NATURAL LIGHTING AND SPATIAL COGNITION IN CAMPUS WAYFINDING: A SYSTEMATIC REVIEW

YARA MURAD SHERO SULAIMAN

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ABSTRACT

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INTERIOR ARCHITECTURE MASTER'S THESIS

Supervisor: Asst. Prof. Dr. Güler Ufuk DEMİRBAŞ
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Often overlooked, wayfinding on university campuses is essential for defining spatial experience and mobility, especially thoroughfares for first-time students, international tourists, and populations of differing cognitive and physical abilities. Signage, color-coding, and architectural layouts are conventional tools for orienting someone in an unfamiliar place; however the cognitive benefits of natural lighting are often disregarded in architectural education. Light is usually viewed as an aesthetic feature of architecture or considered a functional means of seeing, and the exploration of light as a cognitive tool for pathfinding and wayfinding is seldom studied.

This thesis conducts a systematic literature review to theorize how natural lighting impacts spatial cognition in campus wayfinding. In the systematic review, peer-reviewed academic research from relevant domains of architecture, psychology, and environmental design was reviewed using the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines, which provide a structured process for identifying, selecting, and synthesizing knowledge. This study identified three main themes: (1) natural lighting improves visibility of space, (2) natural lighting reduces space's perceived complexity, and (3) mental maps as a function of built-environmental factors, where natural lighting interacts with

architecture as architectural elements, such as corridors, atria, and visual anchors (Gibson 1979; Boyce et al. 2003).

Furthermore, environmental conditions such as light and personal context, including the age of individuals, cultural background, and sensitivity to visual stimuli, interact with how users perceive and navigate through space. The insights gained about natural lighting quality provide actionable design recommendations, including maximizing natural lighting orientation, minimizing glare, and leveraging natural lighting to create spatial cues. The systematic review revealed several gaps in the literature, including the lack of interdisciplinary studies that integrate architecture and cognitive science.

In summary, the systematic literature review provides a comprehensive synthesis of the current state of knowledge, actively changing the cognitive perceptions of architecture, from a mere background in design theory to its impact on spatial cognition. The implications of this research will inform the design of more intuitive and inclusive campuses, while also contributing to prospective interdisciplinary research that emphasizes human-centered spatial navigation.

Keywords: Wayfinding, Natural lighting, Campus, Systematic review, Spatial Cognition.

ÖZET

KAMPÜS YOL BULMADA DOĞAL AYDINLATMA VE MEKANSAL BİLİŞ: SİSTEMATİK BİR İNCELEME

SULAIMAN, YARA MURAD SHERO
İÇ MİMARLIK YÜKSEK LİSANS TEZİ

Danışman: Dr. Öğr. Üyesi Güler Ufuk DEMİRBAŞ
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Üniversite kampüslerindeki genellikle göz ardı edilen yön bulma, özellikle ilk defa gelen öğrenciler, uluslararası ziyaretçiler ve farklı bilişsel ya da fiziksel yeterliliklere sahip bireyler için mekânsal deneyim ve hareketliliği tanımlamada kritik bir öneme sahiptir. Yönlendirme tabelaları, renk kodları ve mimari düzenlemeler yabancı bir mekânda bireylerin yönlendirilmesinde kullanılan geleneksel araçlardır; ancak doğal aydınlatmanın bilişsel faydaları mimarlık eğitiminde çoğunlukla göz ardı edilmektedir. Işık genellikle yalnızca mimarinin estetik bir unsuru ya da görme işlevini sağlayan pratik bir araç olarak değerlendirilmekte, yön bulma ve yol bulma süreçlerinde bilişsel bir araç olarak kullanımı ise nadiren araştırılmaktadır.

