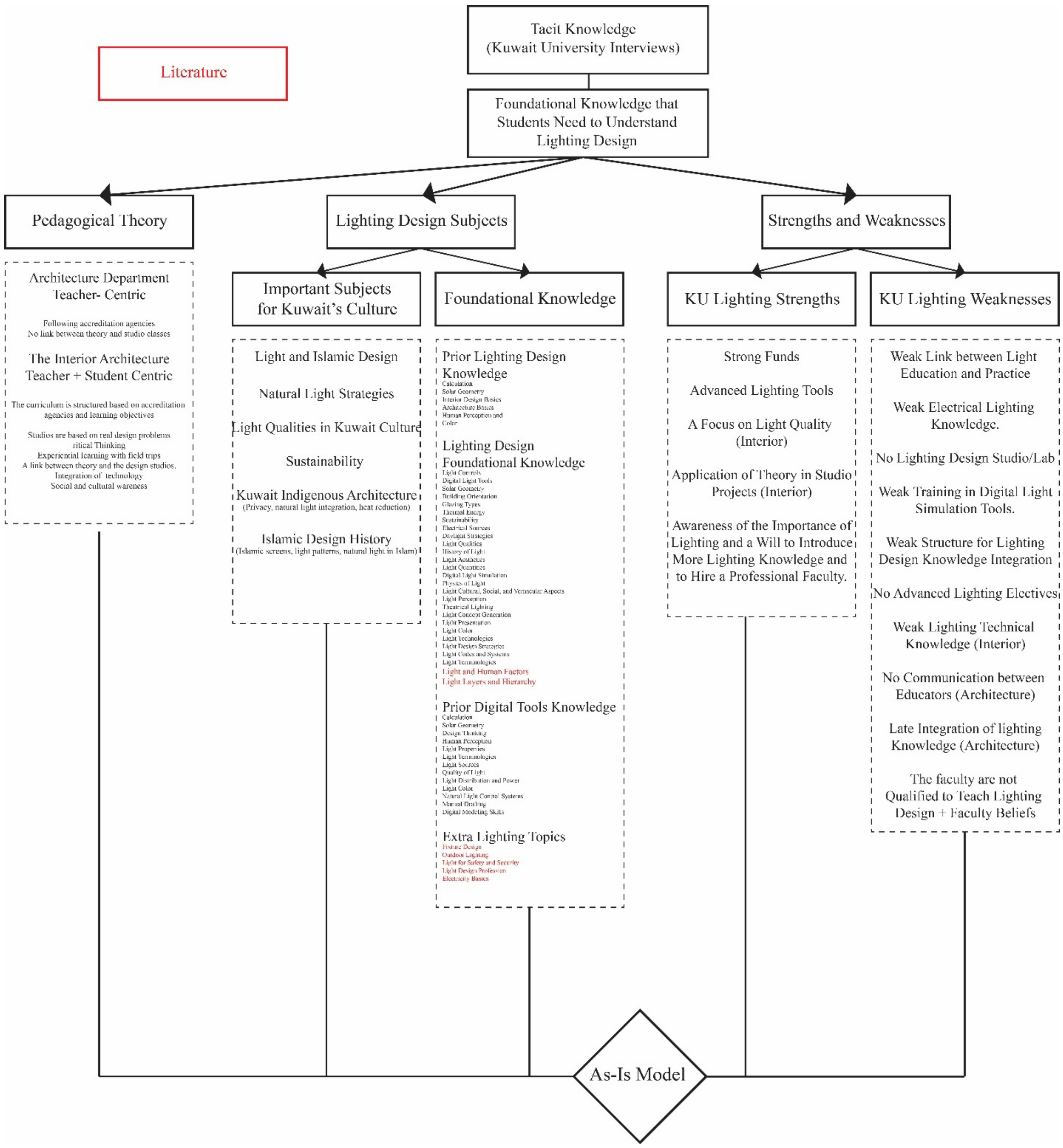


Figure 7-2. The literature's influence on the Tacit Knowledge of Kuwait's As-Is framework

Note: the text highlighted in red is the additional knowledge from the literature

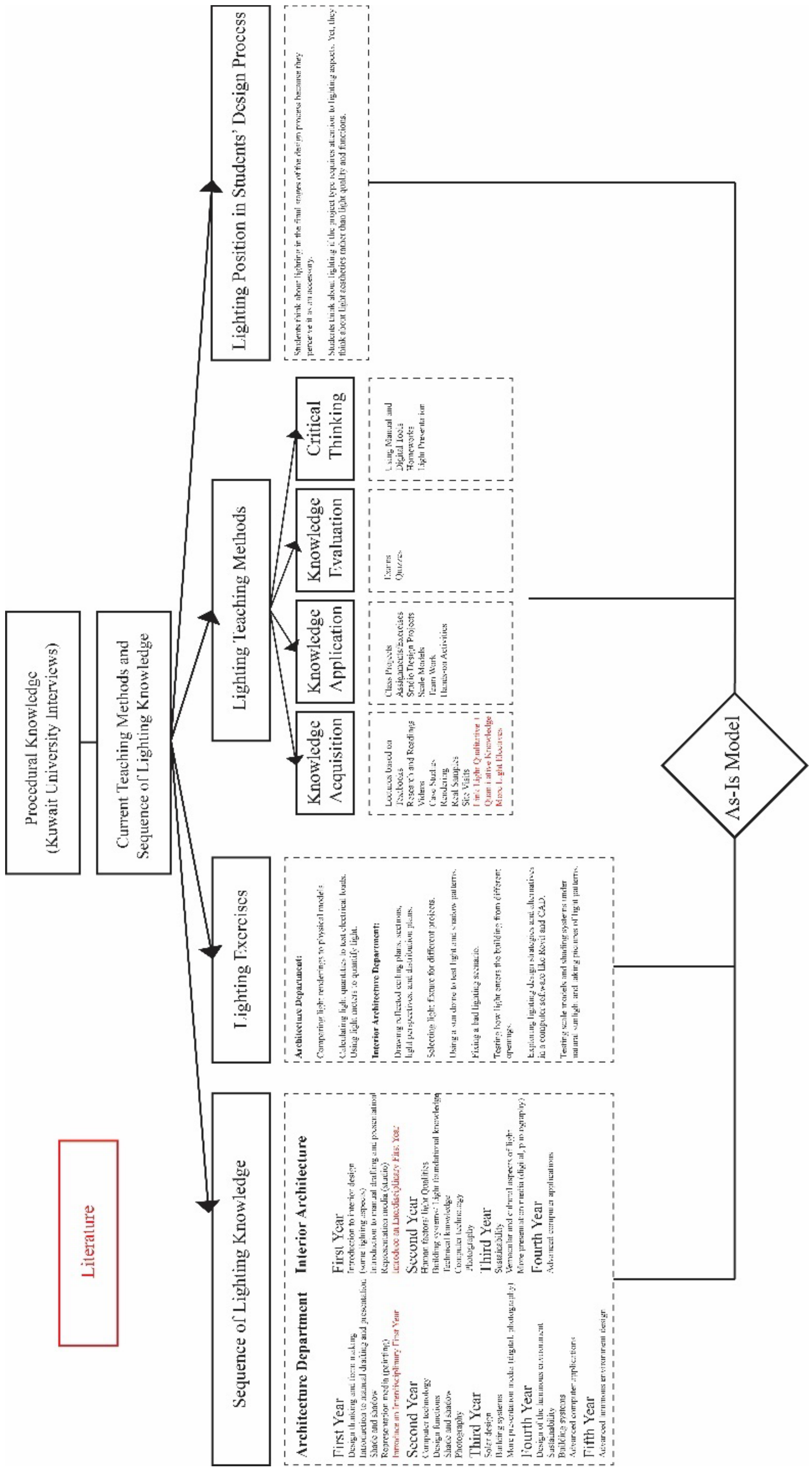


Figure 7-3. The literature's influence on the Procedural Knowledge of Kuwait's As-Is framework

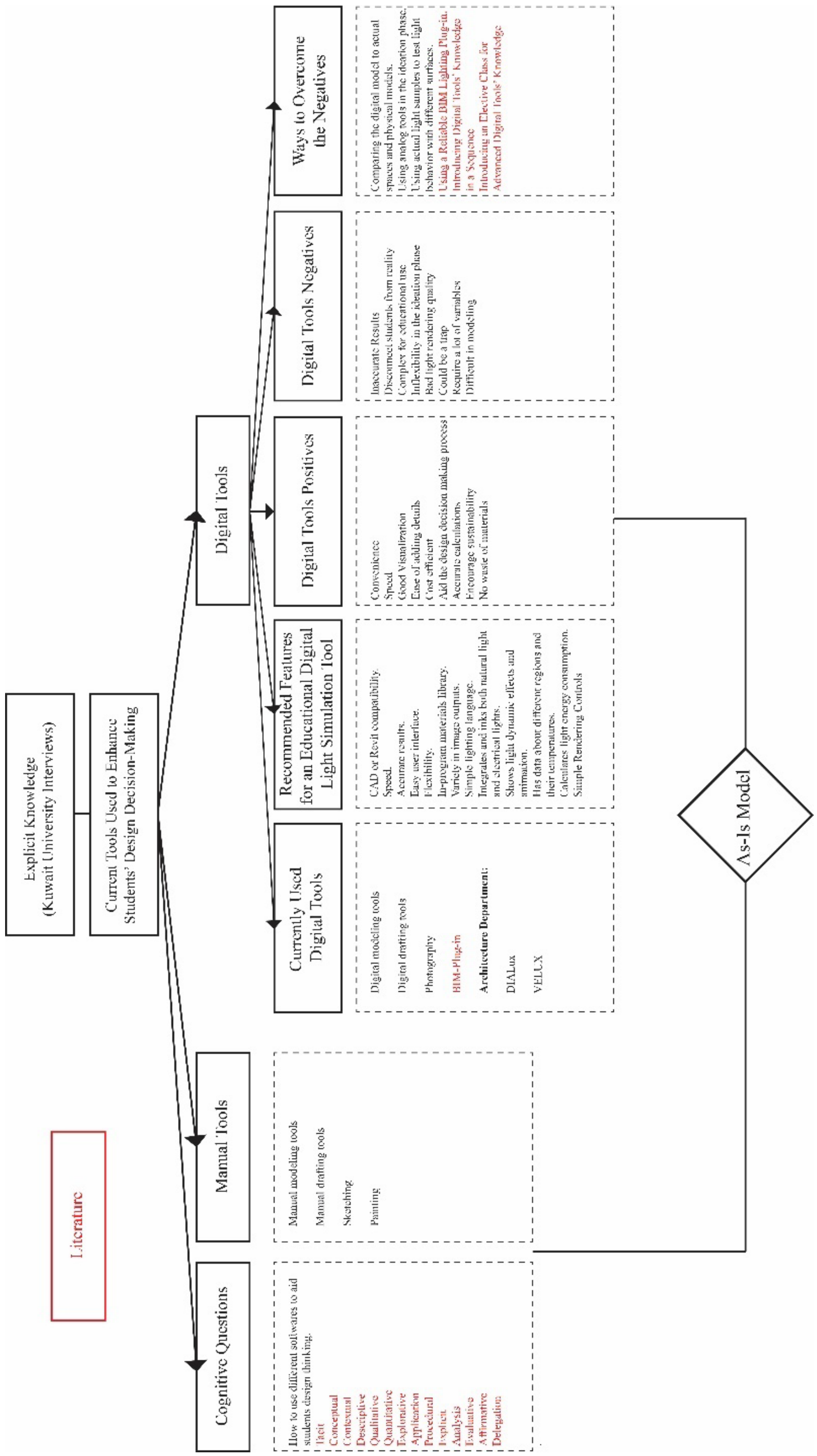


Figure 7-4. The literature's influence on the Explicit Knowledge of Kuwait's As-Is framework

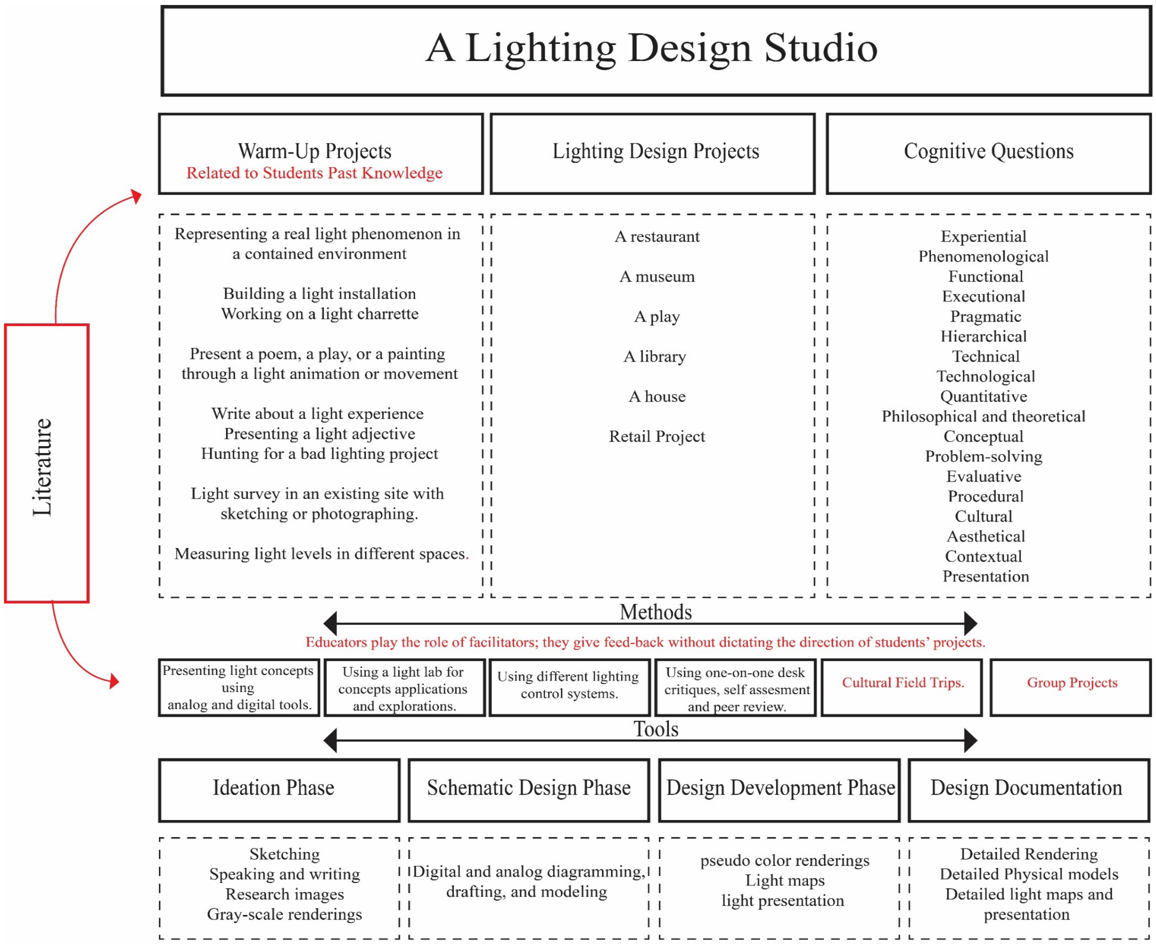


Figure 7-5. The literature's influence on the Lighting Design Studio

Examples of the Cognitive Questions

Explorative: What is the relationship of the building's openings to the sun orientation?
Qualitative: How to create a relaxed environment through light manipulation?
Functional: How to distribute light to minimize shadows on a critical task?
Explicit: What tools needed to perform certain light design objectives or tasks?
Quantitative: How many fixtures or how much light does a designer need for a specific function or task?
Philosophical and theoretical:
Conceptual: What is the overall theme?
Evaluative: Which lighting design alternative create the most sustainable design?
Affirmative: Does the chosen lighting design alternative consume the least energy?
Procedural: What lighting design aspects should students focus on in each design phase?
Cultural/Contextual: What are the lighting design features that represent a certain culture or community?
Analysis/Reasoning: What materials absorb light? What surfaces reflect light the most? What causes glare?
Descriptive: What are the color components of a white light?
Delegation/ Executional: Which design task does the designer need to delegate to other team members?

Figure 7-6. Examples of Design Cognitive Questions

Sequence of Lighting Design Knowledge and Decision Making Tools

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design Design Elements and Principles Shade and Shadow Tools: Manual Drafting and Presentation Language and Communication			Introduction to Interior Design (Architecture) Painting
2	Building Environmental Systems class (technical,fundamental, and general knowledge of light) (Interior) Tools: Computer Technology (modeling and Drafting)	Human Factors class (qualitative aspects) Different Design Functions		Photography I Graphic Design
3	Innovative Interiors Class (Interior) Tools: Analog and Digital + Technical Writing	Technical Design Knowledge Design of the Luminous and Sonic Environments (Architecture)	Environmental Sustainability + Sustainable Interior (environmental, vernacular, and cultural aspects of light) (Interior) Tools: DIALux + VELUX	Solar Energy elective class (Architecture) Architectural Research Photography II Fixture Design
4	Building Systems I (Architecture)	Mandatory lighting class (Architecture): Design of the Luminous and Sonic Environments Sustainability + Lighting Design Studio	Comprehensive Application of Light Internship (Interior) Tools: Advanced Digital Tools	Advanced Computer Application BIM Technology + BIM Lighting Plug-ins
5			Comprehensive Application (Architecture) Tools: Working Drawings	Advanced Lighting and Acoustics class Professional Training (Architecture)

Sequence of Lighting Design Topics and Digital Knowledge

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Calculation Design Thinking Human Perception Light Properties Manual Drafting Shade and Shadow Design Process and Basics Color Theory			
2	Light Fundamentals Light Design Process Light Terminologies Light Perception Physics of Light Natural Light + Solar Geometry Electrical Light Sources Light Color History of Light Digital Modeling Skills	Light Quality Light Quantity Light Aesthetics Light Effects Light and Human Factors Light Functions Light Hierarchy and Layers		
3		Digital Light Simulation Tools	Light Technologies Light Applications Light Sustainability (energy calculation) Light Controls Light Role in Islamic Design Light Culture (indigenous aspects)	
4				Advanced Computer Analysis and Modeling Theatrical Lighting Light for Safety and Security Light Design Profession Outdoor Lighting

Table 7-1. The literature's influence on the Lighting Design Knowledge and Decision-Making Tools Sequence at Kuwait University

7.2 – The Influence of the United States Documents' Analysis on Kuwait's Framework

The documents provide the researcher with a lighting design studio, a photography class, and extra lighting topics like light and movement, and shade and shadow. For the procedural knowledge domain, the documents encourage educators to use demonstrations in the lighting lab, invite students to conduct individual lighting research, introduce students to various professional lighting design competitions, and involve them in cultural and environmental contexts. For student evaluations, the documents recommend peer reviews, seminar discussions, and evaluative cognitive questions.

For the explicit and analytical knowledge domain, the documents present different analytical tools such as renderings, cut sheets, schedules, IES handbooks, collages, light measuring devices, installation construction, and different digital light simulation tools, such as Rhino with Diva plug-in, SketchUp with Light Stanza plug-in, Ecotect, AGi32, Sun Surveyor, Sun Seeker, and VectorWorks. In addition, the documents offer recommended features for an educational digital light simulation tool such as CAD or Revit compatibility, accuracy, simple rendering controls, user-friendly interface, flexibility, variety in images outputs, speed, and simplicity in calculations. The researcher sorted the extra topics and decision-making tools in the lighting design sequence tables presented subsequently (see Table 7-2).

Sequence of Lighting Design Knowledge and Decision Making Tools

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design Design Elements and Principles Shade and Shadow Tools: Manual Drafting and Presentation Language and Communication			Introduction to Interior Design (Architecture) Painting
2	Building Environmental Systems class (technical,fundamental, and general knowledge of light) (Interior) Tools: Computer Technology (modeling and Drafting)	Human Factors class (qualitative aspects) Different Design Functions		Photography I Graphic Design
3	Innovative Interiors Class (Interior) Tools: Analog and Digital + Technical Writing	Technical Design Knowledge Design of the Luminous and Sonic Environments (Architecture) Tools: IES Handbook + Light measuring devices	Environmental Sustainability + Sustainable Interior (environmental, vernacular, and cultural aspects of light) (Interior) Tools: Digital Light Simulation Tools	Solar Energy elective class (Architecture) Architectural Research Photography II Fixture Design
4	Building Systems I (Architecture)	Mandatory lighting class (Architecture): Design of the Luminous and Sonic Environments Sustainability + Lighting Design Studio Tools: Analog and digital analysis tools like renderings, collages, and sketches Cognitive Questions	Comprehensive Application of Light Internship(Interior) Fixture Design Tools: Advanced Digital Tools Schedules and Cut-sheets	Advanced Computer Application BIM Technology + BIM Lighting Plug-ins
5			Comprehensive Application (Architecture) Tools: Working Drawings	Advanced Lighting and Acoustics class Professional Training (Architecture)

Sequence of Lighting Design Topics and Digital Knowledge

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Calculation Design Thinking Human Perception Light Properties Manual Drafting Shade and Shadow Design Process and Basics Color Theory			
2	Light Fundamentals Light Design Process Light Terminologies Light Perception Physics of Light Natural Light + Solar Geometry Electrical Light Sources Light Color History of Light Digital Modeling Skills Light Hierarchy and Layers	Light Quality Light Quantity Light Aesthetics and Arts Light Effects Light and Human Factors Light Functions Light Hierarchy and Layers Light Philosophy Daylight Strategies		Light and Movement Light Installation Photography
3		Digital Light Simulation Tools Lighting Design Profession Outdoor Lighting Sustainability Light Controls Safety and Security Light Applications	Light Technologies Light Applications Light Sustainability (energy calculation) Light Controls Light Role in Islamic Design Light Culture (indigenous aspects) Digital Light Simulation Tools Fixture Design	
4				Advanced Computer Analysis and Modeling Theatrical Lighting Light for Safety and Security Light Design Profession Outdoor Lighting

Table 7-2. The United States' Documents Analysis influence on the Lighting Design Knowledge and Decision-Making Tools Sequence at Kuwait University

Note: the text highlighted in green is the additional knowledge from the United States documents analysis

7.3 – The Influence of the United States' To-Be Model on Kuwait's As-Is Model

Figures 7-7, 7-8, and 7-9 show the knowledge transfer between the To-Be model and the As-Is model. Section 7.4 explains the proposed framework in detail.

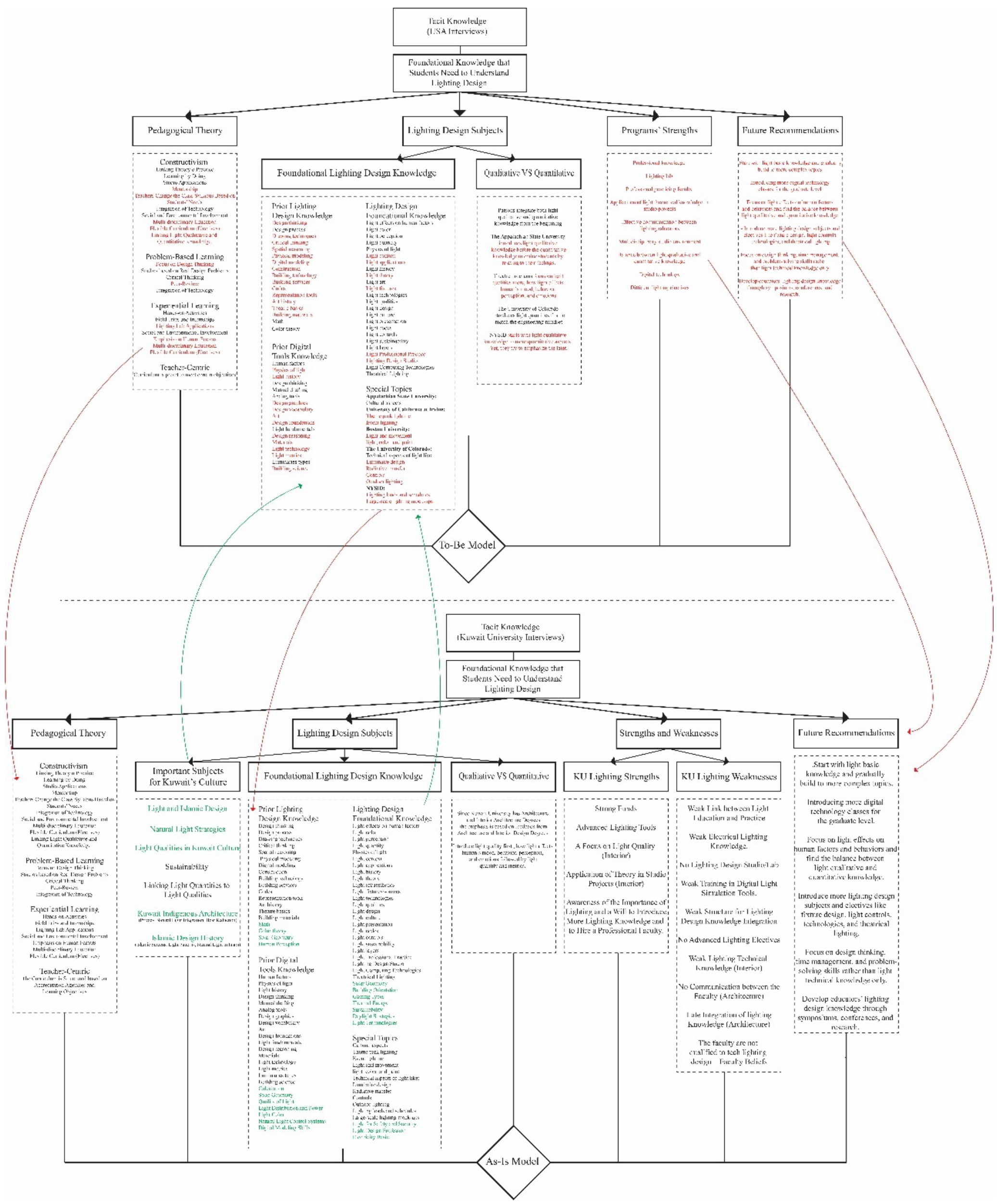


Figure 7-7. The Influence of the United States' To-Be Model on Kuwait's As-Is Model

(Tacit Knowledge Domain)

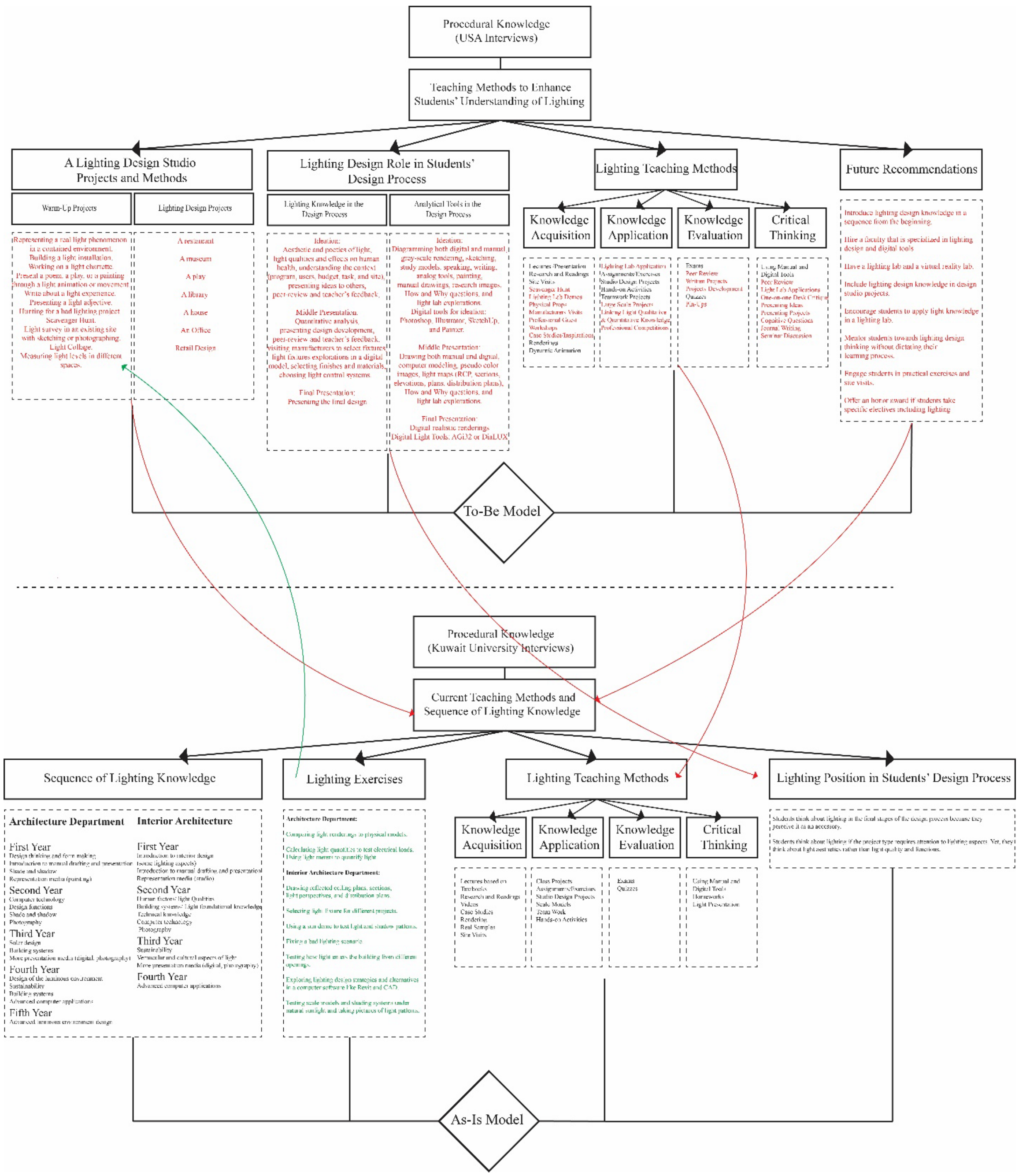


Figure 7-8. The Influence of the United States' To-Be Model on Kuwait's As-Is Model

(Procedural Knowledge Domain)

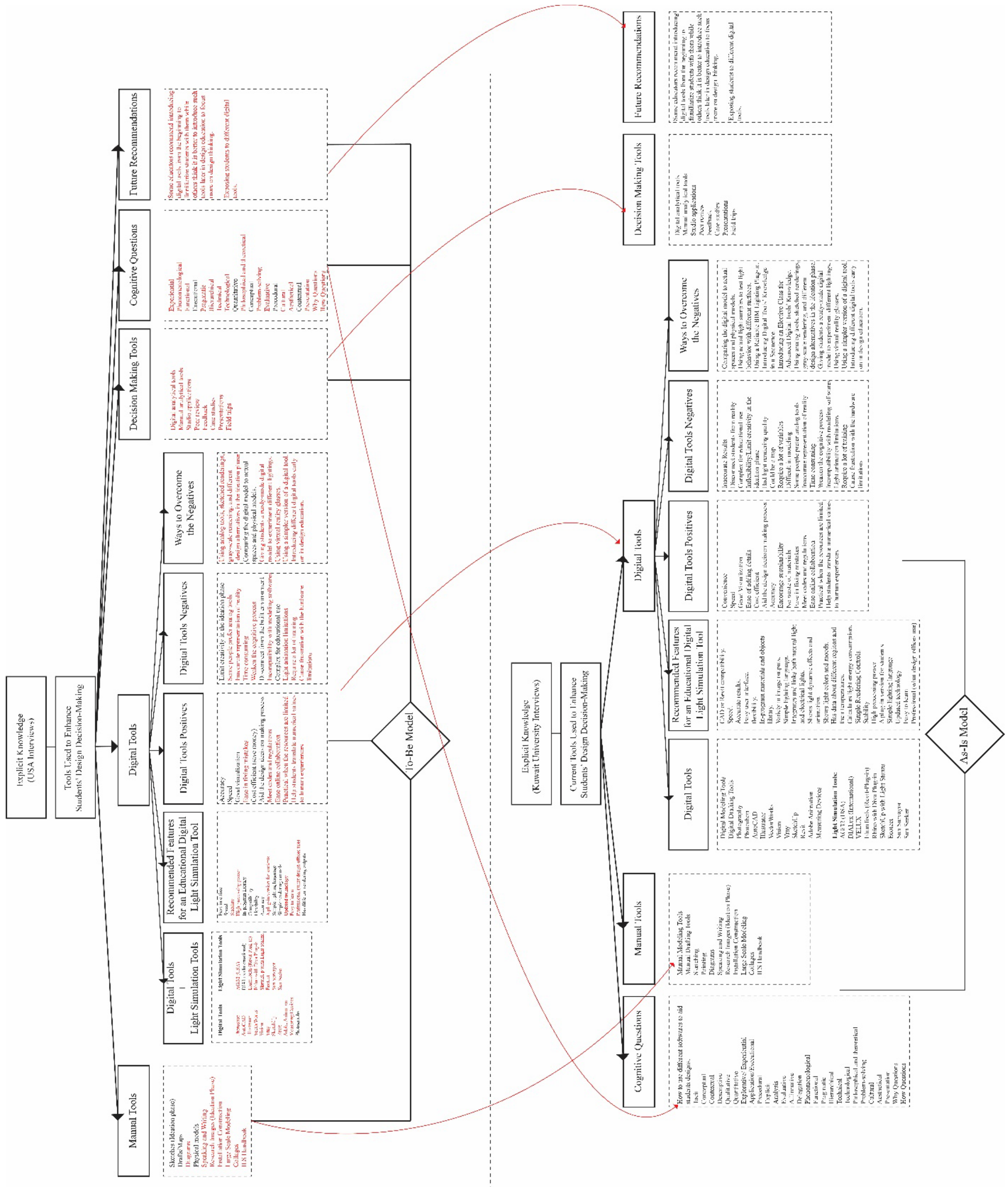


Figure 7-9. The Influence of the United States' To-Be Model on Kuwait's As-Is Model

(Explicit Knowledge Domain)

7.4 – The Proposed Lighting Design Framework

The proposed framework is developed based on Kuwait's and the United States' important lighting design topics, teaching methods, procedures, and analytical tools. The framework aims to provide a flexible curriculum for different design pedagogical systems with a focus on Kuwait University as a prototype. The framework is divided into three knowledge domains. The tacit and theoretical knowledge domain covers foundational lighting design topics, knowledge needed before engaging in lighting design and using digital light simulation tools, cultural aspects of Kuwait, and special lighting design topics. The procedural and application knowledge domain addresses recommended teaching methods for knowledge acquisition, knowledge application, and student evaluations. It proposes lighting design exercises, a studio scenario, and processes to develop students' design thinking in each design task/phase. The explicit and analytical knowledge domain includes analytical and decision-making tools, digital light simulation tools, recommended features of an educational digital light simulation tool, and cognitive questions to guide students' design thinking. These knowledge domains fall under a suggested overarching pedagogical theory.