Bu tez, doğal aydınlatmanın kampüslerde mekânsal biliş üzerindeki etkilerini kuramsallaştırmak amacıyla sistematik bir literatür taraması gerçekleştirmektedir. Sistematik incelemede, mimarlık, psikoloji ve çevre tasarımı gibi alanlardan hakemli akademik araştırmalar gözden geçirilmiş ve bilgilerin belirlenmesi, seçilmesi ve sentezlenmesi için yapılandırılmış bir süreç sağlayan PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) kılavuzları kullanılmıştır. Çalışmada üç temel tema belirlenmiştir: (1) doğal aydınlatma mekânın görünürlüğünü artırır, (2) doğal aydınlatma mekânın algılanan karmaşıklığını azaltır ve (3) mekânsal bilişsel haritalar, koridorlar, atriumlar ve görsel odak noktaları gibi mimari unsurlar aracılığıyla doğal aydınlatmanın yapılı çevre ile etkileşiminin bir fonksiyonu olarak ortaya çıkar (Gibson 1979; Boyce ve diğerleri 2003).

Ayrıca, ışık gibi çevresel koşullar ve bireylerin yaşı, kültürel arka planı ve görsel uyaranlara duyarlılığı gibi kişisel bağlamlar, kullanıcıların mekânı algılama ve içinde yön bulma biçimleriyle etkileşim içerisindedir. Doğal aydınlatma kalitesi üzerine elde edilen bulgular, doğal ışığın yönelimde en üst düzeyde kullanılması, parlama etkisinin en aza indirilmesi ve mekânsal ipuçlarının oluşturulmasında doğal aydınlatmadan yararlanılması gibi uygulanabilir tasarım önerileri sunmaktadır. Sistematik inceleme, mimarlık ile bilişsel bilimleri bütünleştiren disiplinler arası çalışmaların eksikliği de dahil olmak üzere literatürde çeşitli boşlukları ortaya koymuştur.

Sonuç olarak, bu sistematik literatür taraması mevcut bilgi birikiminin kapsamlı bir sentezini sunmakta ve mimarlığın bilişsel algılarını yalnızca tasarım kuramında arka plan unsuru olmaktan çıkararak, mekânsal biliş üzerindeki etkisini ortaya koyarak aktif bir şekilde değiştirmektedir. Bu araştırmanın sonuçları, daha sezgisel ve kapsayıcı kampüslerin tasarımına katkı sağlayacak ve insan merkezli mekânsal dolaşımı vurgulayan gelecekteki disiplinler arası araştırmalara yön verecektir.

Anahtar Kelimeler: Yön Bulma, Doğal Aydınlatma, Kampüs, Sistematik İnceleme, Mekansal Biliş.

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CHAPTER I
INTRODUCTION

1.1 BACKGROUND AND CONTEXT

University campuses operate as vibrant, multi-user environments with a mix of architecture, spatial dimensions, and changing user motivations. Such environments are likely to include intricate networks of learning buildings, administrative spaces, outdoor spaces with courtyards, transition spaces, and circulation pathways that accommodate diverse users (e.g., students, faculty, staff, and international visitors, persons with cognitive or physical disabilities). A comprehensive understanding of navigating dynamic campuses is essential for effective campus operation, psychological health, and adequate perception (Marquardt 2011; Passini 1996).

In this case, wayfinding is the process of connecting two spaces—cognition and navigation (knowing where you are, selecting a path to a destination, and arriving at a location). This cognitive process of wayfinding relies on previous experience and environmental cues (e.g., landmarks, signage, spatial configuration) as well as cognitive functions (e.g., recall, perception, mental mapping). While past research has primarily focused on wayfinding through signage systems, color coding, and building configuration, recent studies have demonstrated that natural lighting is vital to wayfinding, yet remains under-appreciated (Huelat 2004; Christensen 2020).

In education, particularly architectural design education, light is addressed generically for aesthetic representation, sustainability measures, and thermal performance, while its impact on user behavior and cognitive navigation is rarely discussed. "Spatial cognition is the set of mental processes through which a person acquires, encodes, retains, and employs knowledge about their physical environment" (Wiener et al. 2009). Light, specifically daylight, can enhance cognition by increasing visibility, orienting attention to architectural objects, reinforcing a spatial hierarchy, or guiding natural movement (Gibson 1979; Boyce et al. 2003).

Furthermore, well-orchestrated daylight can support environmental legibility, a term referenced by Kevin Lynch (1960) to reflect how clearly a space communicates its organization and structure to its users. It has been argued, that daylight can define boundaries, emphasize circulation, and highlight landmarks, supporting the development of mental maps. Environmental legibility is essential in transitional spaces-, i.e., hallways, lobbies, and atriums, as these are where users often process information when making navigation decision (Zacharias 2006).