7.4.1 – The Proposed Pedagogical Philosophy

The proposed pedagogical theory is a mix between teacher-centric and student-centric pedagogical approaches. The program directors set the curriculum based on certain objectives and learning outcomes to meet professional demands and accreditation agencies' standards. The classes' syllabi and electives, on the other hand, are designed to meet students' needs and individual interests. Educators are encouraged to link the theory classes to hands-on activities, studio projects, and practical applications with internship opportunities and social involvements to meet the experiential, problem-based learning, and constructivism theoretical philosophies (see section 2.4.3). The proposed pedagogy also focuses on design thinking and cognitive development. Educators are invited to expose students to different analytical tools, including digital technology, and develop cognitive questions to help them in design decision-making. They are encouraged to mentor students without dictating their learning process, as well as immerse them in multidisciplinary learning environments.

7.4.2 – The Merge of Kuwait's Lighting Cultural Aspects into the United States Model

Kuwait's framework provides current lighting topics, exercises, teaching methods, analytical tools, cultural factors, and course sequences to establish a base for the proposed framework. In other words, it provides the As-Is model. Kuwait is an Islamic country with an abundance of sunlight all year long; thus, the design curriculum requires lighting design topics that focus on solar geometry, daylight strategies, sustainability, energy use, light perception, light quality, Islamic design history, and indigenous design methods, as Kuwait educators mentioned in their interviews (see Chapter IV). In addition, Kuwait's buildings need shading systems that let in daylight, provide privacy, and keep the heat at bay. Traditionally, a *mashrabiya* was used to let in light, shade the window from the heat, and provide privacy, because privacy is an important aspect of Islamic culture. Another method that is used to reduce heat gain in hot climates is concrete construction. Concrete reduces heat transfer during the day due to its high-temperature absorbing capacity; it then releases the stored heat at night when the temperature drops. Some of the lighting design exercises that educators at Kuwait

University present correspond to the aforementioned factors. For example, Participant A invites his/her students to create different shading systems and test daylight patterns to control heat gain and daylight penetration in buildings.

Additionally, the current lighting design sequence provides the researcher with courses that she can weave into the additional recommended lighting design topics and proposed teaching methods. The researcher combined some courses from the Architecture and Interior Architecture departments, such as the sustainability courses, electives like the solar geometry and photography classes, the lighting design studio, and an advanced digital light simulation course to create multidisciplinary learning opportunities for students because lighting is important for both majors. Other classes like the Building Systems classes and the Design of the Luminous and Sonic Environments remain separate for educators to focus on certain aspects that are important to each major (see Table 8.1). As for lighting design simulation tools, Kuwait University mainly focuses on DIALux because it is the standard software outside of the United States.

7.4.3 – The Merge of the United States Knowledge into Kuwait's Framework

The United States' knowledge provides educators with a new framework, structure, and learning path to integrate lighting design knowledge and lighting-related cognitive tools in existing design curricula. The new framework is developed from the United States interviews' results, document analysis, interpretation of the literature, and existing Kuwait University structure. The proposed framework is presented in response to the tacit, procedural, and explicit knowledge domains, and integrated into the foundational, intermediate, advanced, and elective learning paths and stages.

7.4.3.1- Tacit and Theoretical Knowledge

The tacit knowledge domain tackles foundational lighting knowledge, the knowledge needed before working with lighting design and digital tools, Kuwaiti cultural topics (refer to section 7.4.2), special lighting topics, the pedagogical philosophy (see section 7.4.1), and the relationship between qualitative and quantitative lighting knowledge.

In detail, students need knowledge about design thinking, interior design and architecture basics, math, drawing and modeling techniques, materials, human perception, color theory, art history, and solar geometry before they are introduced to lighting design. As for foundational lighting design knowledge, students need to learn solar geometry and daylight strategies in detail, including glazing types and building orientation. They need knowledge about sustainability, thermal energy, light foundations, history of light, light qualities (light poetics), electrical light sources, light quantities and metrics, light terminologies, physics of light, light aesthetics, light cultural, social, and vernacular aspects, light design process, light concept generation, light technologies, light functions and applications, light color, light perception, light presentation, light hierarchy and layers, light's effects on human factors, light codes and regulations, some aspects of theatrical lighting, and digital light simulation tools.

Students are also encouraged to understand foundational lighting knowledge, knowledge needed before engaging lighting design, manual modeling and drafting techniques, and digital modeling basics before they learn digital light simulation tools to ease their learning process. In addition to foundational lighting knowledge, some extra lighting topics can be introduced in different classes and electives to further develop students' interest in lighting design, such as fixture design, outdoor lighting, light for safety and security, lighting design professions, electricity basics, photography, light and shadow, light color and paint, light movement, event lighting, and a design studio that is focused on lighting design.

Educators recommend introducing qualitative lighting knowledge first, especially in architecture and interior architecture schools, to relate it to human experiences, comfort levels, mood, and health. Quantitative lighting knowledge, on the other hand, works better in the junior year after qualitative lighting knowledge. Figure 7-10 summarizes the proposed framework's tacit knowledge.

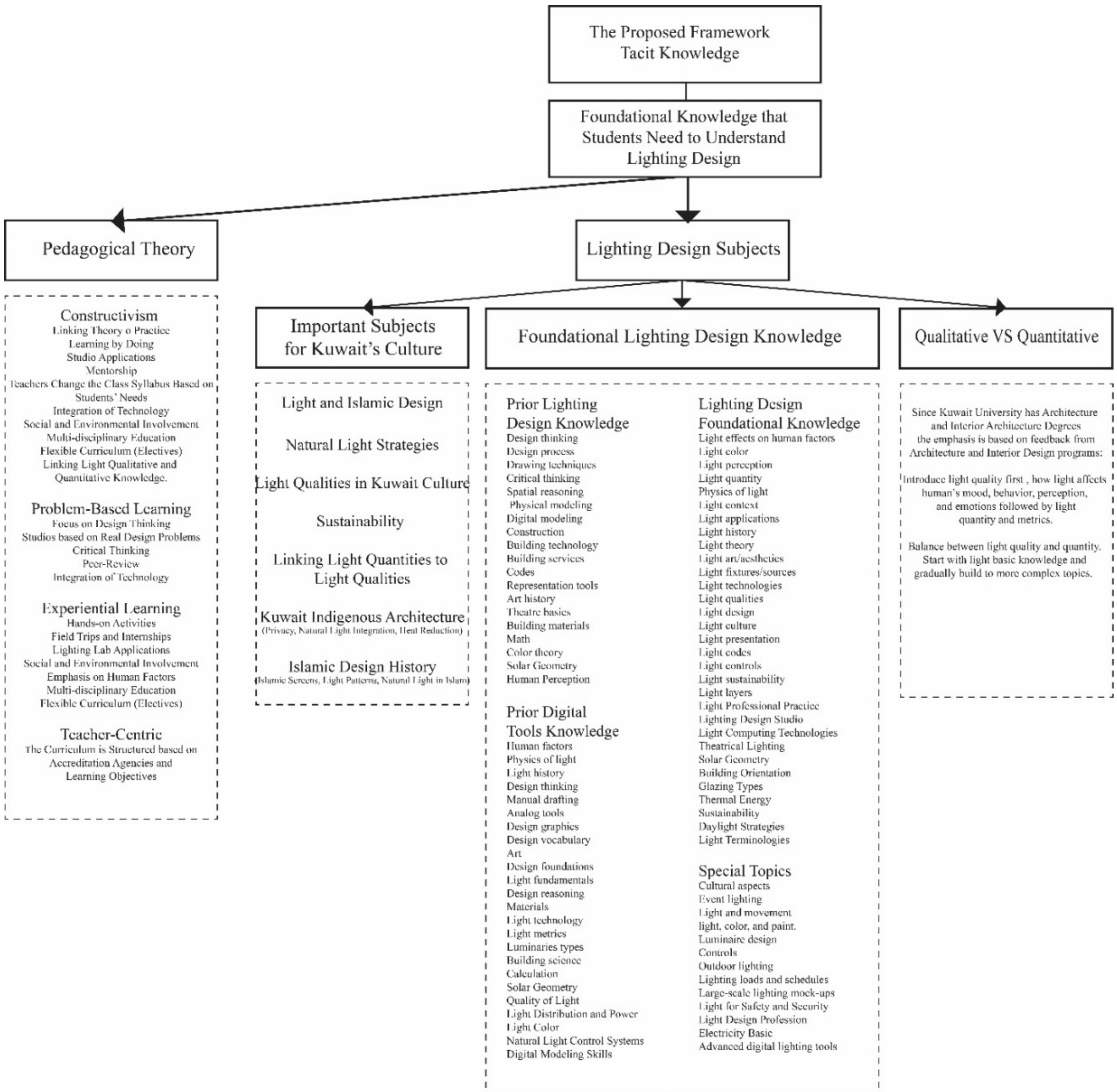


Figure 7-10. The Proposed Framework Tacit Knowledge Domain

7.4.3.2- The Procedural knowledge

The procedural knowledge domain focuses on the roles of lighting design and cognitive tools in students' design process; the teaching methods that enhance students' lighting design knowledge acquisition, application, and evaluation; and the sequence of lighting design knowledge in the curriculum. It also proposes a studio scenario with lighting design projects to develop students' cognitive thinking.

Educators are encouraged to present lighting design knowledge using lectures, audiovisual materials, demos and props, renderings, real samples, and case studies. They are also encouraged to take their students on field trips; prompt them to conduct individual research; help them apply light theoretical knowledge in hands-on exercises, assignments, and projects, both as individuals or within groups; and encourage them to participate in studio projects, professional competitions, and social and environmental community projects. Students are invited to build large-scale mockups, use a lighting lab, or present new lighting materials to the class. This multi-method approach enhances students' knowledge retention and engagement in the subject matter.

Another important quality is investing in the educators themselves. The university needs professional faculty members who are specialized in lighting design and digital light simulation tools. Faculty need to update their lighting design knowledge regularly by attending conferences and conducting research. If resources for such professional development are limited, the school can invite professional guest lecturers or introduce crash courses/workshops for certain lighting design topics. The school may also offer an honor award to encourage students to take different lighting design electives. Effective communication among faculty members is another important method to save time, enhance students' knowledge retention, and encourage students to apply light theoretical knowledge in practical studios or classes.

Moreover, establishing a clear link between qualitative and quantitative lighting knowledge is important when transforming numerical data into human experiences. In the design process, students are advised to start with qualitative aspects of lighting and treat light as a concept generator. For example, they are encouraged to think about light's effects on the overall mood and atmosphere; light's relationship to human health and comfort levels; and the aesthetical, cultural, and poetic aspects of light. Students are also invited to understand the context of light in the ideation phase and to present their thoughts and ideas to others using analog and digital tools such as sketches, diagrams, paintings, collages, research images, grey-scale renderings, and light lab explorations. In the schematic and design development stages, they are encouraged to link light's qualities to its quantitative qualities. For example, they are invited to visit manufacturers and select specific fixtures, explore different fixtures in a digital model, select finishes and materials, choose control systems, and analyze light quantities either through manual calculation or computer analysis. Students are advised to present their design development through analog or digital drawings, plans, perspectives, renderings, pseudo color renderings, models, and light lab explorations.

As for student evaluations, educators are encouraged to use pragmatic evaluation to assess the students' design projects development. They can also use exams, quizzes, homework, reflective critical writings, pin-ups, peer-review, seminar discussions, readings' questions, scavenger hunts, and evaluative cognitive questions to evaluate their students' performance. Figure 7-11 summarizes the proposed framework's procedural knowledge.

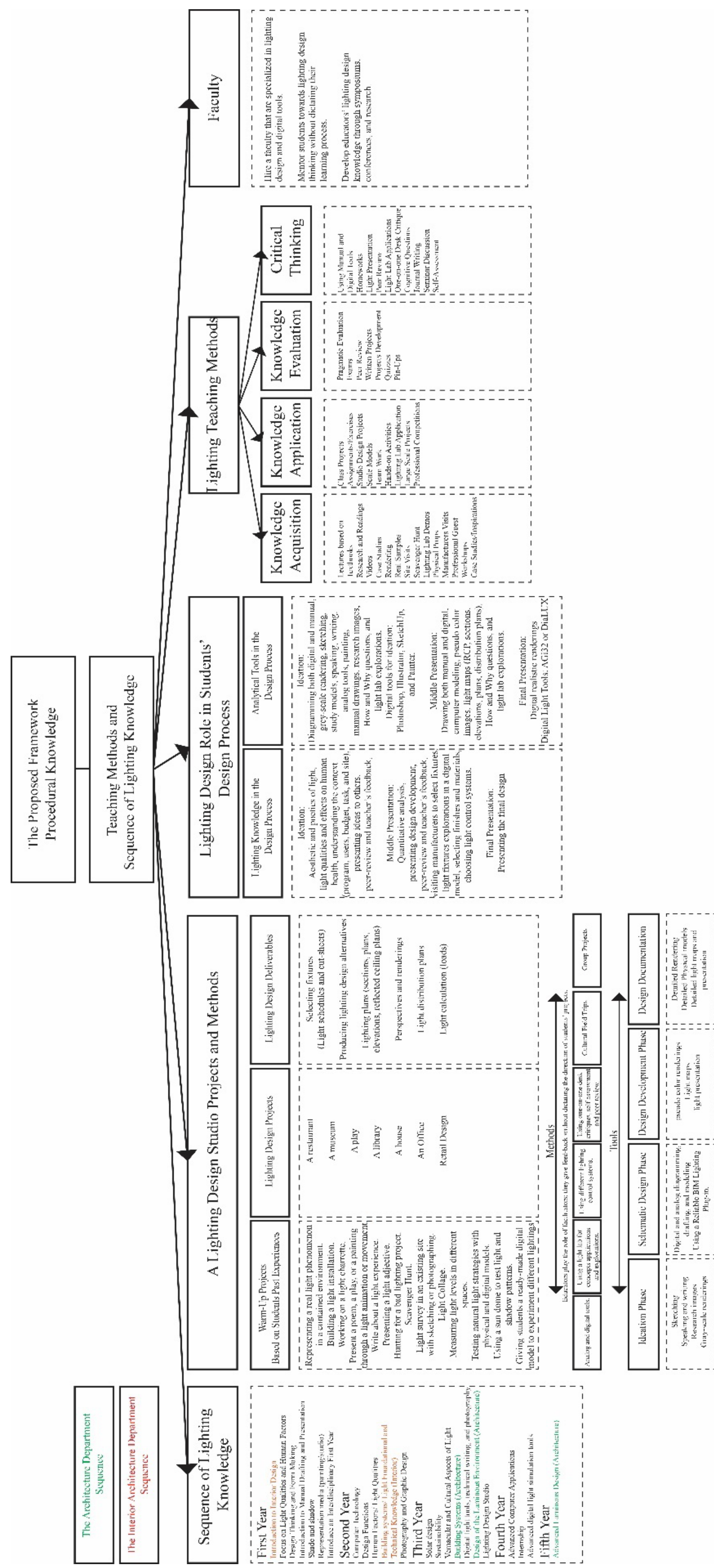


Figure 7-11. The Proposed Framework Procedural Knowledge Domain

7.4.3.3- Explicit Knowledge

The explicit knowledge domain concentrates on lighting design cognitive tools that help students in design decision-making. Students need both analog and digital tools to meet all their design objectives from the conceptual design phase to the design development and construction documentation phases. These tools include hand sketches and diagrams, physical models, manual drafts, paintings, photographs, collages, research images, writings, digital modeling and drafting, digital renderings, digital analysis software, lightmaps, schedules, cut sheets, light measuring hand devices, the IES handbook, big scale installations, mockups, and cognitive questions. All these tools work hand in hand in each design phase. Students choose from them based on their interests, needs, and design objectives.

Digital technology is an essential part of the lighting design process and education. Constructivism and the experiential pedagogical approach call for the integration of technology in education. Different digital light simulation tools ease the analysis and understanding of lighting. Educators in Kuwait and the United States use DIALux, VELUX, Elumtools (a BIM/Revit plug-in), Diva (A Rhino plug-in), Light Sanza (SketchUp plug-in), AGi32, Ecotect, and VectorWorks for light analysis. One educator in the United States also reported using Sun Surveyor and Sun Seeker applications. In addition to digital light simulation tools, educators use different digital tools to draft, diagram, and animate light such as Adobe Photoshop, Adobe Illustrator, AutoCAD, Revit, Adobe Animation, and Vision. When choosing a software program, instructors teach the software that is professionally known in their region and the one with which they are most familiar. They also introduce their students to lighting plug-ins based on the main digital modeling software they use to make light analysis easier instead of transforming the model into a different lighting software.

Students need both analog and digital tools in the lighting design process to overcome the limitations and utilize the strengths of each tool. Educators are encouraged to overcome the digital tools' drawbacks by using different methods such as:

- Comparing the digital model to actual spaces and physical models to understand the strengths and limitations of the tool.
- Using analog tools or grey-scale renderings in the ideation phase.
- Using actual light samples and mockups to test light behavior.
- Using a reliable BIM lighting plug-in for more ease.
- Introducing digital tools in a sequence from the beginning of design education to familiarize students with them.
- Introducing an elective class for advanced digital tools.
- Giving students a ready-made digital model to test light alternatives in less time and using virtual reality glasses for better depiction of real light experiences.

Additionally, educators recommend the following features for an educational digital light simulation tool: CAD or Revit compatibility, simple rendering controls, accurate photometric data and results, easy user interface, flexibility, variety in image outputs, speed and simplicity in calculations, stability, high processing power, in-program library, simple language, updated technology, easy to learn, and professional (used by design offices).

Cognitive questions are other important analytical tools that students need to guide their cognitive thinking. Key recommended questions are listed in Figure 7-12. Lastly, educators think that studio applications, feedback, peer-review, case studies, analog and digital tools, presentations, and field trips are important tools to help students in design decision-making. Figure 7-12 summarizes the proposed framework's explicit knowledge. The following sections link the analytical tools and cognitive questions to each design phase/task and give examples of each to ease students' design decision-making and learning processes.

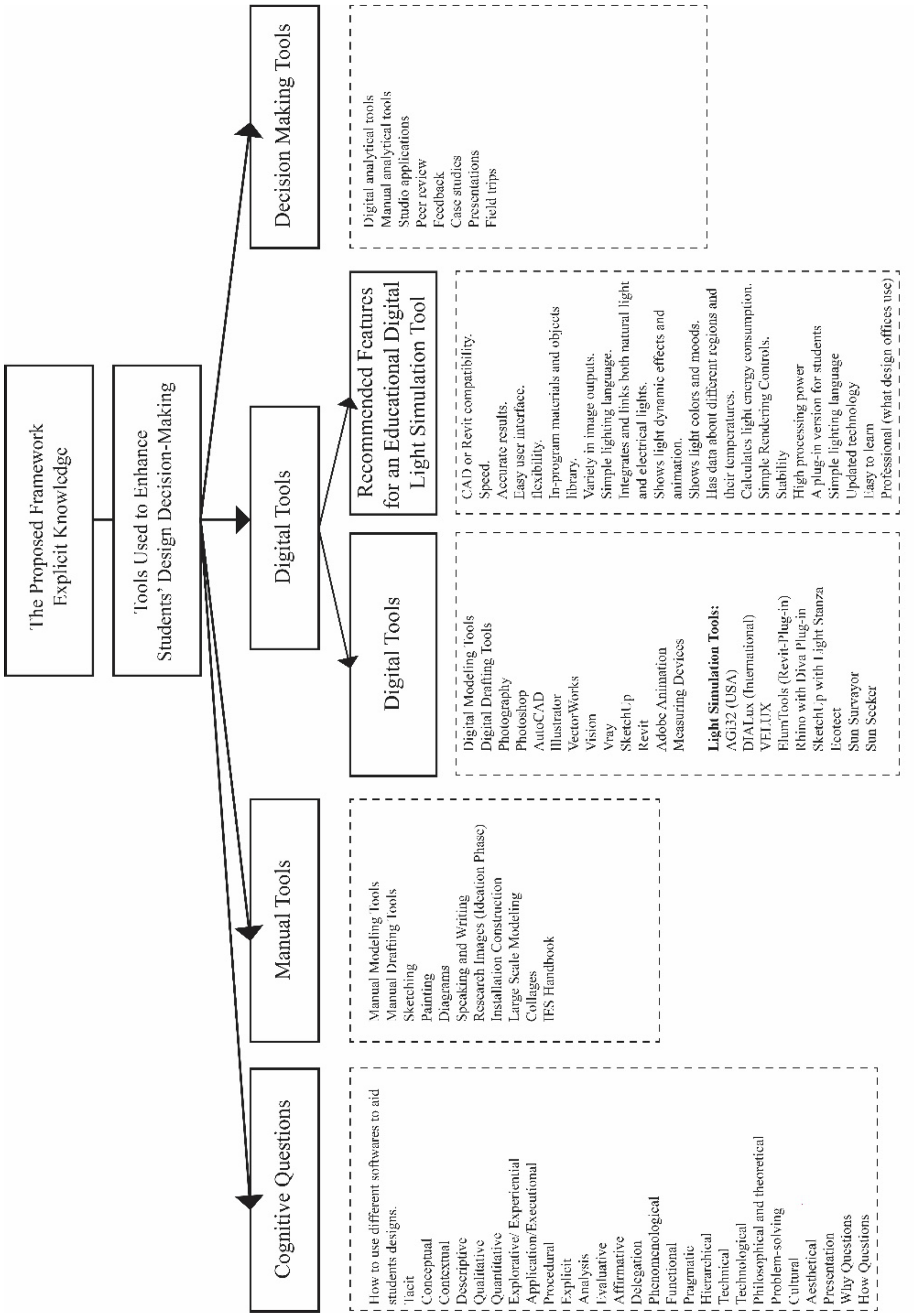


Figure 7-12. The Proposed Framework Explicit Knowledge Domain

7.4.3.4- The Learning path

The learning path divides lighting design topics, classes, and decision-making tools into a yearly sequence and according to the foundational, intermediate, advanced, and future knowledge stages. The researcher gave the interviewees a list of topics to sort into the four stages and asked them in an interview about the foundational knowledge that they think students need to learn. The researcher integrated some of the lighting design topics into the available courses at Kuwait University. Any extra topics that did not fit within the existing classes are sorted as electives and additional classes (see Tables 7-1 and 7-2 for details).

7.4.3.4.1- Foundational Knowledge

In the first year, students are encouraged to develop foundational design and lighting knowledge such as design thinking, design elements, design principles, the design process, shade and shadow, light qualities, human factors, human perception, light properties, light theories, color theory, math basics, and natural light basics. The design-related topics such as design process, design thinking, design elements and principles, and natural aspects of lighting like shade and shadow may be given in the introductory communication courses, such as the introduction to interior design or architectural communication courses. The math basics are usually given in a calculus course. Color theory, basic light theories, principles, light qualities, and human factors may be part of a new light poetics course or part of the introductory studio courses. As for the foundational decision-making tools, students need manual drafting skills, verbal communication skills, writing skills, and some basic digital modeling skills. These tools are usually given in the introductory studio courses and communication classes.

In the second year, students are invited to learn more about light quality and perception, the lighting design process, light fundamentals and terminologies, physics of light, solar geometry, electrical light sources, design functions, light color, history of light, and light hierarchy and layers. These topics may be part of the Building Environmental Systems class for the Interior Architecture department, the Solar Energy elective, through the Design of Luminous and Sonic Environment, or the Building Systems 1 classes in the Architecture department. Students are also encouraged to take computer application courses in the second year.

7.4.3.4.2- Intermediate Knowledge

In the second year, students are encouraged to take intermediate lighting design knowledge such as light quantity and metrics, light art and aesthetics, light functions, and light philosophy. These topics can be given in the Building Environmental Systems class for the Interior Architecture department, and the Design of Luminous and Sonic Environment class in the Architecture department. Please note that the architecture courses are given in the third year because it is a 5-year program in comparison to interior architecture, which is a 4-year program. The intermediate lighting design decision-making tools include the IES handbook and the light measuring devices.

In the third and fourth years, students may take professional lighting knowledge, sustainability and thermal energy, light controls, safety and security, outdoor lighting, and light applications. Light sustainability and thermal energy may be given in the sustainable interiors and environmental sustainability courses. Professional lighting knowledge, light controls, safety and security, light applications, and outdoor lighting may be part of the Building Environmental Systems class or a lighting design studio in the Interior Architecture department, the advanced lighting and acoustics classes in the Design of Luminous and Sonic Environment, or a lighting design studio in the Architecture department. Professional lighting knowledge, in contrast, may be part of the students' internship opportunities. In addition, students are invited to develop their analog and digital tools knowledge and skills in the third and fourth years of design education.

7.4.3.4.3- The Advanced knowledge

In the third year, students are invited to learn advanced lighting design knowledge like light technologies, light culture, lighting's role in Islamic design, light's effects on human health and circadian rhythms, and fixture design. Light culture and its role in Islamic design may be given in the Sustainable Interiors or Environmental Sustainability classes. Light technologies and light's effects on health may be part of the Building Environmental Systems class or a lighting design studio in the Interior Architecture department, the advanced lighting and acoustics classes in the Design of Luminous and Sonic Environment, or a lighting design studio in the Architecture department. Fixture design may be part of a lighting design studio or a product design elective.

The advanced lighting analysis tools are digital light simulation tools. These tools may be part of the lighting or studio courses. If students need more digital light knowledge, including tools that calculate light's effects on the circadian rhythm like Alfa, they can take an Advanced Computer Application class or a BIM elective class with some lighting analysis plug-ins such as ElumTools. Students are encouraged to apply all the lighting design knowledge they gain over the years in their comprehensive graduation or capstone projects.

7.4.3.4.3.1- Light's Effects on Human Health

Light's effects on human health and the circadian rhythm are the new trend in lighting design. Educators from the United States emphasize the importance of light and human health. For Example, Interviewee F stated: "At least one, maybe two classes that are more about the impact of lighting on health for occupants will be critical for the interior designers." There is also a digital light simulation software that is specific for circadian lighting analysis called Alfa, a Rhino plug-in that measures the non-visual effects of light like melatonin levels to help designers meet certain lighting design objectives (Solemma, 2021).

7.4.3.4.4- Future/Elective Knowledge

The future/elective knowledge component provides students with opportunities to widen and develop their lighting design interests. In the first year, they can learn painting with light and abstract light art. Architecture students may also take the introduction to the interior design studio. In the second year, they may take topics in light and movement, photography, graphic design, and light installations and art. In the third year, they can extend their knowledge in solar energy, fixture design, and photography. In the fourth or fifth year, they can develop their digital skills by taking advanced computer application classes, they may take theatrical lighting and light for safety and security topics in the advanced lighting elective, or they can develop their lighting professional knowledge through internship opportunities.