However, from the psychological and cognitive possibilities, natural light does not play an essential role in wayfinding in academia and campus design. It was observed that discussions around wayfinding rarely include lighting, which clearly affects user depth perception, spatial clarity, and emotional comfort (i.e., components of wayfinding).

This reflects similar conclusions from multiple architectural studies that articulate purposeful design centered on human users (Degen and Rose 2012; Al-Dulaimi 2022).

This disparity between perceiving lived experience and space planning represents a missed opportunity; designers inadvertently complicate a user's experience by not considering lighting as a cognitive form. This is significantly valuable for those struggling to negotiate a new environment. Thus, a focused area of inquiry at the intersection of natural light and spatial cognition is timely and warranted—especially on university campuses, where orientation, inclusion, and accessibility are essential to the mission of an educational institution.

Clarification of Terminology

In this thesis, three related terms are employed with meager definition to prevent caution. When used, sunlight refers only to the direct rays of the sun, which can be a source of glare or heat when penetrating enclosed interior spaces. Daylight includes both direct and diffuse natural light that you perceive indoor, affecting visibility, seeing and spatial orientation. Natural lighting is used in the architectural sense of design practices and building components (e.g. windows, skylights, atria) that intentionally utilize daylight to assist with environmental quality and user experience.

1.2 PROBLEM STATEMENT

In recent years, architectural research has increasingly recognized the importance of human-centered design, emphasizing user experience, diverse and inclusive environments, and psychological well-being in the built environment. Yet advances in research and adoption of this concept in practice have largely overlooked the role of natural lighting in supporting wayfinding and spatial cognition. Lighting has become a secondary design consideration, referring primarily to aesthetic, energy performance, or thermal comfort, and has yet to be considered a fundamental part of spatial orientation and cognitive mapping (Boyce et al. 2003; Ghamari and Amor, 2016).

This limited framing overlooks emerging interdisciplinary evidence suggesting that natural light can significantly influence users' spatial experience in various ways. The existing knowledge base from environmental psychology and neuroscience suggests that natural lighting has implications beyond visual perception, visual memory encoding, emotional regulation, and decision-making—all essential components of effective wayfinding (Vartanian et al. 2015; Küller 2002). For example, variation in lighting is instrumental for people to distinguish zones in space, perceive depth, and build mental maps—especially in complex public buildings with multiple destinations such as hospitals and transit hubs or even less complex locations like academic campuses (Marquardt and Schmieg 2009; Huelat 2004). However, very little of this cognitive dimension has been considered from an architectural design perspective or written about in campus planning policy.

In addition to these gaps, the available knowledge on lighting and navigation has been dispersed across silos of information, each discipline utilizing different research paradigms, terminologies, and measures of outcomes. Architectural studies may understand light through formal and spatial logic, while psychological studies on lighting may understand light though its implications on mental load, cognitive fatigue, or visual search behavior. This disconnection between common places of research in built environment studies has not produced cohesive design strategies that incorporate cognitive planning alongside spatial form. Even projects based on the cited seminal book by Lynch (1960) on the legibility of the environment by design strategies with lighting are rarely captured in terms of architectural design practice.

The engagement of students in learning environments is potentially problematic. As students acclimate to entering an unfamiliar spatial context, learning

institutions design their learning environment to ensure students can orient themselves immediately. Poorly designed lighting can affect orientation; exacerbate anxiety, and lower spatial confidence for students (Al-Azzawi 2021). Even with high-performance daylighting technologies and daylight simulation programs, designers continue to produce guidelines for cognitive support systems that prioritize natural light as ambient lighting, rather than intuitive and user-experience-positive solutions.

Also, previous literature reviews (e.g., Grant and Booth 2009; Snyder 2019) indicated that almost all of the studies are either:

- Limited to artificial light and not liable for using natural lighting sources.
- Look at lighting in isolation, which is not connected to user behavior.
- Lack of empirical evidence in actual campus environments.