Sequence of Lighting Design Knowledge and Decision Making Tools for the Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Basic Design Studio (Design Thinking, Design Process and Basics, Color Theory, Natural Light) Light Qualities and Human Factors Light Properties and Theories, Shade and shadow) Tools: Manual Drafting, Physical Modeling, Sketching, Research Images, and Language and Communication	Tools: Cognitive Questions Peer-Review, Self-Assessment Pin-Ups		Introduction to Interior Design Light and Painting
2	Tools: Computer Technology (modeling, drafting, rendering)	Building Services, Codes, and Materials Building Technologies Building Construction Tools: Cognitive Questions		Light Installation Photography I Graphic Design Light and Movement
3	Building Systems I (Light Quality and Human Factors, Design Functions, Physics of Light Light Fundamentals and Terminologies Light Design Process, Light Perception, Solar Geometry , Electrical Light Sources Light Color, History of Light Light Hierarchy and Layers) Tools: Analog and Digital + Technical Writing	Design of the Luminous and Sonic Environments (Light Quantity, Light Aesthetics and Arts, Light Functions, Light Philosophy and Theory Technical Lighting Design Knowledge, and Light Technologies and Controls) Lighting Design Studio (Light Controls, Light Applications, Outdoor Lighting,) Tools: IES Handbook + Light measuring devices, Cognitive Questions Peer-Review, Self-Assessment Pin-Ups	Tools: Digital Light Simulation Tools	Solar Energy elective class Photography II Kuwait Indigenous Architecture Fixture Design
4		Internship Opportunities (Profession) Tools: Analog and Digital Analysis Tools Cognitive Questions Peer-Review, Self-Assessment Pin-Ups	Environmental Sustainability (environmental, vernacular, and cultural aspects of light + light role in Islamic design + light effects on the circadian rhythm) Tools: Advanced Digital Tools Schedules and Cut-sheets	Advanced Computer Application BIM Technology + BIM Lighting Plug-ins
5			Comprehensive Application Tools: Working Drawings Cognitive Questions Peer-Review, Self-Assessment Pin-Ups-	Advanced Lighting and Acoustics class (Light for Safety and Security) Theatrical Lighting Professional Training

Table 7-1. The Proposed Sequence of Lighting Design Knowledge and Decision-Making Tools in the Architecture Department

Sequence of Lighting Design Knowledge and Decision Making Tools for the Interior Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design Studio (Design Thinking, Design Process and Basics, Color Theory, Natural Light) Light Qualities and Human Factors Light Properties and Theories, Shade and shadow) Tools: Manual Drafting, Physical Modeling Sketching, Research Images, and Language and Communication	Building Services, Codes, and Materials Tools: Cognitive Questions Peer-Review, Self-Assessment Pin-Ups		Light and Painting
2	Building Environmental Systems class (Light Quality and Human Factors , Physics of Light, Light Fundamentals and Terminologies , Light Design Process, Light Perception, Solar Geometry , Electrical Light Sources, Light Color, History of Light, Light Hierarchy and Layers) Tools: Computer Technology (modeling, drafting, grey-scale rendering)	Building Environmental Systems class (Light Quantity, Light Aesthetics and Arts, Light Functions, Light Philosophy and Theory Technical Lighting Design Knowledge, and Light Technologies and Controls) Lighting Design Studio (Light Controls, and Light Applications) Tools: Cognitive Questions Peer-Review, Self-Assessment Pin-Ups		Light and Movement Light Installation Photography I Graphic Design
3	Innovative Interiors Class Tools: Analog and Digital + Technical Writing	Tools: IES Handbook + Light Measuring Devices Cognitive Questions Peer-Review, Self-Assessment Pin-Ups	Environmental Sustainability + Sustainable Interior (environmental, vernacular, and cultural aspects of light + light role in Islamic design – Light effects on the circadian rhythm) Tools: Digital Light Simulation Tools	Photography II Kuwait Indigenous Architecture Fixture Design
4		Internship Opportunities (Profession) Tools: Analog and Digital Analysis Tools Cognitive Questions Peer-Review, Self-Assessment Pin-Ups	Comprehensive Application of Light Tools: Advanced Digital Tools Schedules and Cut-sheets Working Drawings	Advanced Computer Application BIM Technology + BIM Lighting Plug-ins Light for Safety and Security Theatrical Lighting

Table 7-2. The Proposed Sequence of Lighting Design Knowledge and Decision-Making Tools in the Interior Architecture Department

7.4.3.4.5- Educational Lighting Design Objectives for each Design Year

Lighting design knowledge is integrated into a sequence in the proposed curriculum based on each year's intentions and according to the foundational, intermediate, advanced, and elective knowledge paths. The first year mostly focuses on design thinking and process, human perception, light theories, presentation tools, and communication skills. The second year tackles qualitative and quantitative lighting knowledge, lighting fundamentals, physics of light, light philosophies, light applications, history of light, light hierarchy and layers, light functions, light color, and solar geometry.

The third year emphasizes technical and technological lighting knowledge, sustainability, light controls, light applications, light's effects on human health, professional lighting knowledge, and cultural aspects of light. The fourth year is mostly a comprehensive application of light knowledge with some advanced electives. This yearly outline enhances the lighting design knowledge delivery sequence.

7.4.3.5- Weaving Qualitative and Quantitative Lighting Knowledge

Quantitative and qualitative lighting knowledge are both essential in design education. In architecture, interior design, and theater programs, most educators emphasize beginning with qualitative lighting knowledge to relate it to human experiences and feelings, followed by quantitative lighting metrics. Both, however, are important to be introduced from the beginning of design education. The proposed framework focuses on qualitative lighting knowledge and its effects on human factors in the first and second years. Qualitative knowledge includes light color, light's effects on human moods and feelings, phenomenological aspects of light, cultural connotations of light, light's effects on human health and psychology, and light's social traits. Cultural aspects of light and light's effects on human health are also introduced in more depth in the third year in the sustainability classes. Quantitative lighting knowledge, in contrast, is introduced from the second year with more depth in the third year. In the second year, students learn about the physics of light, light calculations, and light technical knowledge. In the third year, they learn about light energy and sustainability, light controls, and light technologies.

7.4.3.5.1- Analytical Tools That Support Qualitative and Quantitative Lighting Knowledge

Qualitative lighting knowledge relates to human factors, experiences, and feelings; hence, it is best assessed using analog tools because students need to experience light through all their senses to be able to feel it. Students are invited to experience light through site visits, light applications and demonstrations in the light lab, physical models that are tested under natural sunlight or actual light sources, material experimentations under different light sources, light installations, and light performances. Quantitative knowledge, in contrast, is better assessed using digital devices, software, or technologies for ease and speed of calculation and analysis. Students are encouraged to use light meters, digital light simulation tools, spreadsheets, light digital applications, manufacturers' IES files, and light analysis plug-ins to quantify light.

7.4.3.5.2- Teaching Methods that Support Qualitative and Quantitative Lighting Knowledge

Theoretical lighting knowledge and practical applications are important to deliver qualitative and quantitative aspects of lighting. Educators teach students qualities of light through lectures, research images, renderings, case studies, videos, real samples, site visits, demos, and props. Quantitative lighting knowledge, in contrast, is taught using lectures, props, site visits, digital analysis demos, light samples, measuring devices, and workshops. Students are encouraged to apply both factors in their projects, exercises, design studio, hands-on activities, and applications in the lighting lab (see section 6.9.2 for more details about effective teaching methods).

7.4.3.6- Accessing and Applying Lighting Design Knowledge

Powers' (2001) principles help educators to deliver lighting design knowledge effectively and guide students to ways of accessing and applying this knowledge. The first principle is prior constructions of knowledge. Educators are invited to understand their students' past knowledge by checking the curriculum and understanding what lighting design classes they usually take before their courses and structure their syllabus accordingly to build on the previous knowledge. Instructors may also present a warm-up project with open-ended questions in a studio environment to understand their students' past knowledge. Thus, the first principle is applied by sequencing lighting design knowledge and establishing effective communication between educators. The second principle is the formative assessment and evaluation of both students and teachers. Educators are invited to use regular pin-ups, rubrics, desk crits, pragmatic evaluation, quizzes, exams, and assignments in a studio environment or other classes to assess their students. Students, in contrast, are invited to use evaluation forms to evaluate their educators. These assessments help both students and educators to grow as individual thinkers and learners.

The third principle is students' negotiation of goals. Students are advised to set their own design goals, reflect on their design process, and negotiate with their teachers in a studio environment. Educators are encouraged to use cognitive questions to guide students in the right direction without influencing their designs. The fourth principle is the creation of authentic problems that emerge in the real world. Educators are advised to choose design problems that students are more likely to encounter in their professional careers. This approach develops students' problem-solving skills. The fifth principle is an emphasis on big concepts and interconnectedness. Students are invited to think about the bigger concepts and ideas of their projects while situating them in social and environmental contexts to gain a deeper understanding of their designs. Educators are invited to involve students in community/cultural projects and field trips to help them situate their projects in the proper context.

The sixth principle is multiple representations. Educators are encouraged to expose students to different representation and analysis tools, both digital and analog. Thus, for lighting design specifically, they are encouraged to teach students digital light simulation tools to broaden their choices and ease lighting design analysis along with light experimentation and application in a lighting lab to help students better understand light's behavior in real life.

Finally, the seventh principle is opportunities emerging from mistakes. Students are invited to self-assess their projects by determining their designs' weaknesses and strengths. They are also encouraged to evaluate their peers' projects through peer reviews or group works to help them grow as critical thinkers and widen their lighting design knowledge. This approach helps students to grow effectively as self-learners.

Powers' principles comply with the constructivism, PBL, and experiential learning pedagogical theories. The principles help students apply theoretical lighting knowledge in hands-on activities and experimentations, reflect on their design thinking and process, and observe light critically as a subject through field trips, reflective thinking, and analysis methods. The seven principles are applied in the proposed lighting design studio for a better application of lighting design knowledge.

7.4.4 – The Lighting Design Studio (The Proposed Framework Narrative)

A studio environment is the core of design education. In a design studio, students apply the theoretical knowledge they gain from different classes in practical projects to solve real-world problems. The previous sections mapped a general sequence and structure for lighting design knowledge and digital light simulation tools' integration in design education. This section discusses lighting design exercises, projects, teaching methods, and tools for a lighting design studio to broaden students' knowledge and enhance their knowledge retention and application. The studio scenario gives several alternatives and projects rather than one example to benefit all lighting design educators around the region. The studio includes light foundational, intermediate, and advanced knowledge domains along with decision-making tools to help students come up with creative and efficient lighting designs that serve the wellbeing and health of users, relate to the cultural needs of the region and meet energy and sustainability codes.

Before taking the lighting design studio, students are advised to build the lighting design foundational knowledge and knowledge needed before studying the lighting design and digital light simulation tools that are discussed in section 7.4.3.1. At the beginning of the lighting design studio, the instructor is encouraged to introduce summaries of some lighting design foundational knowledge with external readings. Students are invited to work on warm-up projects that are focused on light's relationship to human factors, color theory, light layers and hierarchy, solar geometry, and natural light strategies for the foundational knowledge domain. The warm-up projects relate to students' past experiences to build on their lighting design knowledge. Educators are advised to use questions and observations during the warm-up projects to understand students' past knowledge and experiences. Examples of start-up projects include light installation that provokes certain feelings or moods; a scavenger hunt for the latest light sources and bad lighting examples; a light performance that focuses on color theory, or human feelings and factors; a light animation that presents a poem, painting, or play; or a written light experience, where students visit a cultural site and reflect on its lighting experience or other light phenomena (these exercises are explained in detail in section 6.9.3). Students are invited to use sketches, diagrams, paintings, collages, photographs, study models, written documents, verbal communication, digital presentation, animation, and performance to present their initial projects. Educators, on the other hand, are invited to use desk crits, a first pin-up with peer-review, and cognitive questions, as well as to encourage their students to self-assess their projects in a written document. In this stage, students focus on light qualities with some cultural connotations.

For the intermediate knowledge domain, educators are advised to give students more complex lighting design projects like a restaurant, a museum, a retail space, a library, an office, or a house. Students are encouraged to focus on light functions, application, layers, qualities, aesthetics, quantities, control systems, wayfinding, safety, security, sustainability, and technologies in their lighting projects. Educators are also advised to take students on cultural field trips and site visits to widen their lighting design knowledge and gain more information about their region and its indigenous approaches. Before the site visits, students should form groups for the site analysis phase to enhance their teamwork and communication. Each group of students will work on the site analysis together, after which they should work individually on their designs. Educators may leave the site selection to the students to develop their logical reasoning and critical thinking skills. Students can select the site that they deem most suitable for the project type supported by the reasons behind the selection. When different groups of students pick different projects and sites, they learn about different lighting scenarios and factors through peer-review and regular pin-ups. Students are encouraged to use photographs, sketches, diagrams, analog and digital drafting and modeling, lighting lab explorations, mock-ups, and preliminary renderings and perspectives for this phase. Educators are advised to use desk crits, a second pin-up with peer-review, cognitive questions, self-assessment methods, and the first jury to evaluate students' performance. Additionally, instructors may bring in lighting professionals and guest lecturers to broaden students lighting design knowledge. In this phase, students focus on qualitative lighting knowledge, Kuwaiti cultural factors, and preliminary quantitative analysis.

Students continue to work on their design concepts, process, and development in the advanced knowledge stage with detailed analysis to produce their final lighting design project. They are encouraged to use detailed drawings, plans, elevations, sections, RCPs, cut-sheets, lighting schedules, detailed renderings, physical and digital models, animations, and lightmaps to present their final design. They are also encouraged to produce detailed light calculations and energy consumption tables and simulations to meet sustainability and building codes. Educators are invited to use desk crits, a third pin-up with peer-review, cognitive questions, self-assessment methods, pragmatic evaluation, and two additional juries, including a final jury, to evaluate students' performance. In this phase, students focus on quantitative and technical lighting knowledge. Educators may also extend students' knowledge by encouraging them to design their light fixtures to meet regional and cultural needs.

In conclusion, the students are expected to come out of the lighting design studio with a clear understanding of how to design efficient and quality lighting environments that correspond to social, cultural, and environmental demands. They are also expected to present their lighting designs professionally using different analysis and presentation tools.

A Lighting Design Studio			
Knowledge Stages	Design Goals	Decision-making and Presentation Tools	Evaluation
Foundational Knowledge	A warm-up project related to students' past knowledge (use questions to understand student's knowledge). Warm-up project ideas: -Representing a real light phenomenon in a contained environment. -Building a light installation. -Working on a light charrette. -Present a poem, a play, or a painting through a light animation or movement. -Write about a light experience. -Presenting a light adjective. -Hunting for a bad lighting project. -Light Sources Scavenger Hunt. -Light survey in an existing site with sketching or photographing or Collaging. -Measuring light levels in different spaces. -Testing natural light strategies with physical and digital models. -Using a sun dome to test light and shadow patterns. -Giving students a ready-made digital model to experiment different lightings	Sketching Diagramming Photographing Collages Study Models Writing and talking Digital presentation Animation Play / Performance Research Images Grey-Scale Renderings	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -First pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking.
Intermediate Knowledge	Field trips to cultural places. Lighting design studio projects: - A restaurant - A museum - A play - A library - A house - An office - Retail Design Concepts generation. Group Work Students focus on light qualities and Kuwait's culture.	Site visits and analysis Photography Sketches Diagrams Analog and digital drafting Digital and Analog modeling Lighting lab explorations/Control systems Mockups Preliminary renderings and perspectives Digital Light Plug-ins Light Plans (RCP, section, elevation, distribution plan)	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -Second pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking. - First jury
Advanced Knowledge	Design development Design process Detailed light analysis The final Project Students focus on light quantities and technical knowledge.	Detailed drawings Cut-sheets Light Schedules Detailed renderings/Pseudo color renderings Physical and digital models Animation Final light maps Light loads and calculation tables	-Desk Crits -Third pin-up : peer-review -Self-assessment -Pragmatic evaluation -Cognitive questions -Second jury -Final jury

Figure 7-13. The Proposed Lighting Design Interdisciplinary Studio

7.4.4.1 – Cognitive Questions

Educators are advised to use cognitive questions to guide students' design thinking without affecting their overall design process. These questions help students in design decision-making. For example, in the concept generation phase, theoretical, conceptual, contextual, descriptive, qualitative, explorative, phenomenological, and cultural questions are recommended to develop students' ideas. Figure 7-14 shows examples of such cognitive questions and Figure 7-15 relates the questions to the phases of the design process.

Examples of the Cognitive Questions

Explorative: What is the relationship of the building's openings to the sun orientation? How light patterns change based on different ground treatments? How different materials react to one light source?
Pragmatic: What are the needs of the client?
Qualitative: How to create a relaxed environment through light manipulation? What is the role of directed light and intimacy? What are the effects of light on the circadian rhythm and human moods?
Functional/Application: How to distribute light to minimize shadows on a critical task? How to manage glare for people with poor vision? How can we improve the eyes' adaptation between dark and bright environments? Is there a good contrast? How light brings texture to a surface?
Explicit/Presentation: What tools needed to perform certain light design objectives or tasks? What tool will you use to present your design?

Quantitative: How many fixtures or how much light does a designer need for a specific function or task? What are the required light levels of a certain task? How will you meet codes?
Hierarchical: Where do you want the eye gaze to go?
Technical: How will you control the light?
Technological: What technology will you use and why?
Philosophical and theoretical: Why did you make that choice?
Conceptual: What is the overall theme? Does the choices you are making relate to your overall concept? What is the ambition with the space? What is the main light idea?
Evaluative: Which lighting design alternative create the most sustainable design? Which design alternative works best?
Affirmative: Does the chosen lighting design alternative consume the least energy?
Procedural: What lighting design aspects should students focus on in each design phase? How do you plan to make the design work?
Cultural/Contextual: What are the lighting design features that represent a certain culture or community? Can cultural dimension of daylight be embodied in a biophilic environment? How to create an environment that is culturally comfortable? What is the context of the building?
Analysis/Reasoning: What materials absorb light? What surfaces reflect light the most? What causes glare?
Descriptive: What are the color components of a white light?
Delegation/ Executional: Which design task does the designer need to delegate to other team members? How to implement the design?
Experiential: How do visitors and workers experience the space? How will people move within the building's thresholds?
Phenomenological: What are the effects of color and light intensity on depth perception? What do you want people to sense?
Problem-solving: How are going to solve the problem?
Aesthetical: What finishes and materials work best with your lighting concept?

Figure 7-14. Examples of Design Cognitive Questions

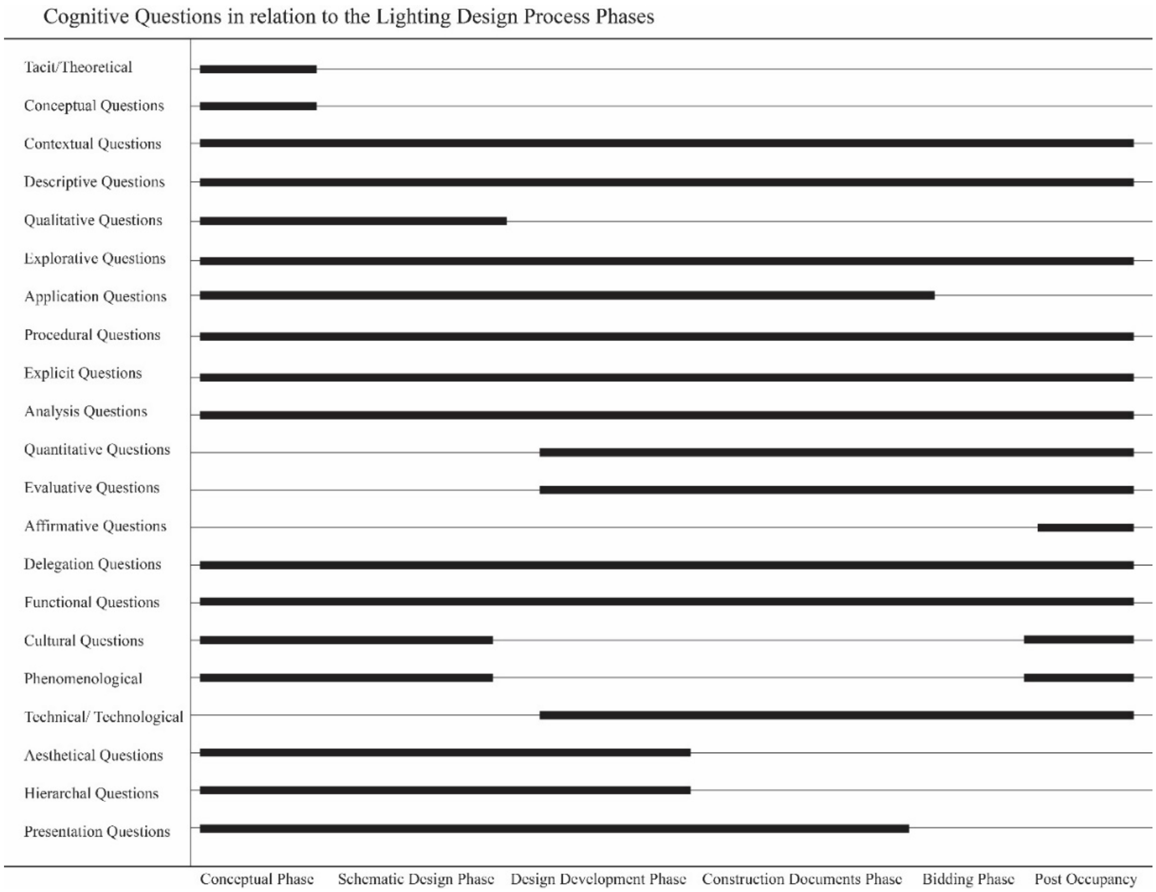


Figure 7-15. Cognitive Questions' Relevance to the Design Process Phase

7.4.4.2 –The Studio Teaching Methods

Educators are encouraged to use different teaching methods within a studio environment to facilitate students' learning journeys and to help them reach their design objectives. They are invited to use cognitive questions, observations, and desk crits, and encourage their students to research on their own, self-assess their projects, and offer peer review to develop their self-learning and problem-solving skills. Educators are also invited to introduce students to different analytical tools to meet their design objectives, develop their design skills, and improve their presentations. Digital and analog tools are both beneficial for different design phases. If the studio instructor is not knowledgeable about a certain design tool, a crash course or a workshop can be introduced to train students. Students are encouraged to build real mockups and use the lighting lab for different lighting explorations. Field trips are another effective teaching method within a studio environment. Educators are advised to take students on cultural, social, and environmental field trips. Moreover, having a guest lecturer is useful, especially if the studio instructor lacks expertise in a certain design area such as sustainability. A guest lecturer provides students with insightful and rich information to help them develop and enhance their design solutions. A lighting manufacturer representative also helps students to understand the available resources in the market.

In addition, an interdisciplinary studio environment is beneficial for students from different majors. The lighting design studio is a great multidisciplinary option because all design majors need lighting design components. Students from different design majors like architecture and interior design learn from each other in a studio culture and through peer-review. They can also collaborate on group projects to benefit from each other's strengths. Teamwork is a great asset; it teaches students how to delegate tasks, learn from each other, and communicate well to deliver their projects effectively. Moreover, educators may introduce real professional design competitions to familiarize students with the professional world, help them meet deadlines, and work efficiently under pressure.

The aforementioned teaching methods address the following student-centric pedagogical philosophies: constructivism, problem-based learning (PBL), and experiential learning approaches. PBL is considered one of the most effective methods in a studio environment. PBL engages students in real-life problems that relate to their past knowledge and training. It encourages self-learning, the use of open-ended questions in a participatory group discussion, peer-review, self-assessment, and the incorporation of technological innovations.

The studio also engages students in their social, environmental, and cultural contexts, involves them in hands-on experimentations, encourages them to research on their own for relevant knowledge, introduces them to different tools and technologies, and encourages reflective thinking to embrace the constructivism pedagogical philosophy. In the constructivism model, educators play the role of facilitators where they observe their students and offer open-ended questions to guide them without dictating their learning process or design direction. Last, the proposed methods are influenced by experiential learning theory. Educators engage students in real-life experiences through field trips. They encourage group work, hands-on activities, and a multi-disciplinary design approach. They relate to students' past experiences, involve them in professional knowledge, invite them to experiment in a lighting lab, and foster reflective thinking and self-assessment.

7.4.5– The Influence of Tacit, Procedural, and Explicit Lighting Knowledge Domains on Design Ideation, Presentation, and Development.

Tacit and theoretical lighting knowledge provide students with the foundational knowledge they need before brainstorming ideas. When students understand design thinking and light foundational knowledge, they can create knowledgeable and creative lighting design concepts. Procedural lighting knowledge equips educators with different methods to help students obtain lighting design knowledge and apply it in their design projects successfully. Explicit lighting knowledge, in contrast, offers different analytical and decision-making tools for students to communicate and present their designs in each design phase.

Students mostly think about lighting design in the schematic and design development phases, even though the lighting design classes are designed to encourage students to think about it from the ideation phase. Students are advised to link qualitative and quantitative lighting knowledge in their design process. In the ideation phase, they are encouraged to think about light's qualities and effects on human health, after which they are invited to link both qualitative and quantitative factors in the schematic design and design development phases. Lastly, they are guided to focus on meeting codes and regulations, as well as meeting energy conservation and sustainability goals. In other words, students are encouraged to focus on the foundational knowledge domain, in the beginning, then switch to the intermediate knowledge domain in the middle, and end with light advanced knowledge.

Educators are encouraged to emphasize design thinking and critical reasoning skills rather than guiding students to master a particular computer software program or any other tool. Students need the tools to aid their design thinking and decision-making process rather than letting the tool design for them. Interviewee B stated: "We don't want to just be a program that's teaching somebody to do something like how to operate a software. We want to teach somebody how to think and in the process of that, use the software to think." They are also advised to challenge their students with philosophical cognitive questions to broaden their thinking and to help them grow as self-learners and independent thinkers. Interviewee A said:

> They're always being challenged around theory and philosophical reasons of what they're doing? Why they're doing it? What the relevance is in relation to how they execute it to the technical… we push our students to be independent thinkers and to be innovators. Not just to follow established standards, but to change positively the future of the industry.

The instructor's role is to encourage students to think about lighting design from the conceptual phases. Interviewee E implied: "I think the natural without any coaching, the students will go directly to schematic or design development … My job is to pull them back and to say the why. Why are you doing this and not that?" Interviewee C said:

> I give them a full-fledged assignment that only says, "Do Something." … We felt like lighting designers are being too reactionary to everything, as I said, we need something to react to, but that doesn't mean we can't have ideas early on.

Interviewee F indicated that the lighting class shifts students lighting designs from a grid format to more creative compositions that include both qualitative and quantitative light approaches from the ideation phase:

> We noticed a fairly significant difference in their thesis projects on things as we've changed the lighting class. So, the lighting gets much more involved. Prior to that, we saw a lot of grids of downlights … After they take the class, … it's leading them to choices in terms of what finishes and what materials they're choosing and where they're going to put lights in their RCPs and lighting plans.

7.4.5.1– Decision-Making Tools

Analog and digital tools are both important to help students in the design decision-making process. Interviewee A encourages each student and designer to choose a representation tool that they are most comfortable with and delivers their ideas clearly and creatively:

> I think it's up to the student and the practitioner to define how they want to represent their work and explore their work creatively. So, whether it's analog or digital and having some way to communicate your intent in an aesthetic and poetic manner clearly, I think is important.

Interviewee B finds that studio applications and digital light analysis tools useful:

> The digital tool and then the application probably in the studio class … those little tools gave them the confidence to then go, "Yeah, this is going to work, and this is why. And I can do a quick calculation that gives me the ballpark"

Interviewee C thinks that hands-on tools, presentation tools, experiencing case studies in real life, and peer review are important for making choices and decisions:

> Hands-on are part of it …. actually, getting up in front of the class or a group of people and presenting your ideas, makes them a much better designer by the time they get done. Also mentoring, working with undergrad students, or being a TA in a class where, on a daily basis, they're critiquing other people's work.

Interviewee E believes that precedents, case studies, feedback, and peer evaluation are important. He/she also thinks that students need to understand the program and the project requirements to be able to make a sound decision:

> You have to start with precedents … what people have done it and why … Then, understanding the program of the project. Understanding who the audience is, what the age of the people is, what the activities are … There are two tools actually if you want to call feedback as a tool, that's a very important tool, right?

> A person in Illumination two is not going to know whether their solution is good or bad until you tell them why it's good or bad … I use peer evaluations and so now they're giving evaluations to each other.

Interviewee F implies that site and manufacturers visits broaden students' resources and help them in design decision-making because they experience light physically:

> The biggest change we see is after we take them to visit a showroom … they come out having seen all these different forms and distributions of light … suddenly their understanding of where light can come from isn't just limited to chandeliers and downlights. They have all these ideas about step lights and coves. So, the biggest tool is actually not a physical tool in the classroom, it's going out and seeing applications.

7.4.5.2– The Cognitive Tools' Positions in the Design Process/Stages

Students are invited to present their lighting design ideas using analog tools such as sketches, paintings, diagrams, collages, written material, verbal communication, research images, case studies, and study models. They can also use digital tools, but in a very abstract way, like making greyscale renderings, diagrams, photographs, or digital sketches and collages to explore different alternatives rather than finalizing the design. Interviewee C stated:

> Research images can help to communicate … there's a difference between a research image and a rendering. Rendering is we have the set, we have the actual thing … versus purely an idea that this show is going to be about a harsh, cold and abusive atmosphere.

Interviewee E believes that monochromatic renderings are beneficial in the ideation phase to communicate and explore concepts, asserting that realistic renderings are only useful to show the final design:

> When you strip away the distracting things like textures and colors and you just work in a monochromatic manner. You can really start seeing patterns in hotspots and how the space is going to load. That's really very important. Obviously, the renderings are important for just showing the final work to a client.

In the schematic design phase, students are encouraged to use analog and digital drafting tools, physical and digital models, and some basic light measuring devices. They may also explore different lighting scenarios in the lighting lab, observe light behaviors in real scale mock-ups, investigate some materials, and specify light fixtures. Interviewee C believes that digital tools are more beneficial in the middle of the design process where students have more details and a concrete understanding of what the design will look like: "I would put the digital stuff really in the middle to the end. Once you've got enough information that you can start communicating that way then it's more efficient". Interviewee F indicates that students present their concepts and initial design ideas in a sketched format:

> Many of them end up using SketchUp, V-Ray, some of them do hand drawing or Photoshop … But generally, what we are seeing consistently is some kind of a reflected ceiling plan with lighting added to it. So, highlighting lighting, whether sketched or in Photoshop. And then we're seeing three-dimensional sketches whether rendered in a computer program or drawing themselves and then they're

adding in lighting with colored pencils or Photoshop to show where those effects are.

In the design development phase, students are invited to refer to the IES handbook for accurate light quantity references, to calculate light using light meters and light simulation tools; to present the quantitative data using pseudo color renderings; to create cut-sheets and light schedules, to evaluate their designs performances; and to use digital and analog modeling and drafting tools to create perspectives, models, plans, sections, elevations, maps, and mock-ups to present their lighting designs in more details. Interviewee F encourages his/her students to analyze light using a digital light simulation software like AGi32 or DiaLUX to evaluate their design performance: "We tend to encourage photometric analysis like AGI or DiaLUX during design development … Photometric tools are mostly to evaluate the performance of a design."

In the construction documents phase, students are advised to further develop their designs with more details using detailed renderings, physical models, lightmaps, schedules, cut sheets, and final sections, plans, and elevations in a working drawing format for the lighting design implementation. In addition to the analog and the digital tools, educators are advised to use cognitive questions to guide students' projects. Students are encouraged to keep on researching and experimenting in the lighting lab as their designs develop and new challenges emerge in each design phase. Figures 7-16 and 7-17 summarize the cognitive tools that are used in the design process.