A significant research and practice gap exists due to the absence of compiled, interdisciplinary knowledge on natural lighting and navigation. While there is still a lack of systematic knowledge on how natural lighting contributes to wayfinding, opportunities for more intuitive and inclusive campus design are constantly being missed. In light of this gap, this thesis aims to further explore it by undertaking a systematic review that collates information from architecture, cognitive science, and environmental behavior to inform a position statement and support evidence-informed design interventions.

1.3 RESEARCH QUESTIONS

To address the knowledge gap identified in the previous section, this thesis is guided by the following research questions:

- How does natural lighting affect spatial cognition within the context of campus wayfinding?

This question aims to investigate how natural lighting affects cognitive processes, including orientation, memory formation, spatial awareness, and environmental legibility, particularly in complex academic settings.

- What environmental and personal variables mediate the relationship between natural lighting and spatial navigation

This includes factors such as time of day, lighting intensity, architectural layout, user age, cultural background, and visual sensitivity, which may influence how individuals perceive and respond to light-based spatial cues.

- How can insights from interdisciplinary research be translated into architectural strategies that support intuitive and inclusive campus navigation?

This question bridges theory and practice by identifying actionable design principles incorporating natural lighting as a cognitive aid in spatial planning.

1.4 AIM AND OBJECTIVES

Aim

The main objective of the thesis is to perform a systematic literature review to observe how natural light can affect spatial cognition and support wayfinding in university campus contexts. The research aims to integrate fragmented knowledge from architecture, cognitive psychology, and environmental behavior to establish a more comprehensive, evidence-based understanding of natural lighting as a cognitive support system for spatial orientation. Therefore, the thesis will conduct a systematic literature review to identify conceptual linkages between theory and design practice, providing tools and formats to inform more intuitive and inclusive campus environments.

While natural day and night designs have been studied in terms of technical, aesthetic, or environmental performance, there has not yet been a dedicated study or exploration on the cognitive and behavioral implications of natural lighting—and especially in actual educational contexts. Therefore, this thesis does not approach natural lighting as a complementary environmental characteristic but as a strategic design feature to enhance user orientation, movement patterning, and emotional comfort in complex, layered architectural configurations.

In this way, the study considers interdisciplinarity as both a challenge and a benefit; marrying the ideas of architecture, cognitive psychology, and environmental behavior is a difficult challenge because there are so many concepts and methodological strategies to compromise, but this interdisciplinarity is also an added benefit for the scope of inquiry. By conceptualizing interdisciplinarity as an opportunity for synthesis rather than as fragmentation, the thesis seeks to produce a better and more consequent awareness of daylight as a cognitive design element.

Objective

To achieve this purpose, the study is designed to address the following goals:

- To review, gather, and discuss peer-reviewed literature from existing sources from disciplines about architecture, neuroscience, psychology, environmental design, and urban planning that study the role of natural light on spatial cognition and navigation behavior.
- To critically assess how natural lighting influences key cognitive processes, such as spatial awareness, memory, visual attention, and environmental legibility, in larger, multifunctional spaces, including university campuses, is essential.
- To examine the possible mediating role, based on some personal and contextual factors (age, culture, visual attention, familiarity with environment) as related to lighting and wayfinding performance.
- To assess methodological trends, theoretical perspectives, and empirical gaps identified in the selected body of literature while emphasizing limitations regarding scope, sampling, and cross-disciplinary research.
- To translate research knowledge into practice by developing interventions incorporating natural lighting into viable wayfinding solutions that will improve user experience, spatial clarity, and environmental inclusivity in campus planning and design.
- To promote future interdisciplinary research by developing a systematic and replicable synthesis that is useful for addressing architectural education, decision- making, and evidence-based design to support cognitive diversity and orientation accessibility.

1.5 RATIONALE FOR A SYSTEMATIC REVIEW

The reasoning behind performing a systematic literature review (SLR) in this research is methodological and conceptual. The relationship of natural light, spatial cognition, and wayfinding is currently situated across various fields of knowledge (i.e., architecture, psychology, environmental behavior, and cognitive science), so an integrative and methodologically rigorous method of organization is both necessary and warranted to integrate its fragmented knowledge into a coherent body of evidence.