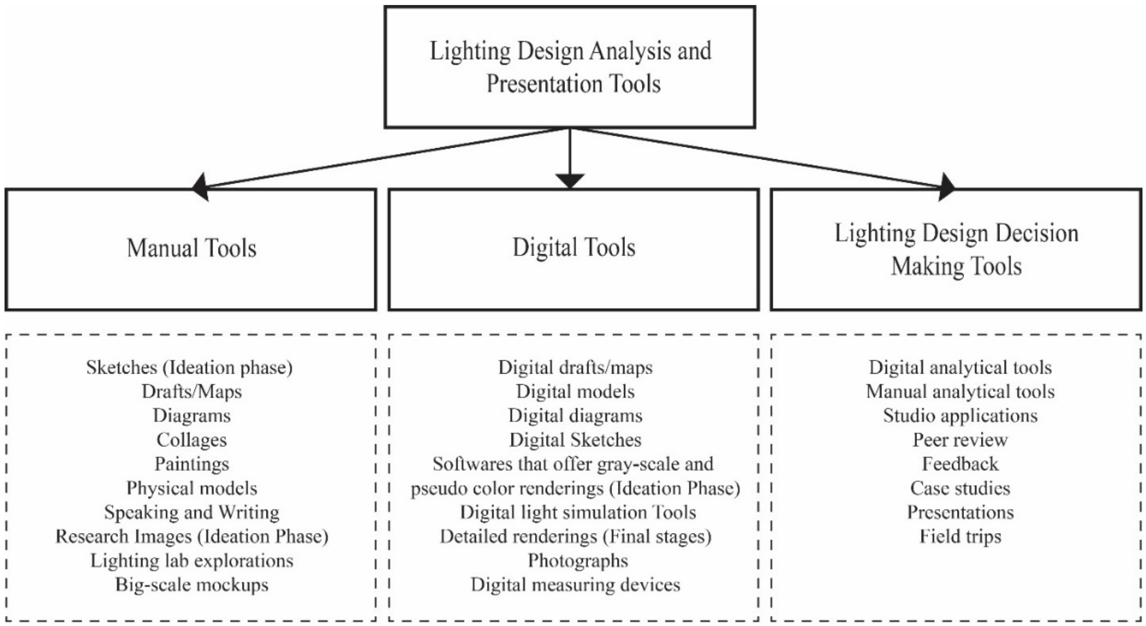


Figure 7-16. Lighting Design Analysis and Presentation Tools

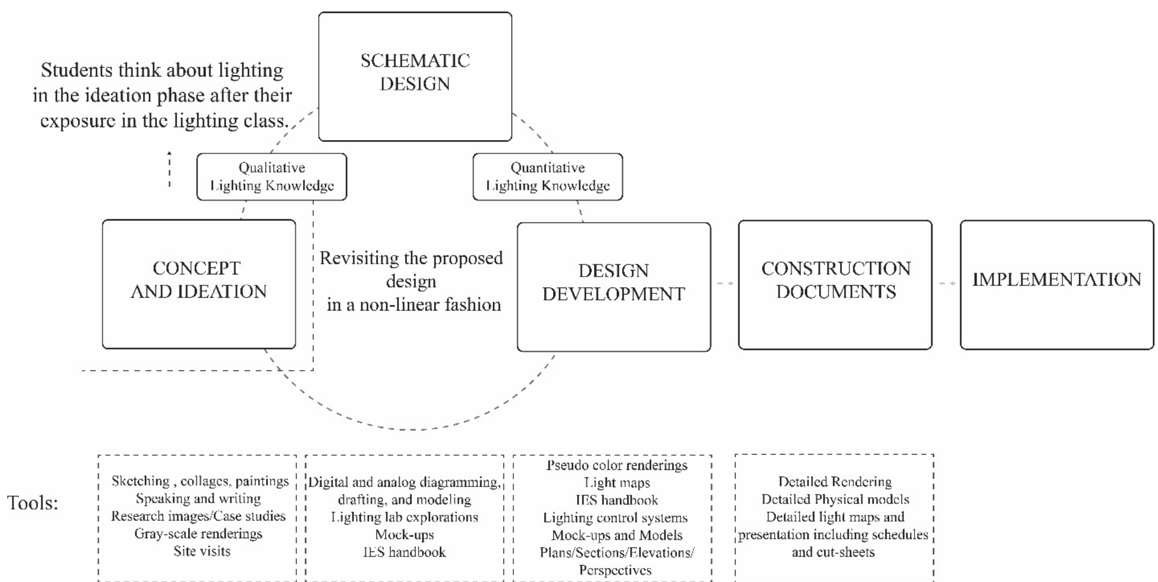


Figure 7-17. Lighting Design Analysis and Presentation Tools in Different Design Phases

7.4.5.3– Examples from the Literature about the use of Cognitive Tools in the Design Process/Stages

Steven Holl begins his design process with two interactive cycles; the first is a hand drawing (paintings and diagrams) that link thoughts to architectural programs, conditions, and phenomenological experiences. The second is communicating ideas through drawings, models, and sculptures to expand the initial thoughts. He starts his initial design ideas in black and white drawings (graphite/pencil drawings) that capture his first thoughts, intuition, and vision about architectural forms, space, textures, color, light, and time (Holl, 2002; Safont-Tria, Kwinter, & Holl, 2012). He also uses black and white and colored watercolor drawings because they are faster in capturing initial ideas and because they present uneven dispositions of dyes that give depth cues and phenomenological experiences (Safont-Tria et al., 2012). Holl stated: "A very rapid concept sketch could simultaneously indicate space – with a swipe of a brush – the direction of light" (Holl, 2002). He encourages the use of sketches and analog tools in the ideation phase:

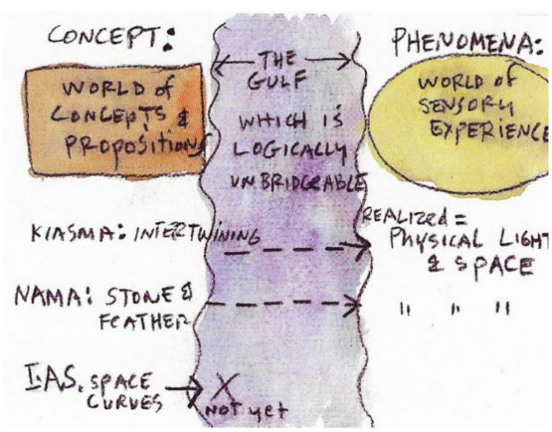
> A small watercolor sketch fuses the institution with a concept and embodies hopes and desires. This direct mind/eye/hand interaction constitutes a link between all the synapses of the mind to circumambient reality … the initial idea in the analog drawing has the potential to embody the spirit which animated its conception. With the advent of new technologies, the initial watercolor can be transformed into a digital hybrid. While the speed at which we can now move from concept sketch to spatial geometry and physical model is provocative, the initial sketch still begins the process.

Holl believes that digital tools do not awaken the human imagination as analog tools do:

> The interaction of the hand and brain engages the human imagination in an immediate, neurologically connected way that cannot be replicated in a digital process … Today, supercharged digital rendering techniques can depict a building in its proposed site in every detail – without an idea- without the thoughts of plans or sections. (Stritzler-Levine, 2018, p. 17)

Figures 7-18,7-19, 7-20, and 7-21 are examples of Holl's work.

Figure 7-18. Concept Drawing by Steven Holl in the year 2001 (Holl, 2002)



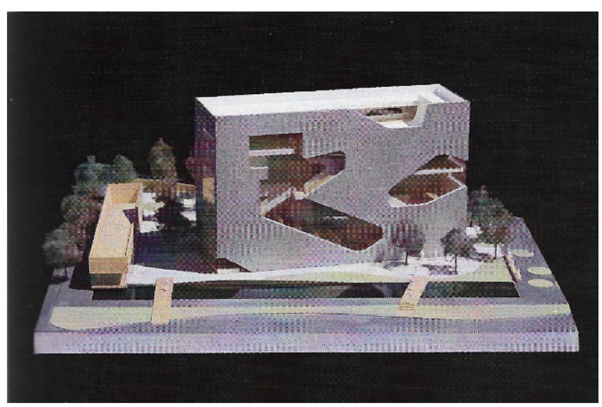


Figure 7-20. Steven Holl, Concept and Phenomena

Figure 7-19. Steven Holl Architects Model, Hunters Point Community Library. (Stritzler-Levine, 2018)

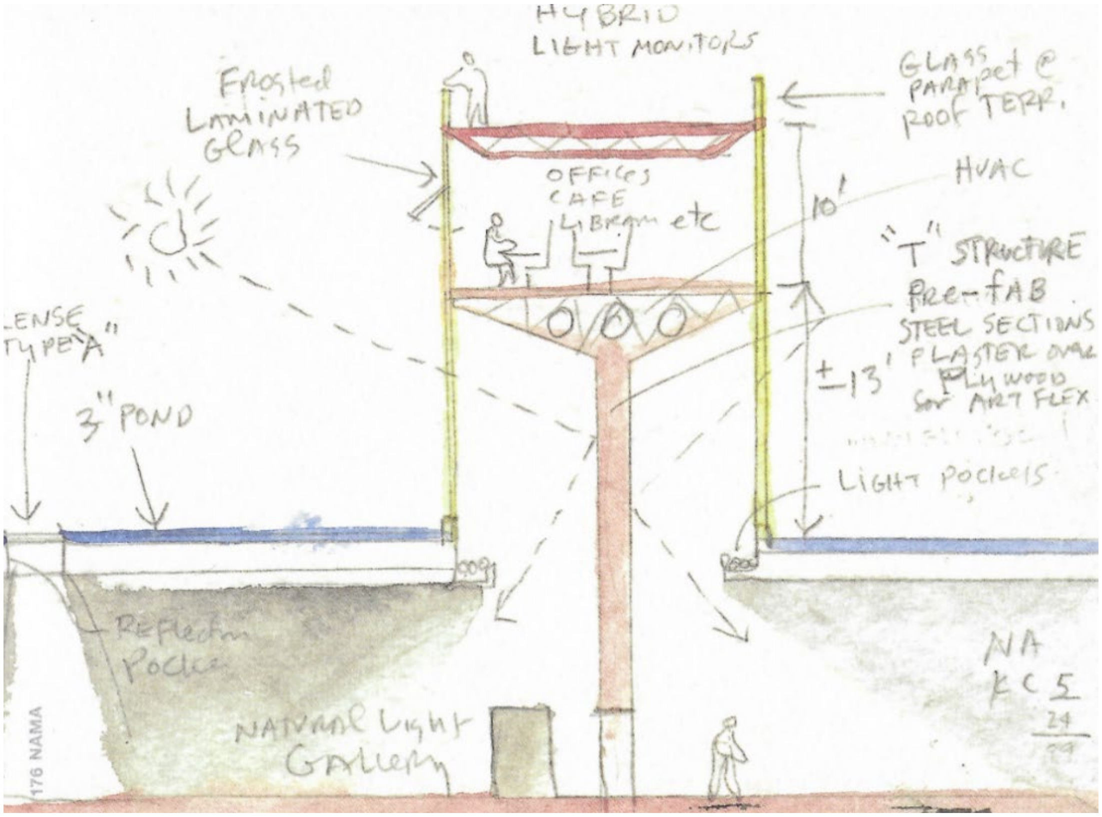


Figure 7-21. Concept Drawings by Steven Holl in the year 1999 (Holl, 2002)

Both Steven Holl and James Turrel conceive of color and light as the creators of spaces (Safont-Tria et al., 2012). They both think about how people feel in space from the conceptual design phases with light and color explorations. James Turrel uses drawings with words that describe the experience he desires in the initial design phase, and he experiments with different light installations as shown in Figures 7-22 and 7-23 (Turrel, 1993).

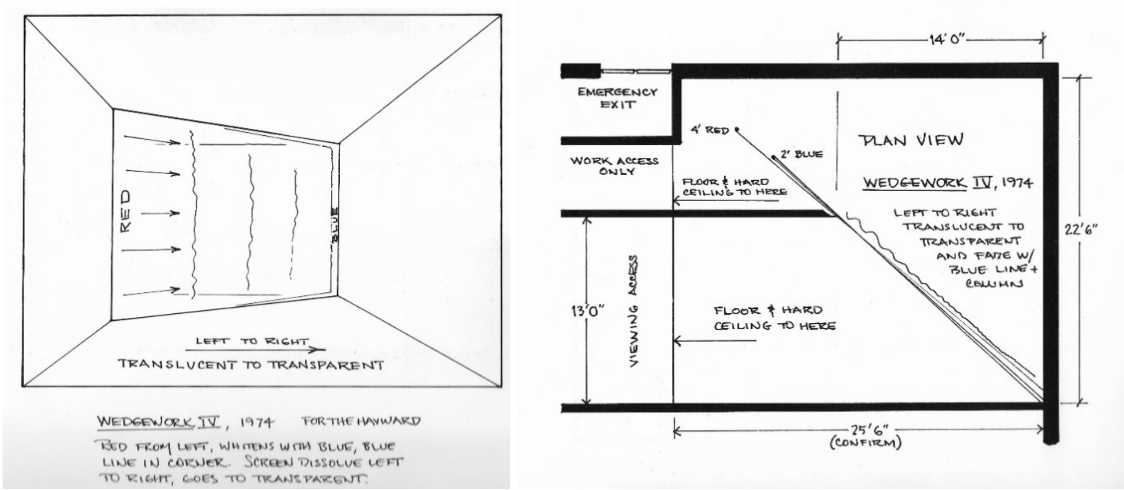


Figure 7-22. James Turrel's Wedgework Drawings/Installation

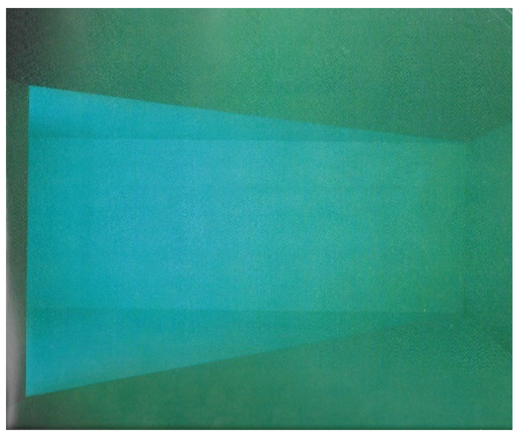


Figure 7-23. James Turrel's Wedgework Drawings/Installation

Peter Zumthor also focuses on light in his spaces/projects from the ideation phase. He thinks about light and shadow, and how light reflects off materials. He begins his lighting design process with one of two methods. One is to subtract a dark mass with light and the other is to reflect light off different textures and surfaces, as he stated:

> Start asking ourselves: okay, so where are we going to put the lighting _ how are we going to light this thing? No, we factor that in from the beginning. So, the first of my favorite ideas is this: to plan the building as a pure mass of shadow then,

afterward, to put in light as if you were hollowing out the darkness as if the light were a new mass seeping in … The second idea I like is this: to go about lighting materials and surfaces systematically and to look at the way they reflect the light.

Peter Zumthor starts the design process with sketches followed by drawings and then more detailed construction documents. He starts with analog tools, after which he develops the design into more detailed digital drawings. Figures 7-24, 7-25, and 7-26 present his work for the Thermal Baths in Zurich. The sketches show the conceptual lighting slots in the ceiling along with phenomenological experiences. The digital drawings, in contrast, are more detailed and technical for the implementation phase (Durisch, 2014)

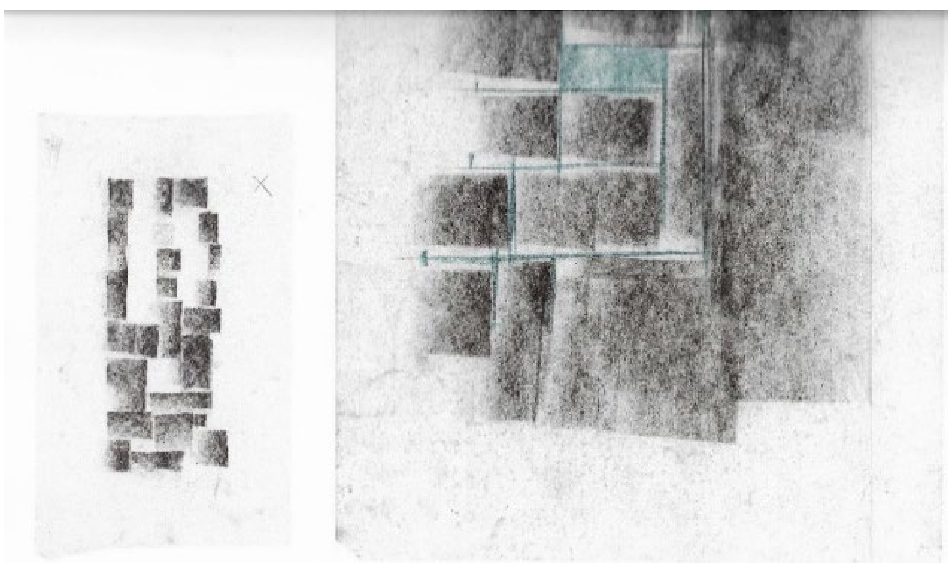
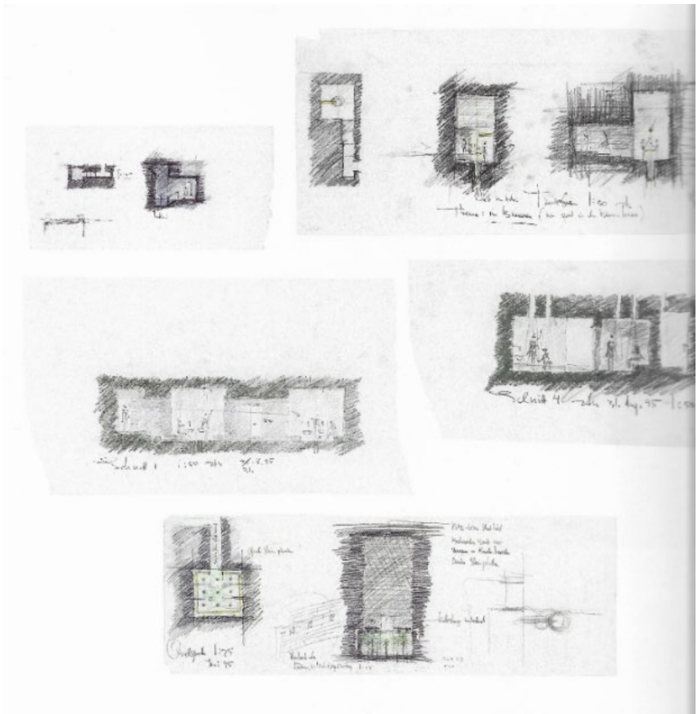


Figure 7-24. Thermal Baths Sketches. Courtesy of Peter Zumthor (Durisch, 2014)



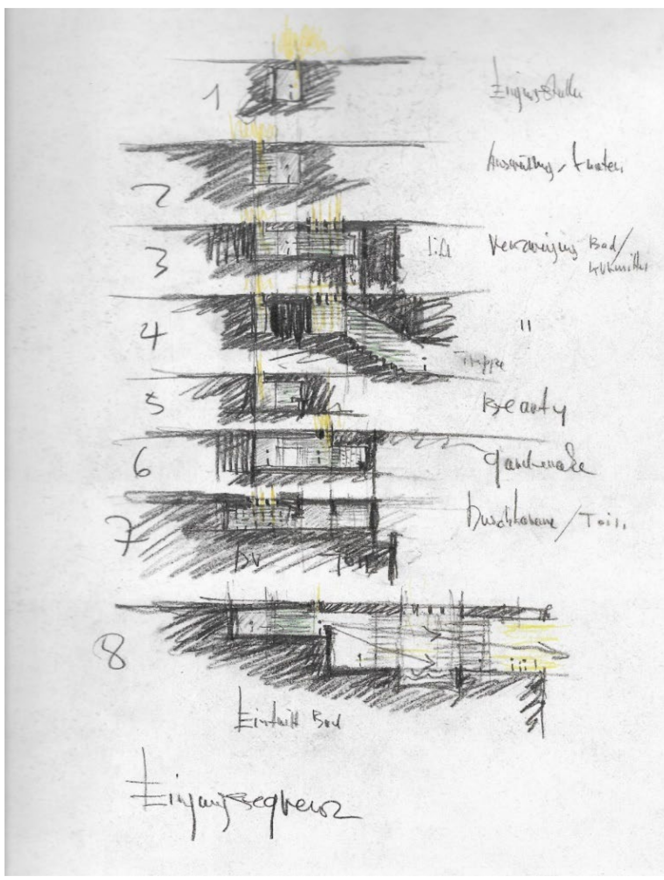


Figure 7-25. Thermal Baths Sketches. Courtesy of Peter Zumthor (Durisch, 2014)

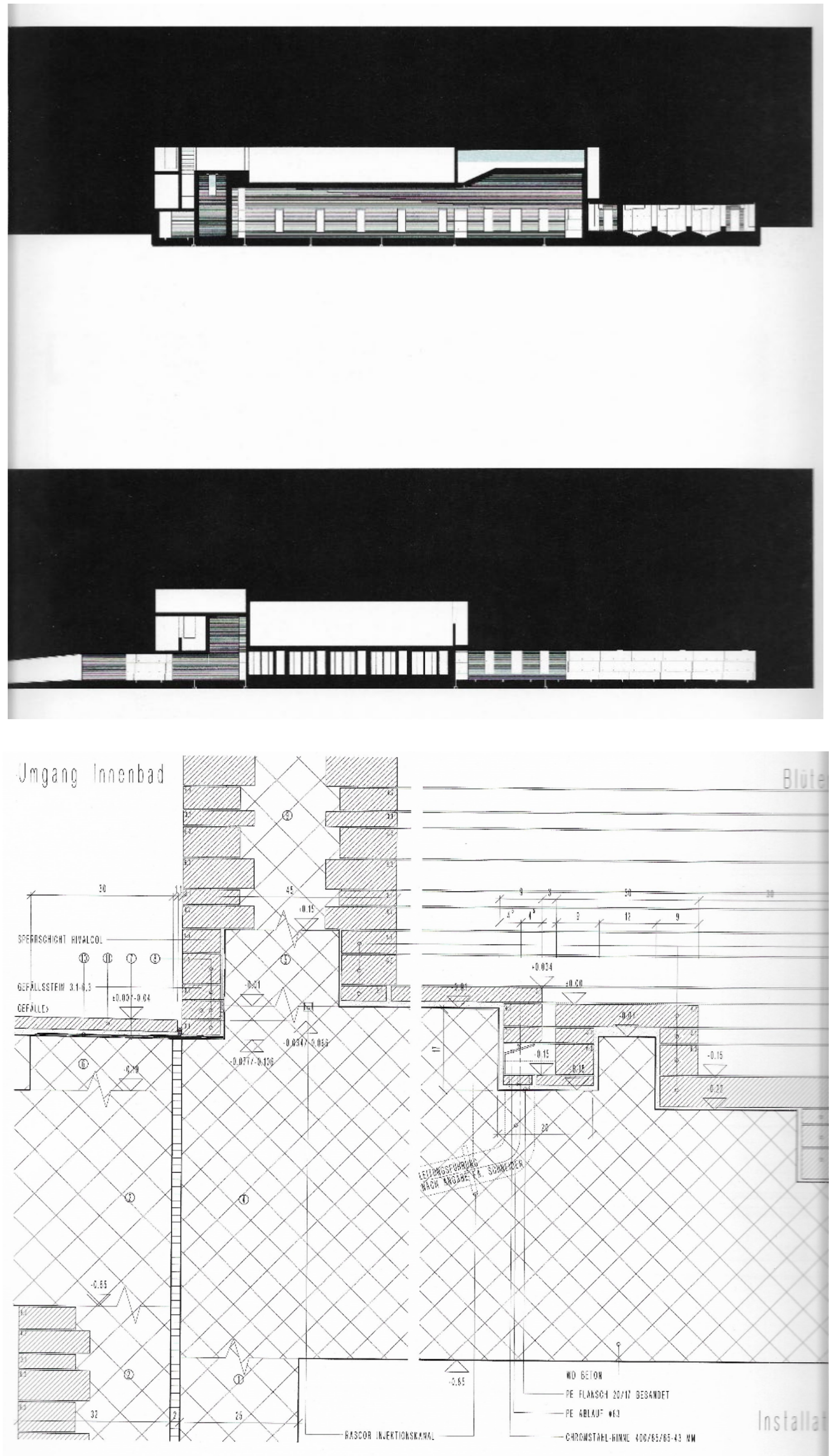


Figure 7-26. Thermal Digital Drawings. Courtesy of Peter Zumthor (Durisch, 2014)

7.5 – Summary

This chapter presented the influence of the literature, the United States documents' analysis, and the interview results on the proposed framework. It displayed the framework's tacit, procedural, and explicit knowledge domains supported by a learning path where lighting design knowledge is integrated into a yearly sequence based on foundational, intermediate, advanced, and future knowledge domains. It outlined a lighting design studio that implements the framework's knowledge in a practical narrative. The studio offers lighting design projects, teaching methods, and cognitive tools that support students' understanding of lighting design knowledge, both qualitative and quantitative, and aid their design decision-making process.

Chapter VIII

8- Research Consensus

The researcher developed the preliminary framework by seeking consensus among experts in the lighting design field. She gathered recommendations from the committee members to enhance the framework before proceeding with the Delphi method. The Delphi method was used to gather feedback, establish consensus, and measure the level of agreement among experts for the framework development and implementation.

8.1- The Committee Feedback on the Preliminary Framework

Each committee member is strong in a certain lighting design field. One member extended the knowledge on qualitative aspects of lighting and cognitive questions. Another member furthered the quantitative knowledge of lighting. A third member enhanced the proposed studio, and the last member developed the framework in general. The following sections explain the committee's contributions in detail.

8.1.1- The Committee's Contributions to the Framework's Knowledge Domains

8.1.1.1- The Committee's Contributions to the Tacit Knowledge Domain

The committee members suggested removing topics that are not relevant to architecture and interior design in the tacit knowledge domain such as fixture design and theatrical lighting. A member also suggested removing outdoor lighting from the interior design department and all members proposed more topics for both qualitative and quantitative aspects of lighting like chromatic space, daylight metrics, temporal effects of light, light figures, symbolic aspects of light, the caustic effect of light, Snell's law, the Gamma shift, aesthetic judgment, and more subjects, as listed in Figure 8-1.

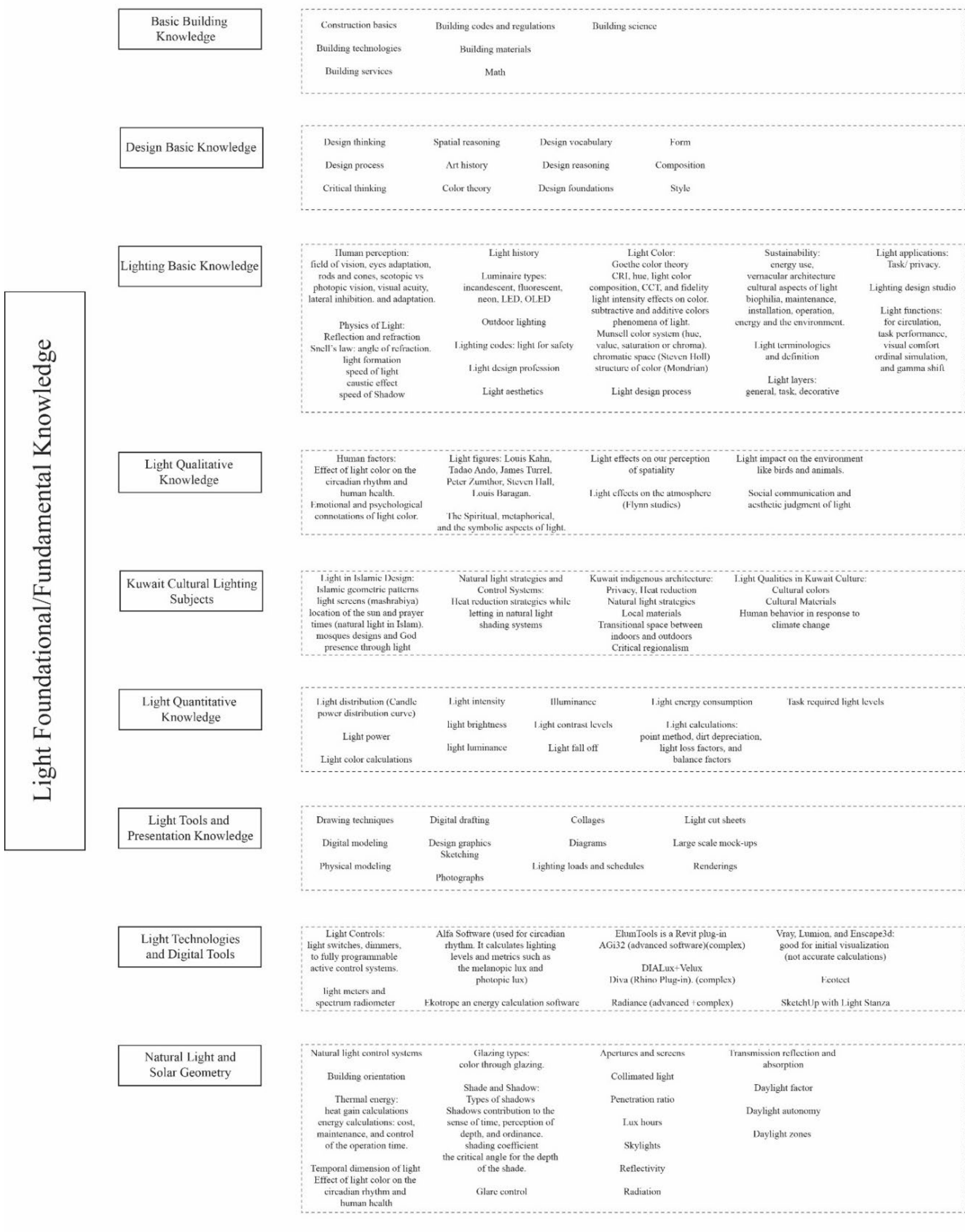


Figure 8-1. The Committee's Contributions to the Framework's Fundamental Lighting Knowledge

Two committee members suggested sorting the topics in two new diagrams (Figures 8-2 and 8-3), one of which describes foundational lighting knowledge, prior design knowledge, and communication skills and tools. The other diagram sorts the topics into qualitative lighting knowledge, performative lighting knowledge, and generative lighting knowledge. Generative lighting knowledge is a new category that was added to emphasize lighting's contribution to the design ideation process. This category includes topics that help students create lighting design concepts and perceive light as an inspirational medium that helps in generating new ideas.

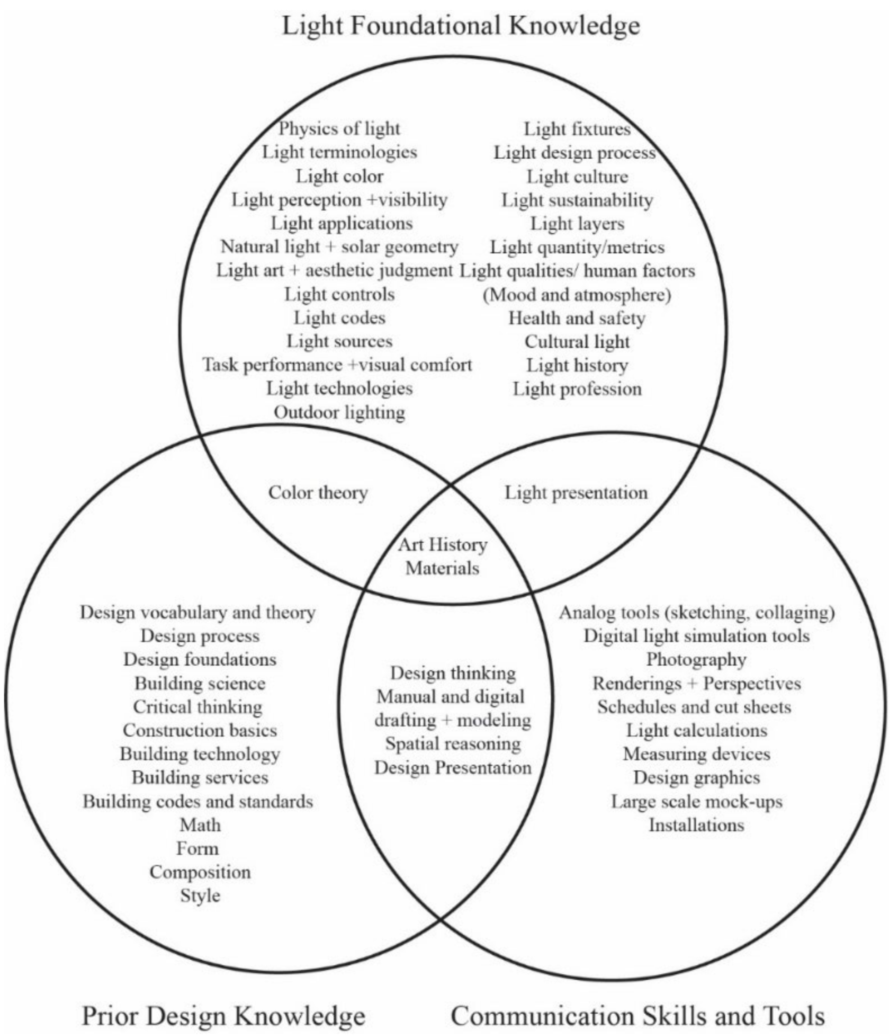


Figure 8-2. The Committee's Contributions to the Framework's Light Fundamental Knowledge Categories

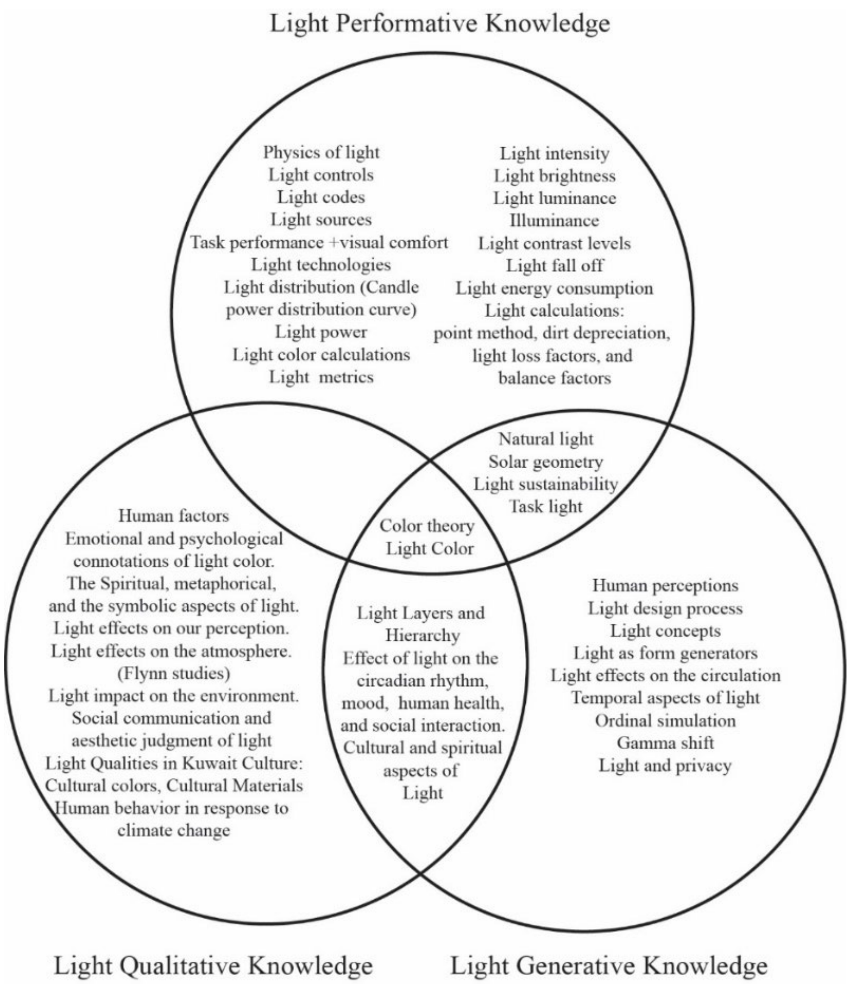


Figure 8-3. The Committee's Contributions to the Framework's Light Fundamental Knowledge Categories

Another suggestion from the research committee was to sort lighting design communication tools into two categories; one category explains the tools that help students communicate their designs with their peers and instructors, and the other category talks about the interpersonal communication tools that help them develop their lighting design ideas and aid their design decision-making process. Figure 8-4 presents the two categories.