Traditional narrative reviews often lead to subjective and unstandardized processes for identifying relevant studies and interpreting study results, whereas systematic reviews follow explicit and systematic protocols for searching, including and excluding studies, assessing the quality of studies, and synthesizing of study results (Petticrew & Roberts, 2006). This level of transparency and replicability leads to richer, less biased, and more evidence-informed understanding of complex topics. A systematic review approach is beneficial in interdisciplinary research contexts, such as architectural cognition, where researchers must balance confirming their own biases with being fair to relevant studies conducted in intersecting disciplines that contribute to the topic (Grant and Booth 2009; Snyder 2019).

In architectural design research, systematic reviews have been relatively few despite the growing complexity of spatial issues and increased demand for evidence-based design (EBD) practices. A systematic review will provide this thesis with empirical evidence concerning natural lighting and cognition, as well as a continued opportunity to develop methodological maturity in architectural scholarship. It demonstrates how architectural concerns, which may ultimately be analyzed as qualitative, subjective or experiential, can be understood in a rigorous, reliable and reproducible manner.

Notably, the focus of the inquiry, on how natural lighting impacts spatial cognition while navigating a campus, presents tensions for a methodology that allows for the description of flowing experiential behaviors by spatial practitioners who are negotiating performance as separate user experience, variable in environmental conditions and contextual behaviors. The systematic review framework will enable the review of research as both quantitative and qualitative, making it helpful in exploring the complex nature of the question. For example, experimental studies in cognitive psychology may measure response times or memory recall under different lighting conditions, whereas case studies in architecture may ascertain that the integration of natural lighting facilitates improved spatial legibility in educational buildings.

This mixed-evidence milieu illustrates the value of a mixed methods review approach, which incorporates both thematic (qualitative) synthesis methods and, where possible, statistical (quantitative) synthesis methods. Provided that a robust evidence base exists, this study may employ a meta-analysis using effect size or correlation measures to further investigate the relationship between lighting features

and cognitive performance. however as it stands now, based on the current evidentiary landscape, a narrative synthesis based on thematic patterns, conceptual categories, and methodological criticisms is expected to be the most prudent approach.

Moreover, a systematic review is uniquely aligned to the study design in that it declares an interdisciplinary purpose. Architectural research is seldom able to explore the invaluable insights of neuroscience or psychology, as scholars struggle with terminology, methods, or academic traditions, especially within one discipline or another. A systematic review helps connect some missing elements by providing a common point of reference, which demonstrates convergence in findings, and areas of theoretical overlap. Additionally, to highlight the methodological deficiencies. This can signal learning in a way that the review is not only advice on the common slave-space key performance indicators, but also facilitates interdisciplinary conversations about lighting as designers are not only thinking of lighting as a design component, but also as a cognitive tool.

In addition to the projective implications of the SLR approach, conducting an SLR also serves the growing trend of evidence-informed spatial policy at the global level; there is an increasing expectation for designers, planners and policy-makers to rationalize their work based on scientific inquiry. The SLR has implications for shaping practice in terms of providing evidence-based guidelines, and practitioner-based frameworks that recognize the cognitive and behavioral dimensions of spatial design, particularly in learning environments, such as university campuses.

Finally, the use of an SLR is significant to the academic and practical relevance of this thesis because it offers an avenue for replicability in future mapping. The overall detail of the methodology (search strategy, inclusion criteria, quality assessment tools and the synthesis methods) provides a clear process for future researchers to verify the findings, or use learnings from studies of different typologies (e.g., hospitals, museums or airports), in other geographies, or with different user groups (e.g., elderly, visually impaired or neurodivergent).

In the context of architectural design research, the decision to pursue a systematic review methodology was prompted by the increasing initiative of interdisciplinary discussions, but also needed to draw together fragmented evidence from environmental psychology, cognitive science, and spatial design. Campus navigation, under the umbrella of lighting in natural light, has been researched in a

dispersed and discipline- specific manner, so a more thorough synthesis was needed. Using this methodology will also help close the knowledge gap in a very real way and help guide future design interventions about the use of evidence and attention to human-centered spatial experiences.