Figure 8-4. The Committee's Contributions to the Framework's Communication/Presentation Tools

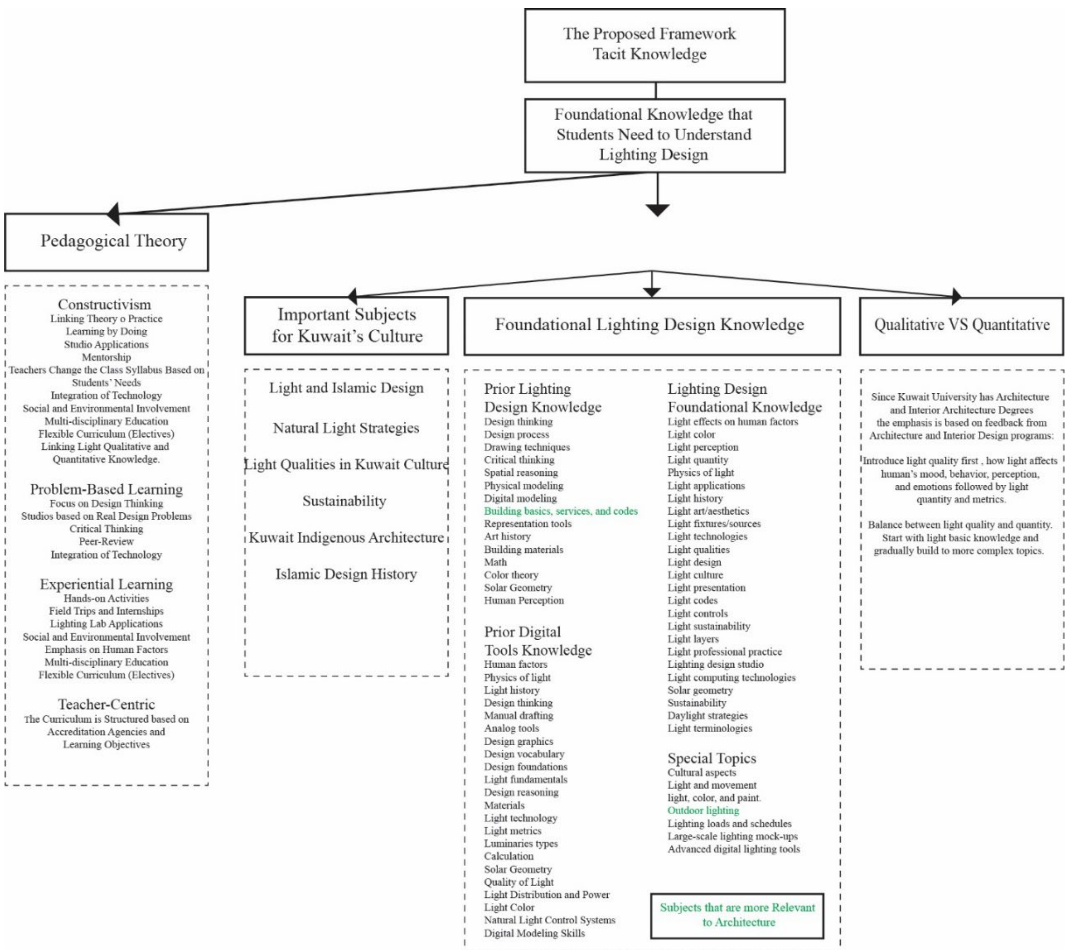


Figure 8-5. The Committee's Contributions to the Framework's Tacit Knowledge Domain

8.1.1.2- The Committee Contributions to the Procedural Knowledge Domain

A member suggested segregating the architecture knowledge sequence from the interior design as shown in Tables 8-1 and 8-2 and Figure 8-9. In the first year, a member recommended adding the types of shadows and the shadows' contribution to the sense of time, perception of depth, and ordinance. Another member suggested introducing Flynn's studies. Other members recommended focusing on qualitative aspects of lighting at the beginning, like the relationship between light and color, prominent lighting figures like James Turrell and Steven Holl, and natural light's contribution to human health and circadian rhythms. In the second year, they suggested extending quantitative lighting knowledge like adding light speed, intensity, light distortion through materials, light refraction, and light color technical knowledge (other topics are listed in detail in Figure 8-1). They also proposed more fundamental lighting knowledge like visual acuity and adaptation, ordinal simulation, and the Gamma shift (more topics are listed in Figure 8-1). Additionally, a member proposed introducing manual calculations before digital light simulation tools to help students understand lighting concepts.

In the third year, the committee members recommended introducing more quantitative lighting knowledge, solar energy, cultural factors, sustainability, light technologies, and a one-semester design studio that is focused on lighting design. For the solar energy class, two members recommended introducing daylight strategies, apertures and screens, collimated light, light contrast levels, and daylight metrics including the penetration ratio, the shading co-efficient, shading calculations, energy calculations, reflectivity, daylight factor, daylight autonomy (amount of time), daylight zones, and daylight controls like light switches, dimmers, and fully programmable active control systems. For lighting technologies, they proposed light meters, light simulation tools (explained in detail in the explicit knowledge domain), spectrum radiometers, and luminaires. For cultural and sustainability lighting classes, they proposed topics on color/light symbolism/connotations in different cultures, critical regionalism, privacy, vernacular architecture, biophilia, screening approaches in different cultures, maintenance, operation, and Islamic patterns and screens (*mashrabiya*).

Sequence of Lighting Design Knowledge and Decision Making Tools for the Interior Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design Studio (Design thinking, design process and basics, color theory, natural light) light qualities and human factors (Flynn studies, moods, symbolism, and spiritual aspects), light properties and theories, shade and shadow)	Building services, codes, and materials		Light and painting (Color theory + light)
	Tools: manual drafting, physical modeling sketching, research images, language and communication	Tools: cognitive questions peer-review, self-assessment pin-ups		
2	Building Environmental Systems class (Light quality and human factors, physics of light, light fundamentals and terminologies , light design process, light perception, solar geometry , electrical light sources, light color, history of light, light hierarchy and layers, light application)	Building Environmental Systems class (Light quantity, light aesthetics and arts, light functions, light philosophy and theory technical lighting design knowledge, light technologies and controls, light codes)		Light and movement Light installation Photography I Graphic Design
	Tools: computer technology (modeling, drafting, grey-scale rendering)	Tools: cognitive questions peer-review, self-assessment pin-ups. IES handbook (sections only) + light measuring devices.		
3	Innovative Interiors Class	A Lighting Focused Design Studio (second semester)	Environmental Sustainability + Sustainable Interior (environmental, vernacular, and cultural aspects of light + light role in Islamic design + light effects on the circadian rhythm)	Photography II Kuwait Indigenous Architecture
	Tools: analog and digital – technical writing	Tools: IES handbook + light measuring devices, cognitive questions, peer-review, self-assessment, pin-ups	Tools: digital light simulation tools	
4		Internship Opportunities (profession)	Comprehensive Application of Light	Advanced Computer Application BIM technology BIM lighting plug-ins
		Tools: analog and digital analysis tools cognitive questions peer-review, self-assessment pin-ups	Tools: advanced digital tools schedules and cut-sheets working drawings	

Table 8-2. The Committee's Contributions to the Framework's Lighting Design Sequence

Sequence of Lighting Design Knowledge and Decision Making Tools for the Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Basic Design Studio (Design thinking, design process and basics, color theory, natural light shade and shadow)			Introduction to Interior Design Light and Painting (light + color theory)
	Tools: manual drafting, physical modeling, sketching, research images, language and communication	Tools: cognitive questions peer-review, self-assessment pin-ups		
2	Light qualitative knowledge (Light qualities and human factors (Flynn studies, moods, symbolism, and spiritual aspects), light Properties and theories)	Building services, codes, and materials Building technologies Building construction		Light installation Photography I Graphic Design Light and Movement
	Tools: computer technology (modeling, drafting, rendering)	Tools: cognitive questions IES handbook (sections only) + light measuring devices.		
3	Building Systems I (Light quality and human factors, design functions, physics of light light fundamentals and terminologies light design process, light perception, solar geometry , electrical light sources light color, history of light light hierarchy and layers, light application)	Design of the Luminous and Sonic Environments (Light quantity, light aesthetics and arts, light functions, light philosophy and theory technical lighting design knowledge, light technologies and controls, light codes) A Lighting Focused Design Studio (second semester)		Solar Energy Photography II Kuwait Indigenous Architecture
	Tools: analog and digital technical writing	Tools: IES handbook + light measuring devices, cognitive questions peer-review, self-assessment , pin-ups	Tools: digital light simulation tools	
4		Internship Opportunities (profession)	Environmental Sustainability (environmental, vernacular, and cultural aspects of light + light role in Islamic design + light effects on the circadian rhythm)	Advanced Computer Application BIM technology + BIM lighting plug-ins
		Tools: analog and digital analysis tools cognitive questions peer-review, self-assessment, pin-ups	Tools: advanced digital tools schedules and cut-sheets	
5			Comprehensive Application	Advanced Lighting and Acoustics Professional Training
			Tools: working drawings cognitive questions peer-review, self-assessment pin-ups	

Table 8-1. The Committee's Contributions to the Framework's Lighting Design Sequence

For the lighting design studio, the committee members proposed talking about light as a concept generator, light applications, and light controls. They also suggested applying theoretical lighting knowledge in practical projects like a spa, a boutique hotel, an office, or a historical preservation site. The warm-up project was advised to be a 2-week project only. A member advised on using cognitive questions to guide students' cognitive thinking. The researcher attended the member's lighting class and gathered cognitive questions that the students proposed. The questions are listed in Figure 8-6.

In addition, the members suggested that the interior design studio focuses on interior lighting, day lighting shading treatments, and electrical light calculations, while the architecture studio focuses on daylight strategies, exterior lighting, and natural light/energy calculations. For student evaluations, the committee members proposed weekly desk crits or informal pinups, and pinups with professional juries for the intermediate and advanced phases as shown in Figures 8-7 and 8-8. For the studio methods and deliverables, the members proposed reflective thinking field trips, teamwork, and using demos and real samples. Other suggestions included inviting students to work together on the warm-up project and then work individually in the design development phase; encouraging them to produce sketches, reflective ceiling plans, and renderings; and guiding them to perform light calculations and specify sources in the studio. One member proposed an interdisciplinary lighting design studio where students from different disciplines work together in teams but then each student works separately to focus on special aspects of light based on their major.

Examples of Cognitive Questions in a Lighting Design Focused Studio

Conceptual Questions	Does the choices you are making relate to your overall concept?
Qualitative Questions	What is the role of directed light and intimacy? What are the effects of light on the circadian rhythm and human moods?
Explorative Questions	How light patterns change based on different ground treatments? How different materials react to one light source?
Experiential Questions	How do visitors and workers experience the space?
Application Questions	How light brings texture to a surface?
Quantitative Questions	How can we make present the variations in light intensity? What are the required light levels of a certain task?
Functional Questions	How to manage glare for people with poor vision? How can we improve the eyes' adaptation between dark and bright environments?
Cultural Questions	Can cultural dimension of daylight be embodied in a biophilic environment?
Phenomenological	What are the effects of color and light intensity on depth perception?

Figure 8-6. The Committee's Contributions to the Framework's Cognitive Questions

An Architecture Lighting Design Studio			
Knowledge Stages	Design Goals	Decision-making and Presentation Tools	Evaluation
Foundational Knowledge	A warm-up project related to students' past knowledge (use questions to understand student's knowledge). Warm-up project ideas (two weeks period): -Representing a real light phenomenon in a contained environment. -Building a light installation. -Working on a light charrette. -Present a poem, a play, or a painting through a light animation or movement. -Write about a light experience. -Presenting a light adjective. -Hunting for a bad lighting project. -Light sources scavenger Hunt. -Light survey in an existing site with sketching or photographing or collaging. -Measuring light levels in different spaces. -Testing natural light strategies with physical and digital models. -Using a sun dome to test light and shadow patterns. -Giving students a ready-made digital model to experiment different lightings. - Experimenting light penetration through a building using different apertures and screens (mashrabiya design). Interdisciplinary Group Work	Sketching Diagramming Photographing Collages Study Models Writing and talking Digital presentation Animation Play / Performance Research Images Grey-Scale Renderings	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -First pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking.
Intermediate Knowledge	Field trips to cultural places. - A restaurant - A museum - A play - A library - A house - An office - Retail Design - Boutique hotel -A spa - Adaptive reuse projects Concepts generation. Group Work Students focus on light qualities and Kuwait's culture.	Site visits and analysis (reflective writing) Photography Sketches Diagrams Analog and digital drafting Digital and Analog modeling Lighting lab explorations/Control systems Mockups Preliminary renderings and perspectives Digital Light Plug-ins Light Plans (RCP, section, elevation, distribution plan)	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -Second pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking. - First jury (professionals)
Advanced Knowledge	Design development Design process Detailed light analysis The final Project Students focus on light quantities and technical knowledge. Architects focus more on natural light strategies and calculations with basic electrical sources selections and calculation Students work individually on the design development.	Detailed drawings Cut-sheets Light Schedules Detailed renderings/Pseudo color renderings Physical and digital models Animation Final light maps Light loads and calculation tables	-Desk Crits -Third pin-up : peer-review -Self-assessment -Cognitive Questions -Final Jury (professionals)

Figure 8-7. The Committee's Contributions to the Framework's Lighting Design Studio

An Interior Architecture Lighting Design Studio			
Knowledge Stages	Design Goals	Decision-making and Presentation Tools	Evaluation
Foundational Knowledge	A warm-up project related to students' past knowledge (use questions to understand student's knowledge). Warm-up project ideas (two weeks period): -Representing a real light phenomenon in a contained environment. -Building a light installation. -Working on a light charrette. -Present a poem, a play, or a painting through a light animation or movement. -Write about a light experience. -Presenting a light adjective. -Hunting for a bad lighting project. -Light sources scavenger Hunt. -Light survey in an existing site with sketching or photographing or collaging. -Measuring light levels in different spaces. -Testing natural light strategies with physical and digital models. -Using a sun dome to test light and shadow patterns. -Giving students a ready-made digital model to experiment different lightings. - Experimenting light penetration through a building using different apertures and screens (mashrabiya design). Interdisciplinary Group Work	Sketching Diagramming Photographing Collages Study Models Writing and talking Digital presentation Animation Play / Performance Research Images Grey-Scale Renderings	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -First pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking.
Intermediate Knowledge	Field trips to cultural places. - A restaurant - A museum - A play - A library - A house - An office - Retail Design - Boutique hotel -A spa - Adaptive reuse projects Concepts generation. Group Work Students focus on light qualities and Kuwait's culture.	Site visits and analysis (reflective writing) Photography Sketches Diagrams Analog and digital drafting Digital and Analog modeling Lighting lab explorations/Control systems Mockups Preliminary renderings and perspectives Digital Light Plug-ins Light Plans (RCP, section, elevation, distribution plan)	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -Second pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking. - First jury (professionals)
Advanced Knowledge	Design development Design process Detailed light analysis The final Project Students focus on light quantities and technical knowledge. Interior designers focus more on interior sources selections and calculations with some daylight strategies. Students work individually on the design development.	Detailed drawings Cut-sheets Light Schedules Detailed renderings/Pseudo color renderings Physical and digital models Animation Final light maps Light loads and calculation tables	-Desk Crits -Third pin-up : peer-review -Self-assessment -Cognitive Questions -Final Jury (professionals)

Figure 8-8. The Committee's Contributions to the Framework's Lighting Design Studio

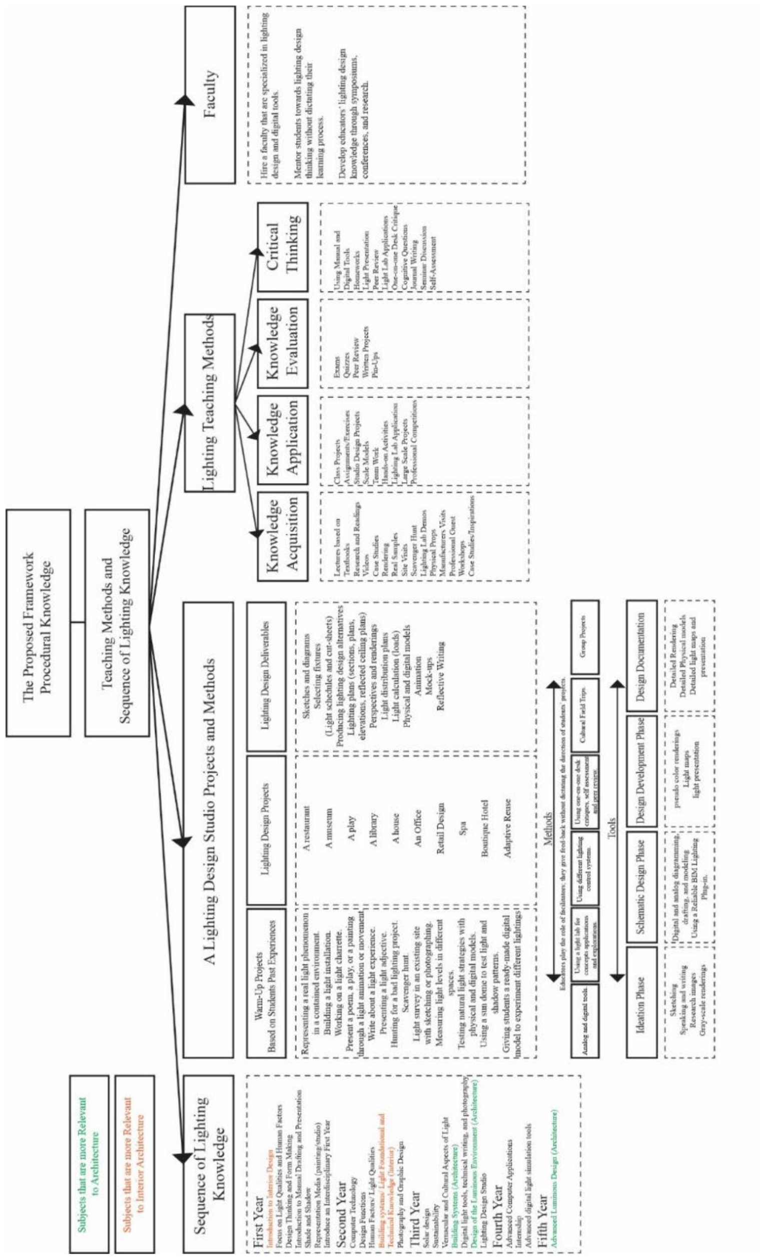


Figure 8-9. The Committee's Contributions to the Framework's Procedural Knowledge Domain

8.1.1.3- The Committee Contributions to the Explicit Knowledge Domain

Two members suggested removing Vision and VectorWorks from the simulation tools because they are not relevant to interior design and architecture. Instead, they suggested adding Alfa and Ekotrope softwares. The first one is used for circadian rhythm lighting design and the other one is for energy use and ratings. In addition, two members suggested introducing the IES handbook in small segments earlier in year two. A member also implied that Radiance, AGi32, and Diva plug-in are too complex for educational use and that Elumtools (a Revit Plug-in) is easier for students, takes less time than AGi32, and is all they need to graduate as designers rather than lighting design professionals. If an educator wants to introduce AGi32, it was advised to be part of an advanced simulation course. For international schools, DIALux is more common than AGi32. Last, a member asserted that Vray, Lumion, and Enscape3d are good for initial lighting visualization, but they are not accurate for light calculation and behavior.

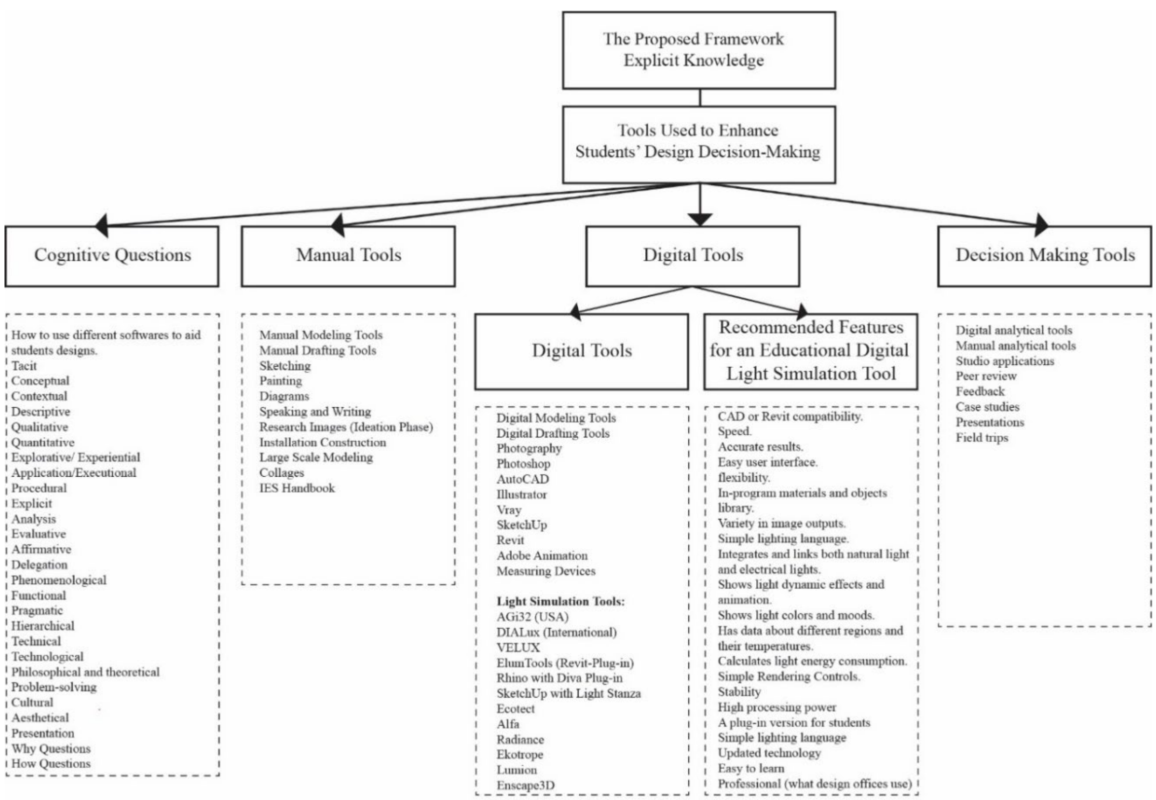


Figure 8-10. The Committee's Contributions to the Framework's Explicit Knowledge Domain

8.2- The Delphi Method

The researcher used the Delphi method to develop the proposed framework based on experts' feedback. The Delphi method is used in subjective research to help the researcher in decision-making through a series of questionnaires with experts in the field (Dalkey & Helmer, 1963; Pill, 1971). This method saves time in developing a research consensus compared to applying the framework for validation, which was not feasible for the current research.

The Delphi method consists of two rounds. Round one included an open-ended questionnaire with lighting design experts. The experts had an opportunity to express their opinions and offer feedback on the proposed framework. The research gathered and organized the feedback into categories and themes and presented the summary with closed-ended questions in a second round. The second round was a multiple-choice questionnaire to rate the framework's implementation possibilities and the experts' agreement level. Figure 8-11 summarizes the Delphi method process.

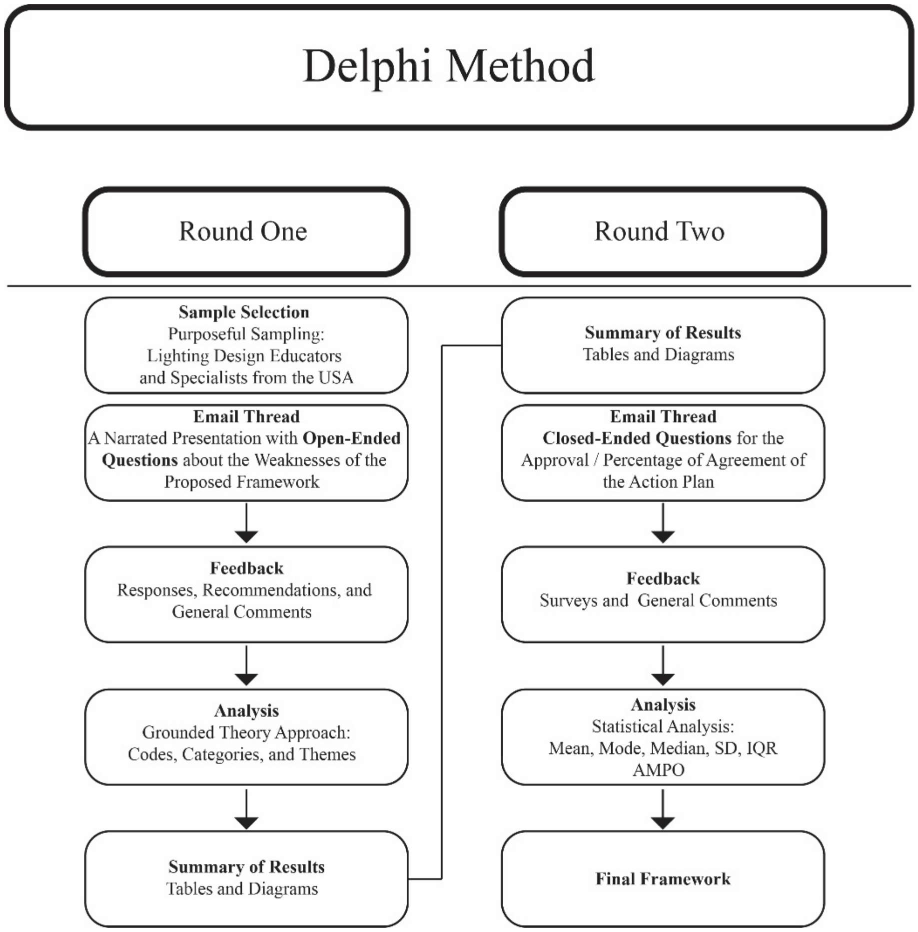


Figure 8-11. The Delphi Method Process

8.2.1 -The Delphi Method Sample

The researcher contacted lighting design educators and practicing professionals from the IALD database and Virginia Tech's lighting design researchers to participate in the Delphi Method. Eight experts agreed to take part in the research. Expert 1 is an award-winning lighting designer and educator with a Bachelor of Fine Arts in Theatre and a Master of Fine Arts in Lighting Design and Integrated Media. He/she is an LC Educator IALD MIES. He/she is the Program Director of the Masters of Professional Studies in Lighting Design at the New York School of Interior Design (NYSID). Expert 1 is also a director/lighting designer for RAB Lighting (a lighting manufacturer). He/she has taught architectural lighting design for 11 years. Expert 1 has received Illumination awards, the IESNA Section Service Award, and the Princess Grace Award. He/she has presented seminars at LightFair International, LEDucation, and the IES National Conference on topics including lighting and media, wireless technologies, and light pollution. He/she has served on the board of managers for the IES New York City Chapter and as an adviser to the Student Lighting Competition Committee. Expert 1 is a certified instructor for AGi32.

Expert 2 has a Bachelor of Science in Interior Design. He/she works at Hartranft Lighting Design. He/she has taught lighting for 4 years, and he/she has been working with lighting for 8 years. He/she specializes in light and wellness with an emphasis on the user experience. Expert 3 is an IALD educator with NCIDQ, LEED A.P., NCQLP [LC], IES, IDEC, NEWH, and VAF affiliations. He/she has a Bachelor of Fine Arts and a Master of Arts in Interior Design. He/she teaches at Appalachian State University. Expert 3's students have won several Cooper Lighting awards. He/she has taught lighting for 18 years. He/she specializes in hospitality, retail design, environmentally-sensitive projects (green design), economically-sensitive projects, lighting design, culture in design, and mid-century architecture and design.

Expert 4 has a Bachelor and a Master of Arts in Interior Design. He/she teaches at the University of Massachusetts. He/she has taught lighting for 15 years. He/she specializes in sustainable design, lighting, and inclusive design. Expert 4 has taught lighting and advanced lighting courses to both graduate and undergraduate students for 8 years. His/her classes are centered around community-based projects and experiential activities. He/she has worked at the Smithsonian Institution in Washington DC for 8 years.

Expert 5 has a Bachelor of Fine Arts. He/she teaches at the Parsons School of Design. He/she has worked with lighting for 30 years, and he/she has taught lighting design for 25 years. Expert 5 specializes in lighting design, luminaire design and art, and how human perception is affected by light and materials.

Expert 6 has a Bachelor of Arts in Theatre and a Master of Fine Arts in Lighting Design. He/she works at Luminous Flux, LLC (NYC). He/she has worked with lighting for 20+ years. Expert 6 owns and runs an architectural lighting design studio in New York City. He/she specializes in lighting design.

Expert 7 has a Master's degree in Architecture. He/she is currently obtaining a Ph.D. in Architecture with a focus on lighting design. He/she has taught/worked with lighting design for 10 years in UAE, Dubai. He/she specializes in architecture studios and sustainable design.

Expert 8 has a Bachelor's and a Master of Science in Architecture. He/she is currently obtaining a Ph.D. in Architecture with a focus on lighting design. He/she has 3 years of research in lighting experience. He/she specializes in light and its effect on human physiological and psychological health.

8.2.2 - Delphi Method Round One

The researcher started round one by explaining the Delphi method's process and goals, the research objectives, and the participants' role in an email to get approval to initiate the Delphi Method. The researcher then sent a narrated presentation to explain the research purpose, goals, contribution to the body of knowledge, the research methodology, and the proposed framework knowledge domains and details (the presentation is presented in Appendix C). After that, she asked the experts to answer open-ended questions in a text format in an email thread. The first round's questions sought to gather feedback on the weaknesses of the framework and other missing information to develop and complete the proposed framework.

8.2.2.1 – Round One Questions

The researcher asked the participants three main questions in round one. She asked them to express their opinions on the framework's strengths and weaknesses, missing data, and ways to develop the framework. The three questions were:

- Do you think the proposed framework is complete in the tacit knowledge domain? If not, what are the weaknesses? What do you think is missing?
- Do you think the proposed framework is complete in the procedural knowledge domain? If not, what are the weaknesses? What do you think is missing?
- Do you think the proposed framework is complete in the explicit knowledge domain? If not, what are the weaknesses? What do you think is missing?

Note: the knowledge domains were explained in detail in the narrated presentation.

8.2.2.2 – The Analysis of Round One

The researcher received the answers for round one's questions via emails in a text format. The researcher started the analysis process by grouping the responses for each question, coding the feedback into excerpts of similar meanings, categorizing the codes into categories, and organizing the categories under the main framework themes as shown in Table 8-2. The main themes addressed the tacit, procedural, and explicit knowledge domains.

Sample of the Delphi Method Coding Procedure

Excerpt	Code	Category	Theme
I recommend focusing on the perceptual/emotional impact of lighting qualities in the first year before getting into the rest of the human factors (which include more visual acuity, task light requirements, etc).	Light perceptual and emotional aspects at the beginning of the first year	Light Qualitative Knowledge	Light Foundational Knowledge (Tacit knowledge)
Studying the use of light and shadow, color and angle in art, theatre, and one's surroundings, and interpreting emotion in light are good tasks during this introductory year.	Light and shadow, light color, light art, theatre, light surroundings, and emotional connotations in the first year.	Basic introductory lighting knowledge	Light Foundational Knowledge (Tacit knowledge)
Tacit had a "Special Topics" section. This could also be a place for "light and health."	Light and health	Light special topics	Light Foundational Knowledge (Tacit knowledge)
Other special topics could include the impact of lighting on ecology (wildlife, dark skies – light pollution/skyglow, light trespass, etc.)	Light impact on ecology	Light special topics	Light Foundational Knowledge (Tacit knowledge)
You outline that interior electric lighting design is not part of the architecture curriculum, but exterior lighting is. I might recommend considering this, at least as an option as it implies that architecture (and lighting) only applies to a building shell. There are obviously many overlaps between architecture and interior design in practice and I would further enhance this through the electric lighting curricular opportunities rather than the more bifurcated recommendations currently in your recommendations.	The architecture curriculum and studio need both electrical and natural lighting knowledge.	Lighting design studio/sequence of lighting design in the architecture department	Light procedural knowledge
Use of narrative. I heard it mentioned in the verbal, but did not see it listed (I may have missed it).	Narratives	Lighting teaching methods	Light procedural knowledge
Use of Analysis Some of the items mentioned can be analyzed (case studies, diagrams, drawings, measurement, etc.)	Light analysis (case studies, diagrams, drawings)	Lighting teaching methods	Light procedural knowledge
Using different light sensors in the lab and also augmented reality and VR can be effective.	Light sensors in a light bab and augmented reality (Virtual Reality)	Digital light simulation tools	Light explicit knowledge
I am not sure the IES Handbook (or the new Lighting Library) qualifies as a manual tool. Can you add a category for research avenues?	Research category for the IES handbook and the lighting library	Research venue	Light explicit knowledge
The cognitive questions section is very thorough. I often ask my students if there are areas that benefit from darkness and high contrast – this is already somewhat present in the questions as written.	How to benefit from darkness and high contrast.	Cognitive questions	Light explicit knowledge

Table 8-2. Examples of the Delphi Method Round One Analysis

8.2.2.3 – The Delphi Method Round One Answers

The answers from the first round provided new knowledge for qualitative lighting knowledge, foundational lighting knowledge, special lighting topics, the lighting design studio, teaching methods, digital light simulation tools, cognitive questions, and a new research category for lighting-related cognitive tools, as shown in Tables 8-3, 8-4, 8-5, and 8-6, and Figures 8-12, 8-13, 8-14, 8-15, 8-16, 8-17, 8-18, and 8-19. Tables 8-3 and 8-4 show the summary of the experts' feedback in round one.

Question (Theme)	Question	Summary and Recommendations
- Do you think the proposed framework is complete in the **explicit knowledge domain**? If not, what are the weaknesses? What do you think is missing?	Digital Tools	-Include 3DSMax and Enscape (Revit) in digital lighting rendering tools. - Include augmented reality and VR in the digital tools. - Include – Twinmotion (Unreal Engine/Epic Games) – similar to Enscape to the digital tools.
	Analog Tools	-Include Schedules and cut sheets in the construction documents phase - Emphasize the importance of a lighting lab to provide access to luminaires for mockups and hands-on learning in the manual tools section. - Add using different light sensors in the lab in the manual tools section. - Add a symbols legend for the plans in the deliverables. - Change the light schedule to light fixture schedule. - Include "cut books" or "lighting fixture cut books" to the manual tools.
	Cognitive Questions	-Add How to benefit from darkness and high contrast in the cognitive questions section. - Circadian rhythm is more of a quantitative question in the design process. - Try not to limit the cognitive questions to specific phases because qualitative, quantitative, and evaluative questions, are a constant at all stages of design and construction.
	Recommended Features for an Educational Digital Light Simulation Tool	- Include a direct link to lighting manufacturer's websites for fixtures and IES files in the digital tool recommended features. - Include having the option to measure the effect of light on health and mood in the software recommended features.
	Research Tools	- Add a new research venue for the IES Handbook (or the new Lighting Library) instead of having them under the manual tools.

Table 8-3. The Delphi Method Round One Answers/Suggestions

Delphi Round One Summary and Recommendations

Question (Theme)	Question	Summary and Recommendations
- Do you think the proposed framework is complete in the **tacit knowledge domain**? If not, what are the weaknesses? What do you think is missing?	Foundational Lighting Design Knowledge (Prior Lighting Design Knowledge)	-Explain math as geometry and trigonometry in the prior lighting knowledge. - Add building site in the basic building knowledge.
	Foundational Lighting Design Knowledge (Lighting Design Foundational Knowledge)	-Add sustainability as a foundational lighting knowledge (already there) - Add LEED and WELL standards as part of light sustainability. - Add to the natural light and solar geometry section shading, plantings, and landscape analysis of the site. - Add local culture as a light foundational topic (already there) - Add the special weather/ region's location + heat, psychology, and human comfort associated with the presence of daylighting in the solar geometry section.
	Foundational Lighting Design Knowledge (Light Special Topics)	- Add the impact of light on ecology (wildlife, dark skies – light pollution/skyglow, light trespass, safety, etc.) as part of the special topics section. - Add understanding of professionalism (organizations, societies, ethics, teamwork, continuing education/life-long learning, greater role in society) to light special topics.
	Foundational Lighting Design Knowledge (Light Qualitative Knowledge)	- List light and health in the foundational knowledge as part of light qualitative knowledge. Include circadian rhythm and light for impaired vision in the light and health section) - Psychology of light includes mood, light perception, human factors. - Add the effect of light on the spatial context in light qualitative knowledge. Example: how light articulates spaces and the presence of the materials, which relates to human response.
	Foundational Lighting Design Knowledge (Light Quantitative Knowledge)	- Add the lumen method in light quantitative knowledge.
	Important Subjects for Kuwait Culture	- Add light and privacy in Kuwait's culture tab
- Do you think the proposed framework is complete in the **procedural knowledge domain**? If not, what are the weaknesses? What do you think is missing?	The sequence of Lighting Design Knowledge	-Focus on the perceptual/ emotional impact of lighting qualities in the first year before getting into the rest of the human factors (which include more visual acuity, task light requirements, etc). Studying the use of light and shadow, color and angle in art, theatre, and one's surroundings, and interpreting emotion in light are good tasks during this introductory year. -Introduce the lighting studio in the second year. The third-year is late. -Include "introduction of electric light sources" in the third year alongside digital light tools in the Sequence of Knowledge in the Interior Architecture department, and "introduction to daylighting techniques" in the third year alongside digital light tools in the Sequence of Knowledge in the Architecture department. - Separate acoustics from lighting. - Move sustainability earlier than year 4. - Expert F thinks that students do not absorb lighting information as part of a building systems approach.
	Lighting Design Studio	- Add lighting lab explorations or mockups in the foundation knowledge section in the studio scenario to provide students with basic lighting language. Example: mockups of applications (this is grazing vs. wall washing): "study models". -The architecture studio should not only focus on daylighting. Students need to understand how electric lighting compliments daylight. Expert B recommends a balance of 40% daylighting, 60% architectural or electrical lighting. -Lighting control systems selections are not necessary for undergraduate architecture or interior design education. Students need to only understand control functionalities and define their control intent through a sequence of operations. -Include demographic analysis in the ideation phase. Example: age, potential cognitive disorders, the background of individuals who use a space, etc. - Expert F questions whether interior design students need to be able to understand and perform advanced calculations as it is unlikely that they will encounter them in practice. - Add "healthcare design" to the studio projects. - Add regional case study visits in the studio methods.
	Teaching Methods	- Clarify that the competitions in the methods are lighting design competitions not fixture design. - Add the use of narrative and the use of analysis (case studies, diagrams, drawings, measurement, etc.) to the teaching methods to enhance the understanding of lighting. - Include experience-based learning for lighting technical topics (evaluating a fixture cut-sheet for its appropriateness to a specific application, or building a simple electrical system to understand the components).

Table 8-4. The Delphi Method Round One Answers/Suggestions

Figures 8-12 and 8-13 present new foundational lighting design topics (highlighted in red) based on the experts' feedback.

Important Subjects for Kuwait's Culture

Light and Islamic Design

Natural Light Strategies

Light Qualities in Kuwait Culture

Sustainability

Linking Light Quantities to Light Qualities

Kuwait Indigenous Architecture
(Privacy, Natural Light Integration, Heat Reduction)

Islamic Design History
(Islamic Screens, Light Patterns, Natural Light in Islam)

Light and Privacy

Foundational Lighting Design Knowledge

Prior Lighting Design Knowledge

Design thinking
Design process
Drawing techniques
Critical thinking
Spatial reasoning
Physical modeling
Digital modeling
Construction basics
Building technology
Building services
Codes
Representation tools
Art history
Building materials
Math (geometry and trigonometry)
Color theory
Solar Geometry
Human Perception

Prior Digital Tools Knowledge

Human factors
Physics of light
Light history
Design thinking
Manual drafting
Analog tools
Design graphics
Design vocabulary
Design foundations
Light fundamentals
Design reasoning
Materials
Light technology
Light metrics
Luminaries types
Building science
Calculation
Solar Geometry
Quality of Light
Light Distribution and Power
Light Color
Natural Light Control Systems
Digital Modeling Skills

Lighting Design Foundational Knowledge

Light effects on human factors
Light color
Light perception
Light quantity
Physics of light
Light context
Light applications
Light history
Light theory
Light art/aesthetics
Light fixtures/sources
Light technologies
Light qualities
Light design
Light culture
Light presentation
Light codes
Light controls
Light layers
Light Professional Practice
Lighting Design Studio
Light Computing Technologies
Solar Geometry
Building Orientation
Glazing Types
Thermal Energy
Sustainability (LEED and WELL)
Daylight Strategies
Light Terminologies
Light and Health
Light Psychology

Special Topics

Cultural aspects (local culture)
Light and movement
light, color, and paint.
Controls
Outdoor lighting
Lighting loads and schedules
Large-scale lighting mock-ups
Light for Safety and Security
Light Design Profession
Understanding of professionalism (organizations, societies, ethics, life-long learning, greater role in society)
Advanced digital lighting tools
Light impact on ecology

Figure 8-12. The Delphi Method Round One Contribution to the Foundational Lighting Design Knowledge

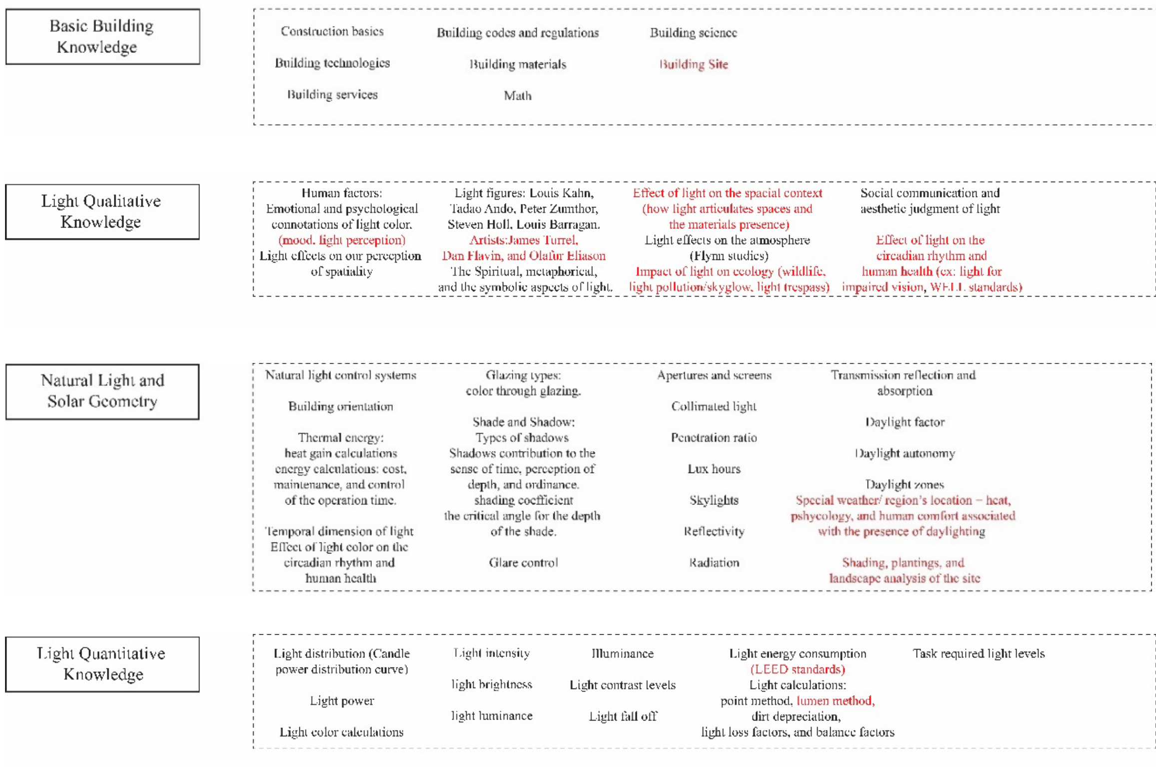


Figure 8-13. The Delphi Method Round One's Contribution to the Foundational Lighting Design Knowledge

Tables 8-5 and 8-6 show the new lighting design topics and lighting-related cognitive tools' yearly sequence based on the experts' feedback. The new knowledge is highlighted in red.

Sequence of Lighting Design Knowledge and Decision Making Tools for the Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Basic Design Studio (Design thinking, design process and basics, color theory, natural light shade and shadow) Light qualitative knowledge (human factors (Flynn studies, moods, symbolism, light color)			Introduction to Interior Design Light and Painting (light + color theory)
	Tools: manual drafting, physical modeling, sketching, research images, language and communication	Tools: cognitive questions peer-review, self-assessment pin-ups		
2	Light qualitative knowledge (Light qualities and human factors (visual acuity, task lighting), light Properties and theories.	Building services, codes, and materials Building technologies Building construction A Lighting Focused Design Studio (second semester)		Light installation Photography I Graphic Design
	Tools: computer technology (modeling, drafting, rendering)	Tools: cognitive questions IES handbook (sections only) + light measuring devices.		
3	Building Systems I (Light quality and human factors, design functions, physics of light light fundamentals and terminologies light design process, light perception, solar geometry , electrical light sources light color, history of light light hierarchy and layers, light application)	Design of the Luminous and Sonic Environments (Light quantity, light aesthetics and arts, light functions, light philosophy and theory technical lighting design knowledge, light technologies and controls, light codes)	Environmental Sustainability (environmental, vernacular, and cultural aspects of light + light role in Islamic design)	Solar Energy Photography II Kuwait Indigenous Architecture
	Tools: analog and digital + technical writing	Tools: IES handbook + light measuring devices, cognitive questions peer-review, self-assessment , pin-ups	Tools: digital light simulation tools Introduction to daylighting techniques	
4		Internship Opportunities (profession)		Advanced Computer Application BIM technology + BIM lighting plug-ins
		Tools: analog and digital analysis tools cognitive questions peer-review, self-assessment, pin-ups	Tools: advanced digital tools schedules and cut-sheets	
5			Comprehensive Application	Advanced Lighting (Effect of light on the circadian rhythm and human health Professional Training
			Tools: working drawings cognitive questions peer-review, self-assessment pin-ups	

Table 8-5. The Delphi Method Round One Contribution to the Lighting Design Sequence

Sequence of Lighting Design Knowledge and Decision Making Tools for the Interior Architecture Department

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Introduction to Interior Design Studio (Design thinking, design process and basics, color theory, natural light) light qualities and human factors (Flynn studies, moods, symbolism, and spiritual aspects, light color), light properties and theories, shade and shadow)	Building services, codes, and materials		Light and painting (Color theory + light)
	Tools: manual drafting, physical modeling sketching, research images, language and communication	Tools: cognitive questions peer-review, self-assessment pin-ups		
2	Building Environmental Systems class (Light quality and human factors visual acuity, task lighting), physics of light, light fundamentals and terminologies , light design process, light perception, solar geometry , electrical light sources, light color, history of light, light hierarchy and layers, light application)	Building Environmental Systems class (Light quantity, light aesthetics and arts, light functions, light philosophy and theory technical lighting design knowledge, light technologies and controls, light codes) A Lighting Focused Design Studio (second semester)		Light and movement Light installation Photography I Graphic Design
	Tools: computer technology (modeling, drafting, grey-scale rendering)	Tools: cognitive questions peer-review, self-assessment pin-ups, IES handbook (sections only) + light measuring devices.		
3	Innovative Interiors Class		Environmental Sustainability + Sustainable Interior (environmental, vernacular, and cultural aspects of light + light role in Islamic design)	Photography II Kuwait Indigenous Architecture
	Tools: analog and digital + technical writing	Tools: IES handbook + light measuring devices, cognitive questions, peer-review, self-assessment, pin-ups	Tools: digital light simulation tools Introduction of electric light sources	
4		Internship Opportunities (profession)	Comprehensive Application of Light	Advanced Computer Application BIM technology + BIM lighting plug-ins Advanced Lighting (Effect of light on the circadian rhythm and human health
		Tools: analog and digital analysis tools cognitive questions peer-review, self-assessment pin-ups	Tools: advanced digital tools schedules and cut-sheets working drawings	

Table 8-6. The Delphi Method Round One Contribution to the Lighting Design Sequence

Figure 8-14 displays the new lighting design studio based on the experts' feedback. The new knowledge is highlighted in red.

A Lighting Design Studio

Knowledge Stages	Design Goals	Decision-making and Presentation Tools	Evaluation
Foundational Knowledge	A warm-up project related to students' past knowledge (use questions to understand student's knowledge). Warm-up project ideas: -Representing a real light phenomenon in a contained environment. -Building a light installation. -Working on a light charrette. -Present a poem, a play, or a painting through a light animation or movement. -Write about a light experience. -Presenting a light adjective. -Hunting for a bad lighting project. -Light Sources Scavenger Hunt. -Light survey in an existing site with sketching or photographing or Collaging. -Measuring light levels in different spaces. -Testing natural light strategies with physical and digital models. -Using a sun dome to test light and shadow patterns. -Giving students a ready-made digital model to experiment different lightings lighting lab explorations or mockups	Sketching Diagramming Photographing Collages Study Models (Mockups of application) Writing and Talking Digital presentation Animation Play / Performance Research Images Grey-Scale Renderings	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -First pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking.
Intermediate Knowledge	Field trips to cultural places (regional). Lighting design studio projects: - A restaurant - A museum - A play - A library - A house - An office - Retail Design - Health Care Concepts generation. Group Work Students focus on light qualities and Kuwait's culture.	Site visits and analysis Photography Sketches Diagrams Analog and digital drafting Digital and Analog modeling Lighting lab explorations Control systems (Control functionalities/ sequence of operations only) Mockups Preliminary renderings and perspectives Digital Light Plug-ins Light Plans (RCP, section, elevation, distribution plan)	-Desk Crits : Educators play the role of facilitators; they give feed-back without dictating the direction of students' projects. -Second pin-up : students give peer-review in pin-ups. -Self-assessment : reflective writing - Cognitive questions to guide students' design thinking. - First jury
Advanced Knowledge	Design development Design process Detailed light analysis The final Project Students focus on light quantities and technical knowledge.	Detailed drawings Cut-sheets Light Schedules Detailed renderings/Pseudo color renderings Physical and digital models Animation Final light maps Light loads and calculation tables	-Desk Crits -Third pin-up : peer-review -Self-assessment -Pragmatic evaluation -Cognitive questions -Second jury -Final jury

Figure 8-14. The Delphi Method Round One Contribution to the Lighting Design Studio

Figure 8-15 demonstrates new lighting design cognitive tools in the design process, whereas Figure 8-16 presents the experts' contributions to the framework's teaching methods. The new knowledge is highlighted in red.

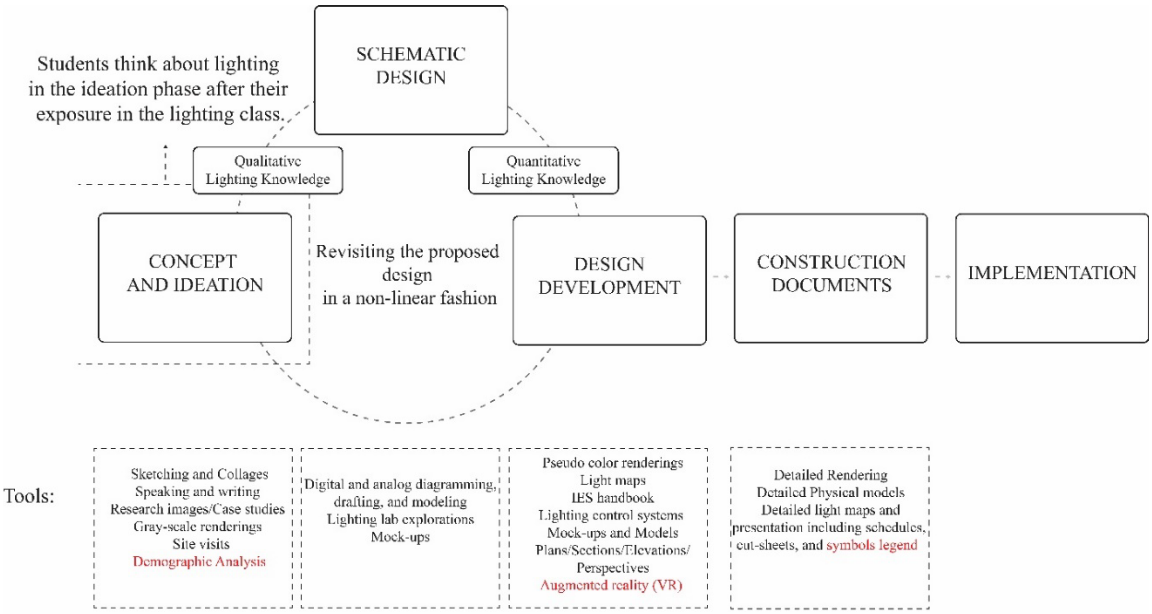


Figure 8-15. The Delphi Method Round One Contribution to the Lighting Design Tools in the Design Process

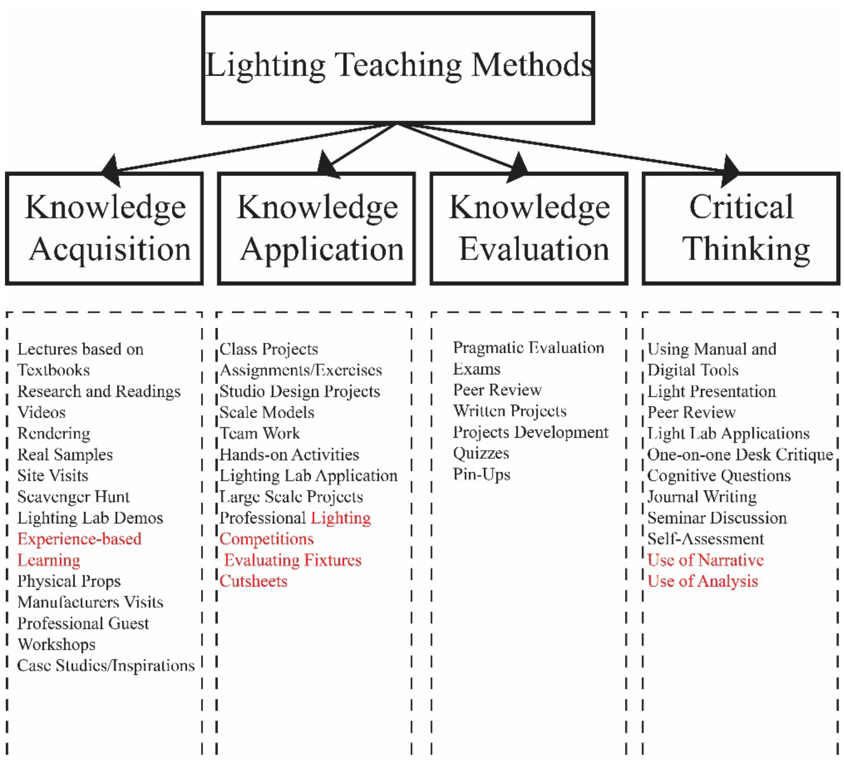


Figure 8-16. The Delphi Method Round One Contribution to the Lighting Design Teaching Methods

Figure 8-16 displays research tools as a new category for the lighting cognitive tools with other new suggested manual tools (highlighted in red).

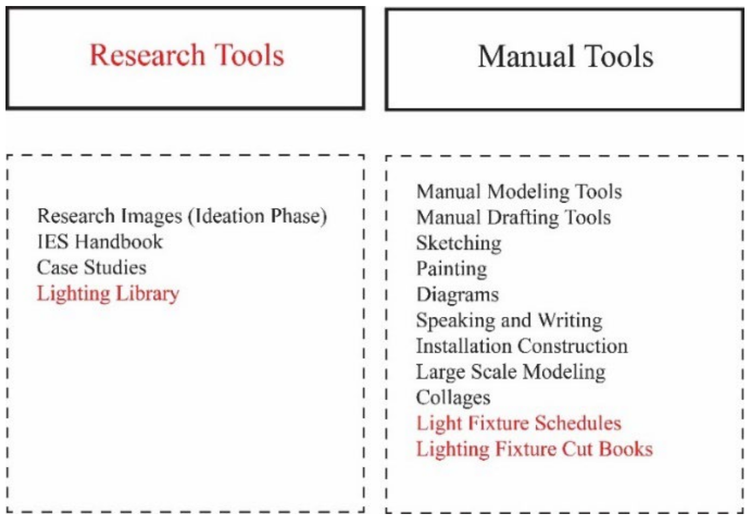


Figure 8-16. The Delphi Method Round One Contribution to the Lighting Design Decision-Making Tools

Figure 8-17 shows the new digital light simulation tools and recommended features for an educational digital lighting tool. The new knowledge is highlighted in red.

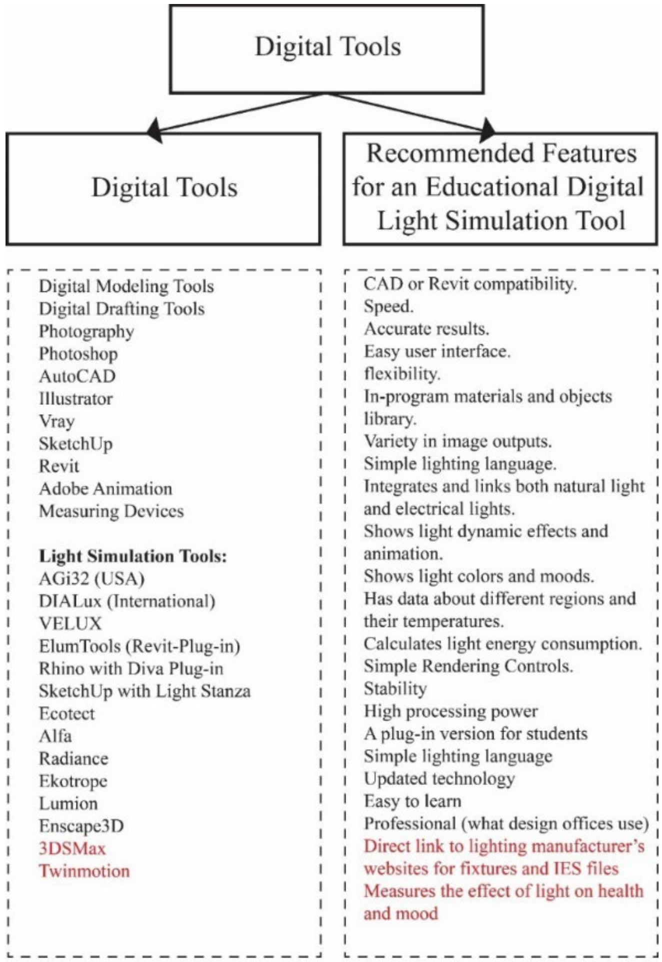


Figure 8-17. The Delphi Method Round One Contribution to the Lighting Design Digital Tools

Figures 8-18 and 8-19 show the experts' contributions to the cognitive question examples and positions in the design process. The new knowledge is highlighted in red.

Figure 8-18. The Delphi Method Round One Contribution to the Lighting Design Cognitive Questions

Examples of the Cognitive Questions

Explorative: What is the relationship of the building's openings to the sun orientation? How light patterns change based on different ground treatments? How different materials react to one light source?
Pragmatic: What are the needs of the client?
Qualitative: How to create a relaxed environment through light manipulation? What is the role of directed light and intimacy? What are the effects of light on the human mood?
Functional/Application: How to distribute light to minimize shadows on a critical task? How to manage glare for people with poor vision? How can we improve the eyes' adaptation between dark and bright environments? Is there a good contrast? How light brings texture to a surface? How to benefit from darkness and high contrast?
Explicit/Presentation: What tools needed to perform certain light design objectives or tasks? What tool will you use to present your design?
Quantitative: How many fixtures or how much light does a designer need for a specific function or task? What are the required light levels of a certain task? How will you meet codes? What are the effects of light on the circadian rhythm ?
Hierarchical: Where do you want the eye gaze to go?
Technical: How will you control the light?
Technological: What technology will you use and why?
Philosophical and theoretical: Why did you make that choice?
Conceptual: What is the overall theme? Does the choices you are making relate to your overall concept? What is the ambition with the space? What is the main light idea?
Evaluative: Which lighting design alternative create the most sustainable design? Which design alternative works best?
Affirmative: Does the chosen lighting design alternative consume the least energy?
Procedural: What lighting design aspects should students focus on in each design phase? How do you plan to make the design work?
Cultural/Contextual: What are the lighting design features that represent a certain culture or community? Can cultural dimension of daylight be embodied in a biophilic environment? How to create an environment that is culturally comfortable? What is the context of the building?
Analysis/Reasoning: What materials absorb light? What surfaces reflect light the most? What causes glare?
Descriptive: What are the color components of a white light?
Delegation/ Executional: Which design task does the designer need to delegate to other team members? How to implement the design?
Experiential: How do visitors and workers experience the space? How will people move within the building's thresholds?
Phenomenological: What are the effects of color and light intensity on depth perception? What do you want people to sense?
Problem-solving: How are going to solve the problem?
Aesthetical: What finishes and materials work best with your lighting concept?

Figure 8-19. The Delphi Method Round One Contribution to the Lighting Design Cognitive Questions

8.2.3 – Delphi Method Round Two

The researcher summarized the round one suggestions into themes and categories and presented them to the participants in round two, along with the updated framework diagrams. The second round consists of closed-ended survey questions that were based on round one's answers. The researcher asked the participants to rate the proposed framework implementation possibilities, action plan, teaching methods, decision-making tools, proposed lighting design studio, and their satisfaction with the overall framework. Table 8-7 presents the round two questions. The researcher used a scale from 0-4, with 0 meaning *highly disagree* and 4 meaning *highly agree*.

8.2.3.1 – Round Two Questions

Q1: The proper implementation of the proposed framework enhances students' understanding of lighting design in the following categories					
Category	Highly Disagree	Disagree	Neutral (neither agree or disagree)	Agree	Highly Agree
a) Foundational lighting design knowledge	0	1	2	3	4
b) Light qualitative knowledge	0	1	2	3	4
c) Light quantitative knowledge	0	1	2	3	4
d) Lighting generative knowledge	0	1	2	3	4
e) Light cultural aspects	0	1	2	3	4
f) Communication skills	0	1	2	3	4

Q2: The proper implementation of the proposed framework enhances students' lighting design process in the following categories					
a) Category	Highly Disagree	Disagree	Nuetral (neither agree or disagree)	Agree	Highly Agree
b) Ideation	0	1	2	3	4
c) Representation	0	1	2	3	4
d) Design Development	0	1	2	3	4
e) Design Evaluation	0	1	2	3	4

Q3: The proposed framework encourages students to think about lighting from the conceptual design phase when properly implemented				
Highly Disagree	Disagree	Nuetral (neither agree or disagree)	Agree	Highly Agree
0	1	2	3	4

Q4: The effective implementation of the proposed framework encourages educators to use different knowledge delivery methods in the following categories					
Category	Highly Disagree	Disagree	Neutral (neither agree or disagree)	Agree	Highly Agree
a) Knowldeg aquisition	0	1	2	3	4
b) Knowledge application	0	1	2	3	4
c) Knowledge evaluation	0	1	2	3	4
d) Critical thinking	0	1	2	3	4

Q5: The proposed framework encourages students to use different effective lighting analysis tools when implemented in the following categories					
Category	Highly Disagree	Disagree	Neutral (neither agree or disagree)	Agree	Highly Agree
a) Digital tools	0	1	2	3	4
b) Manual tools	0	1	2	3	4
c) Research tools	0	1	2	3	4
d) Desiscion making tools	0	1	2	3	4
e) Cognitive questions	0	1	2	3	4

Q6: How satisfied are you with the sequence of lighting design knowledge as presented in the framework				
Dissappointed	Somehow Satisfied	Nuetral	Very Satisfied	Impressed
0	1	2	3	4

Q7: How satisfied are you with the proposed features of an educational digital light simulation tool as listed in the framework				
Dissappointed	Somehow Satisfied	Nuetral	Very Satisfied	Impressed
0	1	2	3	4

Q8: The proposed lighting design studio supports the application of the proposed framework's recommendations in the following categories					
Category	Highly Disagree	Disagree	Neutral (neither agree or disagree)	Agree	Highly Agree
a) Warm up projects	0	1	2	3	4
b) Lighting design projects	0	1	2	3	4
c) Lighting deign delivarables	0	1	2	3	4
d) Studio teaching methods	0	1	2	3	4
e) Studio decision-making tools/presentation tools	0	1	2	3	4
f) Studio evaluation	0	1	2	3	4

Q9: The proposed framework effectively contributes to lighting design pedagogy when implemented properly				
Highly Disagree	Disagree	Nuetral (neither agree or disagree)	Agree	Highly Agree
0	1	2	3	4

Q10: How likely would you implement the proposed framework in your teaching?				
Very Unlikely	Unlikely	Nuetral	Likely	Most Likely
0	1	2	3	4

Additional Comments

Table 8-7. The Delphi Method Round Two Questions

8.2.3.2 – The Analysis of Round Two

The researcher used quantitative statistical methods to analyze the round two survey answers. The objective of the statistical analysis is to show the participants' level of agreement with the framework's implementation and usefulness. There is no general percentage of agreement suggested for the Delphi method due to different variables such as the sample size, however, the consistency of responses for different sections of the survey can suggest a consensus (Hasson, 2000).

For the current research, the researcher followed Al-Rqaibat's (2019) Delphi method analysis procedures. Just like her approach, this research aimed for a 69.7% level of agreement. The average percent of majority opinions cut-off rate (APMO) and the central tendency analysis were used to measure the agreement rate.

8.2.3.2.1 – The Average Percent of Majority Opinions (APMO) Cut-Off Rate

The researcher used the average percent of majority opinions (APMO) to reach a consensus of either agreement or disagreement that was higher than the APMO cut-off rate. The APMO cut-off rate was 69.7%, as suggested by (Al-Rqaibat, 2019).

APMO=Majority Agreements + Majority Disagreements/ S Opinions Expressed.

Round two's APMO was 176 agreements + 0 disagreements divided by 210 responses. The result was 83.8%, which is higher than the cut-off rate of 69.7%, meaning that a consensus was reached.

It is important to note that the experts did not disagree on any of the framework sections (refer to Appendix C); however, most of them answered the last question (How likely would you implement the proposed framework in your teaching?) with a neutral response. The reason behind such answers is that they come from developed lighting design programs that are already established, whereas the framework addresses design schools that are still developing their lighting design knowledge and lighting cognitive tools. Expert 5 stated:

> Content of the framework needs to be adapted to specific disciplinary focus and per unique attributions of individual institutions. I believe overall this is a great structure for all institutions (or at least many) to reference as they consider content delivery within courses. It's bound to be a complimentary resource to other academic structures that currently exist.

Expert 1 said:

> The framework is very well suited for institutions with strong architectural programs. The framework may not implement as well depending on the given body of students and faculty at different institutions. Generally, this is a very sound framework. It does not fit my specific institution, but should work well in many academic environments.

8.2.3.2.2 – Statistical Analysis

Hasson (2000) recommends using central tendencies (means, medians, and mode) and levels of dispersions (standard deviation and the inter-quartile range [IQR]) to reach a consensus when using a Delphi method (Hasson, 2000). Table 8-8 and the following sections explain the statistical results of round two.

Question	IQR >2	Mode	Median	Mean	Standard Deviation	AMPO in %
Q1a	0	4	4	3.86	0.38	100
Q1b	0.5	3	3	3.29	0.488	100
Q1c	0.5	4	4	3.71	0.488	100
Q1d	1.5	4	4	3.14	1.113	71
Q1e	0.5	3	3	3.14	0.69	85.7
Q1f	0.5	3	3	3.29	0.488	100
Q2a	0.5	3	3	3.14	0.69	85.7
Q2b	1.5	2	3	2.86	0.9	57
Q2c	1	3	3	3	0.816	71
Q2d	1	3,4	3	3.29	0.756	85.7
Q3	0.5	3	3	3.14	0.69	85.7
Q4a	0.5	4	4	3.71	0.488	100
Q4b	0	4	4	3.71	0.756	85.7
Q4e	1	3	3	3.43	0.535	100
Q4d	1.5	4	3	3.14	0.9	71
Q5a	1	3	3	3.43	0.535	100
Q5b	1	3	3	3.43	0.535	100
Q5c	1.5	4	3	3.14	0.9	71
Q5d	2	2,4	3	3	1	57
Q5e	0.5	4	4	3.71	0.488	100
Q6	0.5	3	3	3.14	0.69	85.7
Q7	0.5	3	3	3.14	0.69	85.7
Q8a	1	3,4	4	3.29	0.756	85.7
Q8b	1	4	4	3.57	0.535	100
Q8c	1.5	4	3	3.14	0.9	71
Q8d	1.5	4	3	3.14	0.9	71
Q8e	1	4	4	3.43	0.787	85.7
Q8f	1.5	2	3	2.86	0.9	57
Q9	1	3	3	3.43	0.535	100
Q10	1	2	2	2.57	0.787	42.8

Mean	3.28
Mode	4
Median	3
SD	0.17349
Q1	2.5
Q3	4
IQR	1.5
AMPO	83.8 %

Table 8-7. The Statistical Results of Round Two

Inter-Quartile Range (IQR)

Round two's IQR was 1.5. Scheibe et al. (as cited in (Al-Rqaibat, 2019)) recommend an IQR of no larger than 2 units on a 10-unit scale to reach a consensus. As a result, consensus was achieved.

Median

Consensus is determined to be achieved if 50% or more of the responses are above the median (Heiko, 2012). For round two, the median was 3 and the mean was 3.28; thus, consensus was reached.

Mode

Round two's mode was 4, and the mean was 3.28. Al-Rqaibat (2019) implies that a consensus is suspected if the mode is higher than the mean.

Standard Deviation

If the ratings' mean is between 1.64 over and under the standard of deviation, consensus is achieved (West & Cannon, 1988). Round two's standard deviation= 0.17349, SD*1.64= 0.285. Of the ratings, 99.8% were higher than 1.64; thus, consensus was reached.

8.2.5 – The Delphi Method: Limitations

- Time constraints only allowed for two rounds of the Delphi method and a sample size of eight participants. More valuable feedback may include more rounds and participants.
- In the second round, the researcher only received answered surveys from seven of the eight participants. This limitation was inevitable due to time constraints.
- One of the participants is a professional lighting designer who does not teach, which may affect the overall feedback.
- The participants' and the researcher's busy schedules limited the interaction to online text exchanges rather than face-to-face interviews.

8.3 – Summary

This chapter presented coverage of the research consensus. It revealed the committee's recommendations and the Delphi method feedback to advance the proposed framework. The Delphi method provided the researcher with lighting design experts' feedback and agreement regarding the framework's action plan in a process of two rounds. In round one, the experts provided feedback for three open-ended questions that tackled the framework's weaknesses and missing information to enhance it. In round two, experts answered 10 closed-ended questions to rate the framework's action plan and appropriateness. A 99.8% consensus was reached in the Delphi method, which means the participants agreed with the framework's contributions to students' understanding of lighting design and their lighting design decision-making process.

Chapter IX

9- Discussion and Summary

This research aims to develop lighting design pedagogy and students' understanding of lighting design at Kuwait University. It provides lighting design knowledge, teaching methods, and cognitive tools to advance students' knowledge and decision-making skills. It also presents features for an educational digital lighting simulation tool to help software developers create a simpler version for educational use to make lighting analysis easier for students. The researcher met the research objectives by transferring knowledge from developed lighting design programs in the United States to Kuwait's design curricula (architecture and interior design). She first created a logical argument and identified the lighting knowledge domains by interpreting the relevant literature. She then analyzed lighting design documents, conducted in-depth interviews with lighting design educators from the United States and Kuwait, and performed a Delphi method to reach consensus among experts regarding the framework's implementation. This chapter presents the research findings and action plan to show how the research goals were met.

9.1- Logical Argument

The logical argument provided the researcher with a theoretical structure for the proposed framework. The theoretical structure supplied the researcher with lighting design topics (section 4.4), cognitive tools, and pedagogical recommendations from the main pedagogical models (PBL, constructivism, and experiential learning), the curricula development bodies, and the cognitive literature. It also provided the researcher with a preliminary action plan, which served as a basis for the proposed framework (knowledge domains, section 4.3) and its research instrument (interview questions, sections 4.2 and 4.5).

9.1.1- The Logical Argument Action Plan

9.1.1.1- Action Plan for a Design Curriculum Development:

- Introduce different analog and digital cognitive tools throughout the curriculum.
- Provide a flexible curriculum with different lighting design electives.
- Provide a foundational year that engages students in different design elements and principles.
- Introduce a BIM lighting analysis plug-in for educational use.
- Introduce lighting design knowledge and digital tools in a sequence.
- Launch an advanced elective for digital light simulation tools.

9.1.1.2- Action Plan for a Lighting Design Studio:

- Start by understanding students' past knowledge. Use warm-up projects, observations, or open-ended questions.
- Facilitate students' learning process by guiding them to the right knowledge domains and providing them with research skills and cognitive tools.
- Invite students to search for new lighting design topics that are relevant to their projects and to present that knowledge in the role of an educator to the whole class.
- Introduce different cognitive tools and questions.
- Take students on field trips and involve them in social, cultural, and environmental projects.

- Invite students to apply the knowledge they gain from a lighting course in the design studio or hands-on exercises.
- Encourage peer-review and self-assessment.
- Engage students in teamwork.

9.2- The As-Is Model

The As-Is model presented the current lighting design knowledge, pedagogical approaches, teaching methods, cognitive tools, students' perceptions towards lighting design, and cultural aspects of lighting at Kuwait University. This model served as the basic structure for the framework development. The researcher interviewed five lighting design educators from Kuwait University and analyzed the lighting design classes' syllabi and curricula to understand the current sequence and structure (see Chapter V).

The researcher added the new knowledge from the United States with Kuwait cultural topics in the new framework. The important cultural topics were:

- Solar geometry and daylight strategies.
- Ways to let in daylight and maintain the privacy of the space's occupants.
- Islamic screens for shading and privacy (*mashrabiya*).
- Sustainability and energy conservation methods to reduce heat gain in buildings while providing adequate natural lighting.
- Concrete construction to manage direct sun heat gain.
- Indigenous methods (e.g., courtyard housing).
- Light perception in Islamic countries (festivity and faith).
- Islamic design history (elements and patterns).
- DiaLUX as the most used lighting analysis software in Kuwait.

9.3- To-Be Model

The To-Be model provided the researcher with advanced and developed lighting design topics, pedagogical approaches, teaching methods, cognitive tools, sequence of lighting design knowledge, and a studio that is focused on lighting design. The researcher interviewed six lighting design educators from developed lighting design programs from the United States (listed in section 6.1) and analyzed the lighting design classes' syllabi and curricula to extract new knowledge for Kuwait's framework. The recommendations and the new knowledge that the researcher obtained from the To-Be model are presented in the following proposed framework section (9.4).

9.4- The Proposed Framework

The proposed framework was developed by transferring advanced lighting design knowledge, teaching methods, cognitive tools, and suggestions from established lighting design programs from the United States to Kuwait University. The researcher used in-depth interviews and document analysis as data sources to create the preliminary framework. The preliminary framework provided an action plan to develop lighting design curricula in a yearly sequence according to the foundational, intermediate, advanced, and elective knowledge domains at Kuwait University. It also categorized the new knowledge and recommendations into three main cognitive domains: tacit, procedural, and explicit (section 7.4.3)

The tacit knowledge domain addressed foundational lighting knowledge, the knowledge needed before learning lighting design and digital tools, Kuwaiti cultural topics, special lighting topics, pedagogical philosophy, and the relationship between qualitative and quantitative lighting knowledge. The procedural knowledge domain tackled the roles of lighting design and cognitive roles in students' design process; the teaching methods that enhance students' lighting design knowledge acquisition, application, and evaluation; and the sequence of lighting design knowledge in the curriculum. It also proposed a studio scenario with lighting design projects to develop students' cognitive thinking. The explicit knowledge domain focused on lighting design cognitive tools that help students in design decision-making. Students need both analog and digital tools to meet all their design objectives. In addition to the analog and digital tools, lighting design experts suggested a new lighting-related cognitive category, which is the research category. Students need research tools to encourage them to obtain and construct new lighting design knowledge on their own and help them in their decision-making process.

The researcher furthered the preliminary framework by seeking experts' feedback using a Delphi Method and suggestions from her committee members. The following sections present a summarized general action plan for design curricula development, theoretical lighting classes, and a lighting design studio that any design institution can adopt. This action plan was reached after the research consensus development (Delphi method and committee feedback).

9.4.1- Action Plan for a Design Curriculum Development

- Introduce a flexible curriculum with different lighting design electives like photography, light and movement, advanced digital light simulation tools, light and painting, graphic design, and an advanced lighting class that offers light effects on human health and circadian rhythms to align with constructivism, PBL, and experiential pedagogical theory, as well as Schon's (1987) recommendations.

- Provide a lighting lab to encourage hands-on exploration and help students apply light theoretical knowledge to align with constructivism and experiential pedagogical theory.
- Introduce an interdisciplinary first design year and offer multidisciplinary opportunities for students from different majors (e.g., a lighting design studio where architecture and interior design students work together on a design project).
- Provide internship opportunities with lighting design professionals.
- Provide the faculty with the tools and technologies needed to deliver lighting design knowledge.
- Raise awareness about the importance of lighting to human health, wellbeing, comfort levels, and energy consumption to reflect on the whole society.
- Introduce crash courses or workshops to introduce different lighting-related cognitive tools.
- Invite adjunct professors and lighting specialists to introduce new lighting design topics and knowledge to students in different classes and studios.
- Offer a lighting design honors degree if students take specific lighting design electives to encourage more lighting knowledge acquisition.
- Offer a lighting design graduate degree to develop lighting design education in Kuwait.

- Introduce foundational and advanced lighting knowledge in a sequence from the beginning of design education to enhance students' knowledge retention.

9.4.1.1- Lighting Design Knowledge Sequence:

- Introduce qualitative aspects of light from the first year like shade and shadow, light's effects on human mood and feelings (Flynn studies), light's effects on human perception, key figures in lighting (i.e., Steven Holl, Peter Zumthor, Louis Khan, James Turrel, and Dan Flavin), and aesthetic judgment of light. These topics can be introduced in a new light poetics class.
- Integrate a lighting design studio in the second year.
- Introduce foundational design knowledge, basic building knowledge, and math in different courses across the curriculum before the lighting theoretical class. The prior lighting topics are listed in Figure 9-1.
- Integrate prior lighting knowledge and light basic knowledge that are listed in Figures 9-1 and 9-2 before introducing a digital light simulation tool.
- Integrate foundational lighting topics that are listed in Figure 9-2 in more than one lighting theoretical class. The topics can be divided into introductory qualitative knowledge in the first year, intermediate qualitative and quantitative knowledge in the second year, and advanced qualitative and quantitative knowledge in the third and fourth years, as listed in Table 9-1.

Sequence of Lighting Design Knowledge and Decision Making Tools

Year	Foundational Knowledge	Intermediate Knowledge	Advanced Knowledge	Elective/Future Knowledge
1	Design thinking, design process and basics, color theory, natural light, and light qualities and human factors (Flynn studies, moods, symbolism, and spiritual aspects, light color), light properties and theories, shade and shadow.	Building services, codes, and materials		Light and painting (Color theory – light)
	Tools: manual drafting, physical modeling sketching, research images, language and communication	Tools: cognitive questions peer-review, self-assessment pin-ups		
2	Light quality and human factors (visual acuity, task lighting), physics of light, light fundamentals and terminologies , light design process, light perception, solar geometry , electrical light sources, light color, history of light, light hierarchy, and light application	Light quantity, light aesthetics and arts, light functions, light philosophy and theory technical lighting design knowledge, light technologies and controls, light codes A Lighting Focused Design Studio (second semester)		Light and movement Light installation Photography I Graphic Design
	Tools: computer technology (modeling, drafting, grey-scale rendering)	Tools: cognitive questions peer-review, self-assessment pin-ups, IES handbook (sections only) light measuring devices.		
3			Environmental Sustainability (environmental, vernacular, and cultural aspects of light – light role in Islamic design)	Photography II Indigenous Architecture
	Tools: analog and digital + technical writing	Tools: IES handbook + light measuring devices, cognitive questions, peer-review, self-assessment, pin-ups	Tools: digital light simulation tools Introduction of electric light sources Introduction to daylighting techniques	
4		Internship Opportunities (profession)	Comprehensive Application of Light	Advanced Computer Application BIM technology + BIM lighting plug-ins Advanced Lighting (Effect of light on the circadian rhythm and human health
		Tools: analog and digital analysis tools cognitive questions peer-review, self-assessment pin-ups	Tools: advanced digital tools schedules and cut-sheets working drawings	

Table 9-1. Lighting Design Knowledge Sequence Example

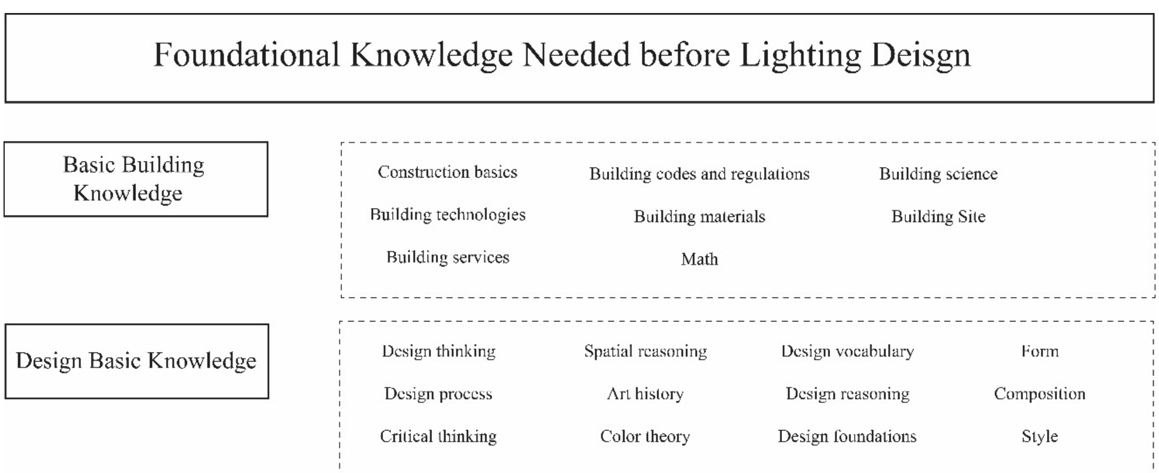


Figure 9-1. Knowledge Needed before Lighting Design

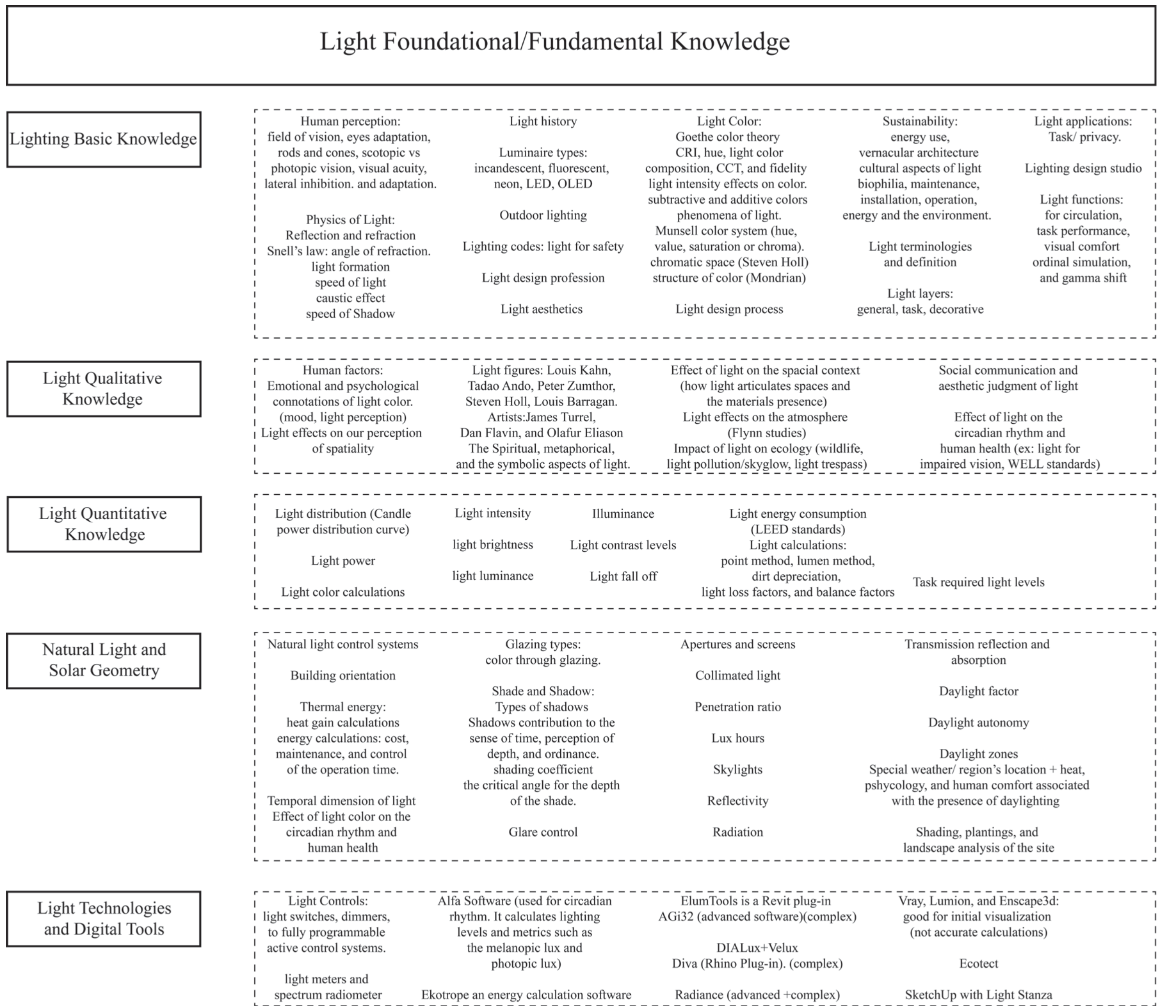


Figure 9-2. Lighting Design Foundational Knowledge

9.4.2- Action Plan for Theoretical Lighting Design Classes:

- Encourage students to conduct individual lighting research and present it to the class (knowledge that is not already covered in the class).
- Link theoretical knowledge to small practical exercises or students' studio projects.
- Use pragmatic evaluation and reflective critical writings to measure how students' projects developed after they were introduced to the new lighting design knowledge.

- Use interactive teaching methods as listed in Figure 9-3.
- Introduce a variety of exercises like finding a bad lighting scenario and emphasizing the weaknesses; presenting a poem or a play using light; writing about a lighting-related experience; creating mood collages using light, materials, and colors; testing natural light penetrations in buildings using different orientations, shading devices, and openings; and experimenting with light distributions and effects using a ready-made digital model.
- Divide the lighting design knowledge listed in Figure 9-2 into different theoretical classes based on the program's objectives.
- Incorporate technology in lighting design education to align with constructivism pedagogical theory and professional demands.
- Table 9-2 presents an example of a light poetics class that can be introduced in the first year.

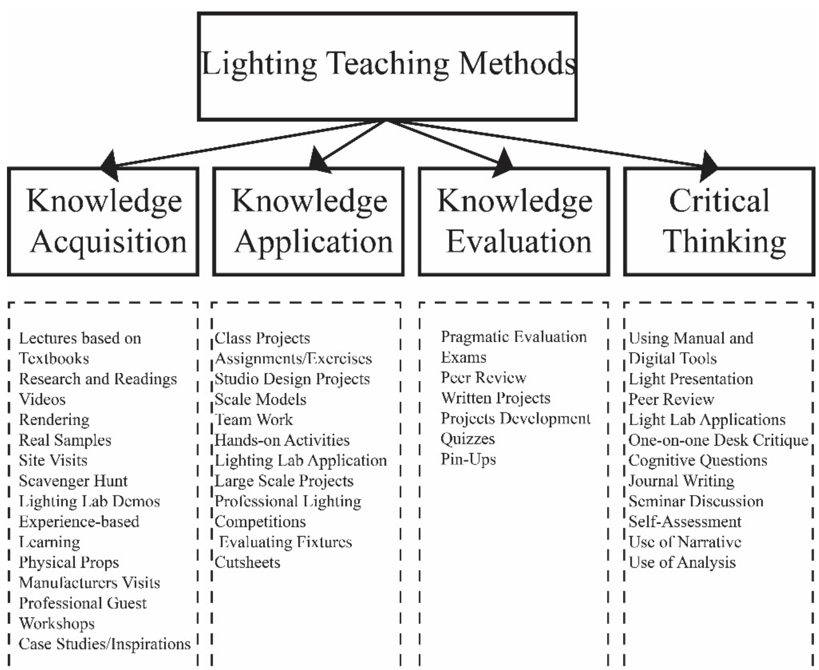


Figure 9-3. Lighting Design Teaching Methods

Light Poetics Class (Introductory Course)

Course Description:

Light qualities affect people moods, feelings, perception of spaces, health, comfort levels, and their spiritual and poetical experiences. This course highlights the qualitative and poetic aspects of light as an introduction to the world of lighting design. Students are invited to explore different lighting atmospheres and their relationship to the users' phenomenological experiences, the spaces' forms and materials, and light symbolic connotations. Students are encouraged to construct their own knowledge to develop their research and problem-solving skills, their interest in lighting design, and their critical thinking. Students will work on an installation project with different hands-on experimentations to understand different light phenomena and their attributes to human's perception and experiences.

The proposed class consists of 14 weeks instead of 16 weeks given that two weeks of classes maybe affected by national holidays.

Schedule

Week	Teaching Method	Lighting Knowledge	Exercises
Week 1	Presentation Videos Light Props and Demos	Introduction to light: What is light light qualities: Light Figures: James Turrell	Search for a light phenomena that interest you and present it to the class using any media (photographs, videos, models, animation, collage, painting, storyboard ...etc).
Week 2	Presentation Audio Visual	Light effects on spaces and human perception Light Figures: Dan Flavin Olafur Eliasson	Scavenger Hunt: Find a painting, a poem, an art piece, a space or a song that resemble a light experience and then reflect on your own perception in a narrative
Week 3	Light Lab Experimentation	Exploring light behavior with surfaces, materials, and forms	Document your light lab explorations in any form (narrative, pictures, videos, sketches, diagrams ... etc.)
Week 4	Presentation Audio Visual Sun Dome Explorations	Shade and shadow Types and shadows Shadow contribution to the sense of time, perception of depth, and ordinance.	Explore the sense of time and shadows using a physical model and the sun dome. (models are provided)
Week 5	Presentation Audio Visual	Light effects on the atmosphere Figure: Flynn Studies Light Spiritual, metaphorical, and symbolic aspects Figures: Tadao Ando and Peter Zumthor	Compose cognitive questions related to light effects on the atmosphere or light spiritual and metaphorical aspects that you wish to explore.
Week 6	Group Work	Installation Brainstorming	Forming Groups based on the cognitive questions and students' interests
Week 7	Props and Demos Audio Visual Presentation Light Lab Explorations	Light Color: Goethe color theory, Munsell color system, additive and subtractive light, color psychological effects. Figures: Steven Holl, Le Corbusier	Explorations with light colors, adding and subtracting light sources. Express in a narrative how different light colors make you feel.
Week 8	Field Trip to cultural places that emphasize lighting	Light Culture	Documenting the field trip. (videos, sketches, photographs, paintings, diagrams ... etc.).
Week 9	Audio Visual Presentation	Light Culture: Cultural perceptions of light and color in different cultures Figure: Louis Kahn, Luis Barragan, Tadao Ando	Light installation concept generation as a group
Week 10	External Reading Reading Discussion	Phenomenology	Installation development Group work
Week 11	External Reading Reading Discussion	Environmental Psychology	Installation development Group work
Week 12	Installation Pin-Up Peer-Review	Installation Materials and Construction	Installation development Group work
Week 13	Desk Crits	Installation Construction	Installation development Group work
Week 14		Installation Construction	Installation Presentation and Event

9.4.3- Action Plan for a Lighting Design Studio:

- Treat light as a concept generator.
- Involve students in lighting design competitions.
- Take students on field trips (manufacturers visits, showrooms, light fairs, buildings with lighting examples, art museums, exhibitions, and natural settings with different light treatments), and involve them in social, political, cultural, and environmental contexts to align with the constructivism and experiential learning pedagogical approaches.
- Use cognitive questions to direct students' design thinking. Examples of key cognitive questions are listed in Figure 8-19.
- Teach students different cognitive tools such as digital light simulation tools (listed in Figure 8-17), physical models, physical mock-ups, materials investigation, hand-held measuring devices, light cut sheets and cut books, collages, paintings, diagrams, sketches, sections, plans, RCPs, elevations, perspectives, light distribution plans, light fixture schedules, light switch plans, light installations, research images, grayscale renderings, realistic renderings, lighting lab explorations, control systems investigations, installations, and pseudo color renderings. Figure 9-4 presents the appropriate cognitive tools for each design phase.
- Introduce research tools to help students construct their own lighting design knowledge. Examples of research tools are the IES handbook, manufacturer visits, cognitive questions, scavenger hunts, case studies, research images, and reflective writings.

- Use pragmatic evaluation to measure how students' projects developed after they were introduced to different lighting design knowledge and tools.
- Encourage peer review, self-assessment, reflective critical writings, desk crits, and pin-ups to evaluate students' projects.
- Introduce a variety of lighting design projects such as a restaurant, a boutique hotel, an adaptive reuse project, a museum, a library, a house, an office, a health care facility, and a retail store.
- Craft design projects around the problem-based learning approach to enhance students' ability to apply the knowledge and meet professional demands.

  A detailed studio scenario is listed in section 7.4.4.

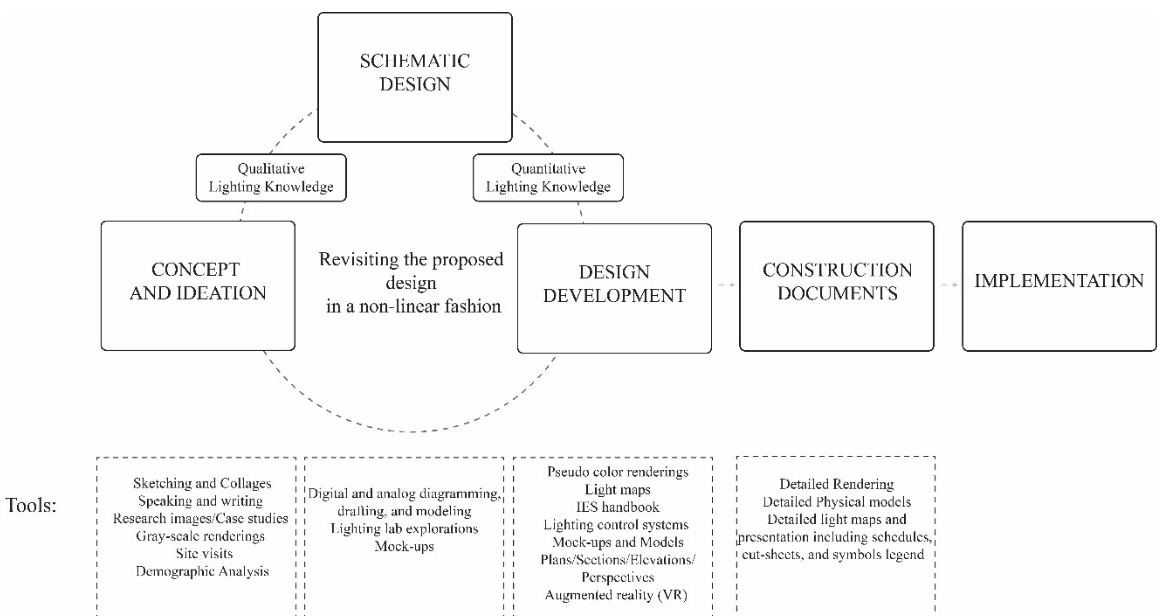


Figure 9-4. Lighting Design Cognitive Tools for Different Phases of the Design Process

9.4.4- General Suggestions for Educators:

- Use different knowledge delivery methods in the theoretical lighting classes and studios. Figure 9-3 lists the different methods that can be used.

- Establish communication with other educators to introduce lighting design in a sequence in different classes in the curriculum.
- Attend conferences, symposiums, exhibitions, and light fairs, and read updated lighting research to develop comprehensive and up to date lighting design knowledge.
- Follow the principles provided by Powers (2001) to apply the constructivist pedagogical model and help students understand lighting design knowledge (section 7.4.3.6).
- Follow Dewey's (1962) steps of applying the experiential pedagogical theory in design education (see section 4.1.1).
- Use different cognitive questions to guide students' design thinking and decision-making.

9.4.5- Recommended Features for an Educational Digital Light Simulation Tool

- CAD or Revit compatibility
- Simple rendering controls
- Accurate photometric data and results
- Easy user interface
- Flexibility
- Variety in image outputs
- Speed and simplicity in calculations
- Stability
- High processing power
- In-program library

- Simple language
- Updated technology
- Easy to learn
- Professional (used by design offices)

9.5- The Research Consensus

The final step of this research was to develop consensus among experts. The researcher used feedback from her committee members and experts using a Delphi method to identify weaknesses in the preliminary framework, develop it, and rate its implementation possibilities.

9.5.1- The Delphi Method

Two rounds of the Delphi method were performed. In the first round, the researcher asked eight lighting design professionals to identify weaknesses and strengths with supporting suggestions to enhance it. The experts added to the framework some new lighting design topics, teaching methods, and cognitive tools (both analog and digital), and enhanced the sequence of lighting design knowledge. They also suggested a new research category for lighting-related cognitive tools. The researcher summarized the feedback and the suggestions from round one into categories and themes (section 8.2.2.3). She then updated the framework and sent the recommendation summary with the updated diagrams and closed-ended questions to rate the framework's action plan and achieve consensus (sections 8.2.3.3 and 8.2.3.1).

The second round had 10 closed-ended questions, responses to which were analyzed using statistical methods: average percentage of majority opinions (AMPO), central tendencies (mean, median, mode), and levels of dispersions (IQR, SD; see section

8.2.3.2). The AMPO cut-off rate for this study was 69.7%. The research AMPO was 83.3%, which is higher than 69.7%; hence, consensus was reached. The results of the statistical analysis also indicate that consensus was achieved; 99.8% of the ratings were higher than 1.64 SD, the mode was higher than the mean, and the IQR was less than 2. Table 8-7 presents the detailed analysis for all the questions.

In sum, the Delphi method helped the researcher enhance the proposed framework and reach consensus among experts for the implementation of the action plan.

9-6- The Limitations and the Challenges

It is important to note that human interviewers have "fluctuating adaptation levels and response thresholds" (Webb, Campbell, Schwartz, & Sechrest, 2000, p. 22), which is an inevitable limitation of the study. Another limitation is that different lighting design programs have different instructors, majors, school systems, and locations. These differences are not controllable and may affect the research results. In addition, the researcher was not able to interview all the target educators due to their busy schedules.

9.6.1- Challenges of Incorporating Lighting Design Knowledge and Digital Tools

Many challenges limit the integration of more lighting design knowledge and digital light simulation tools in the architecture and interior architecture curricula.

9.6.1.1- Lighting Design Knowledge Challenges

The architecture program requirements and NAAB criteria leave little time for lighting design pedagogy at the Department of Architecture at Kuwait University. The lack of communication between lighting design educators also challenges the integration of lighting design knowledge. Participant A stated: "I don't think this will make them happy because this is an extra load. An extra effort that the lighting instructor will go to get involved in the design. That is like an extra course.” Another challenge is that the mandatory lighting design class is usually paired with acoustics, so there is no time to teach students lighting design knowledge in depth: “There is no time. You have only one month and a half to cover the entire lighting principles, so there is no time to try.”

The challenges in the Interior Architecture department, in contrast, include a shortage of faculty members who are specialized in lighting design and the absence of a lighting lab as Participant B, D, and E explained, respectively: “No faculty member specialized in lighting,” “It’s only a matter of having some faculties and professionals that are specialized,” and “Limitation of lighting labs.”

Participant D asserted that the Interior Architecture or Architecture degrees are not meant to focus on lighting unless they are labeled as a graduate lighting design degree or if the student also pursues a minor in lighting design: “because again, this is not a lighting design program per se. It’s an Interior Architecture program and the same case with Architecture.”

The experts in the Delphi method also mentioned some challenge because some of them believe that interior design students do not need to learn a lot about light calculations and daylight. Expert 6 said,

> Teaching AGi/calculations or ElumTools in an Interior Design or Architecture program can cause designers to fixate on quantitative aspects of lighting when their role is to consider the qualitative, and illuminance levels are typically confirmed by the electrical engineer or lighting designer.

Expert 2 recommends a balance of 40% daylighting and 60% architectural or electrical lighting. In addition, Expert 5 agreed with Participant D in that the framework may suit lighting design-focused degrees:

> A major concern is that the framework suits lighting-focused degrees or a degree with a lighting design minor … A big challenge is to determine what core content can be extracted from the research and effectively applied to architecture and interior design courses as a complement to existing disciplinary content.

In sum, educators' beliefs, a lack of specialized faculty, degree requirements, time constraints, lack of communication between educators, and lack of lighting design facilities limit the integration of more lighting design knowledge in the architecture and interior architecture curricula.

9.6.1.2. Digital Light Simulation Tools Challenges

The faculty members' beliefs and attitudes toward digital tools challenge the integration of digital light simulation tools in the Architecture and Interior Architecture curricula at Kuwait University. Some educators focus on manual tools due to their past training. Participant B does not teach his/her students digital light simulation tools because he/she does not know how to use them. Participant D is not familiar with them either, due to his/her past education and training, "because of the specialty and it wasn't offered through my education." Other educators do not keep up to date with developing technologies and accordingly do not encourage their students to use digital tools, as Participant D implied: "I'm not highly updated to how advanced the lighting simulation softwares are."

Some educators encourage the use of different digital design tools rather than lighting simulation tools specifically. Participant C indicated that light can be presented digitally in practice using 3dsMax, Photoshop, and AutoCAD rather than using a digital lighting simulation tool. Participant D also explained that educators focus on digital drafting and visualization with some daylight analysis rather than detailed lighting analysis:

> The computer courses are focusing on equipping students with drafting skills … so they focus on how to build the project and how to visualize it, the accuracy of the materials. They add lighting but, definitely the one I've seen related to daylighting is again the analysis throughout the year, the shadow analysis.

Other challenges in the Architecture and Interior Architecture curricula are time constraints, lack of facilities, limited courses, program requirements, and shortage of faculty. Participant B said:

> We don't have time ... When I allow them to explore softwares, they start playing and lose focus on the actual stages of design. … We were short on faculty, so sometimes the course doesn't happen to appear only for once a year, or once every other year.

In sum, the challenges of integrating digital light simulation tools are a lack of specialized faculty and lighting labs, educators' past training and education, educators' beliefs, and time constraints. The NVivo software word count particularly emphasized time constraint challenges.

9.7- Summary and Conclusion

The research presented a new pedagogical framework for lighting design knowledge and cognitive tools. The researcher met the target goals by using different data collection and analysis procedures. She first interpreted the relevant literature to create a logical argument and a theoretical structure for the framework. She also interviewed lighting design educators from Kuwait and analyzed lighting design documents to understand the current status of lighting design education at Kuwait University and establish the As-Is model. After that, she analyzed lighting design documents and interviewed lighting design educators from developed lighting design programs in the United States to establish the To-Be model. She transferred knowledge from the To-Be model to the As-Is model to create a preliminary framework. Lastly, she presented the preliminary framework to lighting design experts to develop it and rate its action plan using a Delphi method. The Delphi method reached consensus that the framework encourages students to use lighting as a concept generator from the ideation phase, enhances students' understanding of lighting design, and provides cognitive tools to aid their decision-making process.

Research Contributions

The research contributes to the body of knowledge in the following ways:

- The framework enhances lighting design knowledge sequence and delivery methods within the existing architecture and interior architecture curricula at Kuwait University to improve students' understanding and application of lighting design in their projects and return their contributions to the design world professionally (section 9.4.1.1).

- The framework proposes ways to integrate light principles, qualitative and quantitative lighting data, and light-related cognitive tools in an effective sequence within existing design curricula at Kuwait University.
- The study provides educators with new methods and tools to improve their lighting design delivery methods, lighting knowledge, and communication with one another to better integrate lighting design and the cognitive tools in design curricula (section 9.4.4).
- Currently, architecture and interior architecture graduates struggle to apply lighting design knowledge in their professional projects due to the previous educational approach. The proposed framework prepares students for their future careers by integrating lighting design knowledge in a sequence within their existing classes or through additional electives to improve its applications in their future careers.
- Lighting design has a great impact on human health, mood, feelings, and behavior in spaces. The study highlights this importance and reminds students of the vital role of lighting design in their projects and the built environment (section 9.4.2 presents an example of a light poetics course).
- The framework highlights the importance of different lighting design decision-making tools, as well as analog, digital, and research tools, to help students grow as self-learners and meet their design goals (Figures 8-16, 8-17, and 9-4).
- The study showcases the strengths and weaknesses of digital light simulation tools and their role in the design process to help students select the best tool to

meet their design objectives, make lighting design analysis and calculation easier, and support their design thinking and decision making.

- The research provides features of educational digital light simulation tools to help software developers meet future educational needs (section 9.4.5).
- Generally, the guidelines and tools highlighted in the framework can be implemented in different design curricula to enhance lighting design education, its knowledge acquisition, and its application in students' projects and careers, which in return enhance indoor air quality, human experiences in spaces, human health and comfort, and sustainability.
- The framework addresses different lighting knowledge domains with an opportunity to extend it beyond architecture and interior design education. The foundational and intermediate knowledge domains (sections 4.4.3.4.1 and 4.4.3.4.2) are essential for both architecture and interior design studies. Additionally, the advanced and elective knowledge domains (sections 4.4.3.4.3, and 4.4.3.4.4) propose elective knowledge that is suitable for students who wish to expand their lighting design knowledge or pursue other lighting-focused degrees.
- The experts' feedback from the Delphi method emphasizes the framework's contribution to the body of knowledge. Expert 8 said, "I think the framework came up really comprehensive and good standing." Expert 5 stated:

> First and foremost, your research is quite impressive. Congratulations. You've outlined content very clearly and comprehensively. I think your work could be very useful to many design academics interested in

> structuring lighting design education. I certainly found it to be a very useful reference and, quite frankly, learned a lot myself on how content may be more clearly delivered and structured across a curriculum - your organization and structural outline lays out a very understandable and logical sequence of steps. Well done.

9.8- Suggested Areas for Future Studies

Design education, lighting knowledge, and lighting technologies are constantly developing and being updated. Some potential areas for future studies include:

- Testing the effectiveness of the studio environment and the principles presented in the study by measuring students' performance in the proposed studio narrative (section 7.4.4)
- Evaluating the teaching methods and the student assessment tools mentioned in the framework and the potential of each within an educational context.
- Developing an educational digital light simulation tool by incorporating the recommended features mentioned in section 9.4.5.
- Proposing a new curriculum for a graduate lighting design degree.

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Appendix

Appendix A: Interview Questions

Kuwait Questions:

- Demographic Questions

1- How would you describe the overarching pedagogical philosophy that shapes design education at your department at Kuwait University?
2- Can you tell me about the key educational intentions and outcomes of each design year/level?
3- Can you describe when light (both electrical and natural) is currently introduced as a design subject in your design education structure/curricula?
4- How do you think the design pedagogical philosophy supports lighting design education at Kuwait University?
5- How do you think is the current sequence of light design knowledge delivery methods supports the key educational intentions of each design year?
6- Can you describe the strengths and weaknesses of current lighting design education at Kuwait University?
7- Can you describe the foundational knowledge that students need to know about lighting design before they graduate?
8- When, if at all, do you think students currently think about lighting design (both electrical and natural) in the design process?
9- Tell me about the lighting teaching methods that you currently use to deliver lighting design knowledge?
10- What do you think about incorporating digital lighting simulation and analysis tools in lighting design education?
11- Tell me about your thoughts on the positive implications of integrating digital lighting simulation tools in lighting design pedagogy?
12- Tell me about your thoughts on the negative implications of integrating digital lighting simulation tools in lighting design pedagogy?
13- Can you describe the prior theoretical knowledge that students need to know before using a digital light simulation tool?
14- How do you think digital light simulation tools relate to the key educational intentions of each design year?
15- How do you think digital light simulation tools relate to learning foundational lighting design knowledge?
16- Where do you see digital lighting design simulation and analysis tools in the future?

17- If you were to design a digital educational lighting simulation software what features would you focus on or add?
18- How would you refine the existing lighting design educational approach and curricula structure for the future?
19- Do you have any additional comments on lighting design pedagogy?

The United States Questions:

- Demographic Questions

1- How would you describe the overarching pedagogical philosophy that shapes design education at your department at the university?
2- Can you tell me about the key educational intentions and outcomes of each design year/level?
3- Can you describe when light (both electrical and natural) is currently introduced as a design subject in your education structure/curricula?
4- How do you think the design pedagogical philosophy supports lighting design education at your university?
5- How do you think is the current sequence of light design knowledge delivery methods supports the key educational intentions of each design year?
6- Can you describe the strengths and weaknesses of the current lighting design education at your university?
7- Can you describe the foundational knowledge that students need to know about lighting design before they graduate?
8- Tell me about the unique features of your university's lighting design program?
9- When, if at all, do you think students currently think about lighting design (both electrical and natural) in the design process?
10- Tell me about the lighting teaching methods that you currently use to deliver lighting design knowledge?
11- What do you think about incorporating digital lighting design simulation and analysis tools in lighting design education?
12- Tell me about your thoughts on the positive implications of integrating digital lighting simulation tools in lighting design pedagogy?
13- Tell me about your thoughts on the negative implications of integrating digital lighting simulation tools in lighting design pedagogy?
14- Can you describe the prior theoretical knowledge that students need to know before using a digital light simulation tool?
15- How do you think digital light simulation tools relate to the key educational intentions of each design year?

16- How do you think digital light simulation tools relate to learning foundational lighting design knowledge?

17- Where do you see digital lighting design simulation and analysis tools in the future?

18- If you were to design a digital educational lighting simulation software what features would you focus on or add?

19- How would you refine the existing lighting design educational approach and curricula structure for the future?

20- Based on your experience, what advice would you give to other lighting design educators?

21- Do you have any additional comments on lighting design pedagogy?

Appendix B: Data Analysis Examples

The United States Interviews Analysis Examples

The United States Interviews Analysis Examples

Example	Excerpt	Code	Category	Theme	Memo
1	"A restaurant as our first project and I think a restaurant is great because it's got a mix of specific task goals like how do you deal with a kitchen or bathroom as well as aesthetic kind of flexibility ... and it usually has some daylight integration".	A restaurant is a good lighting studio project.	Lighting Design Studio	Future Recommendations to enhance lighting design pedagogy.	A restaurant makes a good lighting studio project because it integrates different lighting tasks like a bathroom, a dining and a kitchen along with some daylight integrations.
2	"It's a real balance of theoretical and pragmatic and then layered on top of that. Definitely experiential learning is huge here".	Experiential learning pedagogical philosophy	A student-centered pedagogical philosophy	USA Design Pedagogical Philosophy	The Appalachian State University focus on both theory and experiences.
3	"We have our lighting laboratory. We were very fortunate of receiving a grant from the IES, a hefty amount of money, to be able to update our facilities. We are enjoying right now things like a new gonio, a photometer, lighting sphere".	A lighting lab and lighting analysis devices	Unique facilities	Strengths of lighting design pedagogy in the US.	The University of Colorado has a unique lighting lab with unique tools such as a light gonio, photometer, and sphere.
4	"Math is the only required prerequisite, but the way the tracks are set up, most of them have already been doing reflective ceiling plans and picking lights for at least two classes before they take lighting and they've had color theory and they've had sketching and rendering and representation class"	Knowledge needed before lighting design	Foundational lighting design knowledge	Lighting design subjects	Students take math, color theory, and design representation tools like sketching, drafting, and rendering before they are introduced to lighting design.
5	"I don't want to do hand calculations. I want to do this fast and easy. I want to know that I'm doing something right ... And now with all the codes and regulations, having to have so many foot-candles, having to meet Watts per square foot and all that kind of thing".	Ease of doing light calculations and meeting codes and regulations	Positive implications of digital light simulation tools	Digital light simulation tools	Digital light simulation tools help designers meet codes and regulation and ease the lighting calculation process.

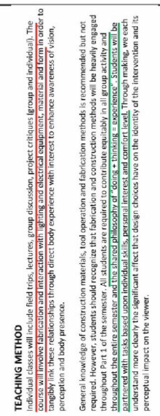
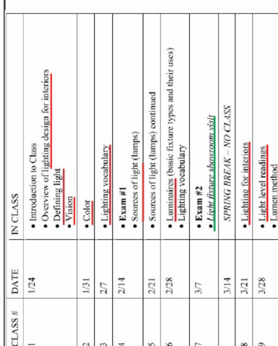
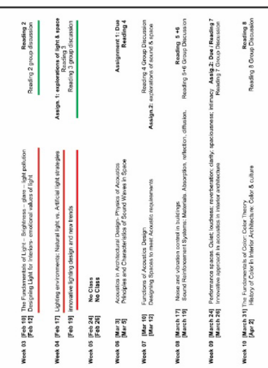
Kuwait University Interviews Analysis Examples

Kuwait University Interviews Analysis Examples

Example	Excerpt	Code	Category	Theme	Memo
1	"The problem is, we at the college, and at the department of architecture, we follow NAAB. NAAB have many requirements. They have many criteria. There are too many things we would love to put in our program, but there is no time".	NAAB requirements leave little time for lighting design knowldge	Challenges associated with lighting design knowledge at Kuwait University	Challenges of incorporating lighting design knowledge and simulation tools at Kuwait University	Challenges of incorporating lighting knowledge: -The program requirements imposed by NAAB and the department administrative rules leave little time for lighting design knowledge at the department of architecture.
2	"I do use videos and bring some samples for the students to see".	Videos and lighting samples are some of the lighting teaching tools	Kuwait University Lighting Design Teaching Tools	Kuwait University Lighting Design Teaching Methods	One of the participants use videos and light samples to deliver and demonstrate lighting design knowledge at the Interior Architecture Department
3	"We don't follow the students' needs or wishes. No, of course not. The students should listen to us, they should follow the curriculum. We do it, again, in accordance with the approval of NAAB".	Teachers follow NAAB requirements rather than students' needs when setting the architecture curriculum.	Teacher Centered Pedagogical Philosophy	Kuwait University Design Pedagogical Philosophy	The Architecture department follows a teacher-centered Pedagogical approach where educators dictate what students learn based on NAAB criteria.
4	"In our society, light represents faith and God. The first thing came to my mind is when we explored light in mosques or schools ... It has a positive psychological impact, like tying religious aspects such as method of fasting in Ramadan and lighting and how fasting happens between sunrise and sunset".	Mosques are built with lighting design considerations because religious acts are tied to light. Light has a good impact on Muslims.	Religious symbolism of light	Kuwait Lighting Cultural Context and Topics	Religious practices are tied to light like fasting in Ramadan is tied to the sunrise and sunset. Also, mosques designs, which are religious places for praying, always have a light component or aspect. light in Islam has a positive impact on Muslims' psychology (represents faith)
5	"VELUX, and DIALux. These two softwares, from the same company. I think one is only for day lighting, and the other one is for day lighting and electrical lighting".	VELUX and DIALux are digital light simulation tools that are used at Kuwait University.	Digital Light simulation tools that educators use at Kuwait University	Educators' perception of digital light simulation tools	An educator from the Architecture department uses and teaches his/her students VELUX and DIALux softwares for digital lighting analysis.

Documents Analysis Examples

Documents Analysis Examples

Example	Document Sample	Code	Category	Theme	Memo
1		Field trips, lectures, group discussion, project critiques, samples, and fabrication opportunities are methods used to deliver lighting design knowledge.	Teaching Methods used to deliver lighting design knowledge in developed programs in the States.	Lighting Design Teaching Methods In USA.	Some of the methods used to deliver lighting design knowledge in Parsons are: Field trips, lectures, group discussion, project critiques, samples, and physical fabrications.
		Students are involved in experiential learning and learning by doing. The class accounts for students interests and skills.	Experiential learning and student-centered pedagogical philosophy	USA overarching pedagogical philosophy	Parsons follow a student-centered pedagogical philosophy where students skills and interests are taken into consideration and they learn through theory and exercises.
2		Light definition, perception, color, vocabulary, sources, levels, calculation, light uses, and design approaches are important l ighting design topics.	Lighting design foundational knowledge.	Lighting design subjects	Some of the foundational lighting design topics at NYSID are: light definition, perception, color, vocabulary, sources, levels, calculation, light uses, and design approaches .
		Field trips are used to deliver lighting design knowledge,	Teaching Methods used to deliver lighting design knowledge in developed programs in the States	Lighting Design Teaching Methods In USA.	The lighting instructor at NYSID takes his/her students to lighting fixtures showrooms as a method to deliver lighting design knowledge.
3		Readings and group discussions are some of the methods used to deliver lighting design knowledge.	Kuwait University lighting design teaching tools	Kuwait University lighting design teaching methods	An educator at the Interior department at KU uses readings and group discussion to deliver lighting design knowledge.
		Light fundamentals, lighting design, light qualitative aspects, light strategies, sources, and lighting design trends are important lighting topics.	Kuwait University lighting design foundational knowledge.	Kuwait University lighting design topics	Some of the foundational lighting design topics at KU are: light fundamentals (glare, brightness, light pollution), light design strategies, light effects on human emotions, light strategies, light sources, and lighting design trends.

Documents Analysis Examples

Interviewees' Answers on Sorting Lighting Design Topics

Lighting Topics Ranking (B) Beginners,(I) Intermediate, (A) Advanced, (E) Elective	Participant A	Participant B	Participant C	Participant D	Participant E
Light Definition and Purpose (what is light + importance of light)	B	B	B	B	B
Physics of Light + Light Behavior with Surfaces	B	B	B	I	B
Light Perception (how humans perceive light)	B	B/I	B	B	B
Daylight Integration and Influence (Daylight Strategies)	B	I	A	B/I	B/I
Layers of Lighting Design (General, Task, Accent, Decorative Lighting)	B	B/I	B	B	B
Lighting Design Tactics (Example: How to Create Certain Moods)	B	I	I	I	I
Electrical Light Sources	I	I	B	B	B/I
Light Color	B	B	B	B	B
Light Distribution, Texture, and Optical Control	I	B/I	B	I	I
Brightness and Glare	B	B	B	B	B
Light Measurements and Calculations	I	I	I	A	I
Luminaires Types and Operation	I	I	E	I/A	I
Energy and the Environment	A	A	A/I	B	A
Human Factors (Light Effects on Human Health, Vision, Emotions, Perception, and Behavior)	A	I	B/I	I	I
Light Applications and Case Studies (Activity Needs) + Lighting Critical Issues	A	A	A	A	A
Light to Enhance Architecture and Interior Spaces (Poetry of Light)	I	A	I	I	I
Lighting Design Process, tools, and Deliverables	I	A	I	A	I/A
History of Light	B	B	E	B/I	B
General Knowledge about Electricity	B	B/I	I	B	B
Color Theory	I	B/E	I	I	I
Outdoor Lighting	A	I	A	I	I/A
Safety and Security (Wayfinding and Communication)	I	A	I/A	I	I
Light Art and inspirational mediums (Example: Installations and photography)	I	E	I	B	I
Lighting Design Profession (professional Practice)	A	E	A	I	A
Design Thinking (as basis before introducing lighting design)	A	B	E	B	B
Fixture Design	E	A/E	E	I/A	E
Lighting Design Digital Computation and technologies (Digital Rendering, Representation, and Analysis)	A	I	I/A	A	A
Design Studio Focused on Lighting Design	E	I	A	A	A
Theatrical Lighting	E	E	E	A	E
Light Theory and Philosophy (Placemaking, Critical Regionalism, Steven Hall, James Turrell, Pallasmaa)	A	B/I	I	A	I/A

Lighting Topics Ranking (B) Beginners,(I) Intermediate, (A) Advanced, (E) Elective	Interviewee A	Interviewee B	IntervieweeC	Interviewee D	Interviewee E	Interviewee F
Light Definition and Purpose (what is light + importance of light)	B	B		B	B	B
Physics of Light + Light Behavior with Surfaces	B	I		I	B/I	B
Light Perception (how humans perceive light)	B	B		B	B/I	B
Daylight Integration and Influence (Daylight Strategies)	I	B		A	A/E	I
Layers of Lighting Design (General, Task, Accent, Decorative Lighting)	I	B		I	B	B
Lighting Design Tactics (Example: How to Create Certain Moods)	I	B		B	B/I	I
Electrical Light Sources	B	B		B/I	I	B
Light Color	B	B		B	I	B
Light Distribution, Texture, and Optical Control	B	B		B	A	B
Brightness and Glare	B	B		B	B/I	I
Light Measurements and Calculations	B/I	I		I	B/I/A	A
Luminaires Types and Operation	B	B		B	B/I	B
Energy and the Environment	I/A	B		A	I	B
Human Factors (Light Effects on Human Health, Vision, Emotions, Perception, and Behavior)	B	I		A	I	I
Light Applications and Case Studies (Activity Needs) + Lighting Critical Issues	I	I		A	A/E	I
Light to Enhance Architecture and Interior Spaces (Poetry of Light)	I/A	I		B	E	I
Lighting Design Process, tools, and Deliverables	B/I	I		B/I	I/A	I
History of Light	I/A	B		B	E	I
General Knowledge about Electricity	B	B		B	B	A
Color Theory	I	B		B/I	I	B
Outdoor Lighting	I/A	E		A	E	I
Safety and Security (Wayfinding and Communication)	I/A	I		A	I	I
Light Art and inspirational mediums (Example: Installations and photography)	B/I	E		I	E	A
Lighting Design Profession (professional Practice)	A	B		B/I/A	I	B
Design Thinking (as basis before introducing lighting design)	B	B		B	I	B
Fixture Design	I/A	A/E		A	A	A
Lighting Design Digital Computation and technologies (Digital Rendering, Representation, and Analysis)	B	A		A	I/A	A
Design Studio Focused on Lighting Design	B	I		I/A	A	B/I/A
Theatrical Lighting	A	A/E		B	A	A
Light Theory and Philosophy (Placemaking, Critical Regionalism, Steven Hall, James Turrell, Pallasmaa)	B	I		I	E	A

Appendix C: The Delphi Method

The Delphi Method Round Two Survey Answers

ID	Q1a	Q1b	Q1c	Q1d	Q1e	Q1f	Q2a	Q2b	Q2c	Q2d	Q3	Q4a	Q4a	Q4a	Q4a	Q5a	Q5b	Q5c	Q5d	Q5e	Q6	Q7	Q8a	Q8b	Q8c	Q8d	Q8e	Q8f	Q9	Q10
Expert 1	4	3	3	4	3	3	3	3	3	4	3	3	4	3	3	3	3	2	3	3	3	3	3	4	3	3	4	3	4	2
Expert 2	3	3	3	3	2	3	3	3	2	3	3	3	2	3	3	3	3	2	2	3	3	2	2	3	3	3	2	3	3	2
Expert 3	4	4	4	4	4	4	2	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	3
Expert 4	4	3	4	2	3	3	3	2	3	3	3	4	4	3	2	3	3	3	2	4	3	3	3	3	2	2	3	2	3	2
Expert 5	4	3	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	3	3
Expert 6	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4
Expert 8	4	3	4	2	3	3	3	2	3	3	3	4	4	3	2	3	3	3	2	4	3	3	3	3	2	2	3	2	3	2