1.6 SCOPE AND LIMITATIONS

This study is carefully limited by both methodological concerns, and content-related criteria that can inform relevant boundaries for the systematic review. The primary data included in this review are peer-reviewed academic studies published in English, with a focus on the interrelationship between natural lighting, spatial cognition, and wayfinding behavior, specifically within the context of universities or similar spatial environments (including campuses, learning centers, educational complexes).

As already mentioned, the core criteria for studies included in this review were:

- Studies investigating natural lighting have identified it as an environmental variable, employing either experimental or observational/case study methodologies.
- Studies that explore the behavior associated with wayfinding, or spatial cognition, including but not limited to: orientation, wayfinding efficiency, mental mapping, legibility, and clarity as perceived by user in relation to and/or in interaction with environmental contexts of built environments.
- Studies that used or collected data from built environments with a scale comparable to campus environments (i.e., multi-building, multi-functional, multi-user type environments).
- Studies that featured empirical data or made meaningful contributions to theory for consideration in light of how we understand human behaviors and interactions with environments in relation to light.

Exclusions of studies were if they:

- Did not present any findings or data based on natural light without reference to the light dynamic features of unnatural light.

- Investigated conveyance by vehicles in relation to navigation, outdoor orientation only, or interface cautioned or explored about an online interface disconnected from a physical built environment.
- Engaged or presented investigations of typologies that are not immersed in ways that related to education or campus typologies, or similarities found in hospitals, airports, retail, or any other transportation hubs, unless there was conceptual alignment with campus use cases.
- Contrasted their findings on lighting without linking/backing to spatial cognition outcomes and wayfinding experiences. The review is also limited in scope due to language accessibility; the authors used only English-language sources because of practical limitations in translation and consistency of interpretation. Nevertheless, the authors consult relevant Arabic language sources as appropriate, provided they fall within the boundaries of their inquiry.

While the main type of methodology for this study is a systematic narrative synthesis, with quantitative research there is the potential to include a meta-analytic component— e.g., pooled effect sizes, statistical correlations—if enough suitable quantitative studies exist. In particular, this would apply if the data sets included the same measurements (e.g., reaction times, navigation errors, confidence scores in two lighting conditions), in which case meta-analytic interpretation could be used as an additional analysis. Suffice it to say, and due to the interdisciplinary and primarily qualitative emphasis of architectural and environmental cognition research, this thesis primarily follows a thematic synthesis.

The review is cognizant of limitations related to:

- The variability of study designs may create limitations in synthesis across disciplines.
- The lack of quality measurement tools in both spatial cognition and lighting studies has lingered in architecture.
- The potential for publication bias, which may result in a scarcity of studies with non-significant findings in indexed journals.
- The architectural design stems from the specificity of its context, which may limit generalizations across cultural or climatic regions.

This review presents a structured critically synthesized review that can contribute to future research, education, and design interventions — especially those that seek to promote user-oriented spatial accessibility through daylight-oriented architectural strategies.

This narrow focus is neither intended to dismiss artificial lighting's role, but simply to focus on what can be argued as under-represented but powerful daylight in wayfinding. Future research could investigate the interaction of artificial and daylight in complex spatial environments.

1.7 THESIS STRUCTURE

The organization of this thesis follows a pattern of 8 interconnected chapters, each contributing to a complete understanding of the impact of natural lighting on spatial cognition and wayfinding on university campuses. The chapter organization represents the systematic review methodology and the reflective nature of the interdisciplinary research, allowing the values of theoretical depth, methodological detail, and practical application to coexist without separation.

- Chapter 1 - Introduction

Introduces the context for and identifies the problem statement, research questions, aim, and objectives for the study. Motivated using a systematic review methodology indicates the scope, and limitations of the research. Introduces the overall organization of the thesis.

- Chapter 2 - Theoretical Framework

Presents perspectives and the underlying theories that ground the research, including notions of spatial cognition, environmental perception, wayfinding behavior and psychological effects of natural lighting. It also mentions other related frameworks such as biophilic design, ecological legibility, and visual hierarchy. It examines interdisciplinary elements from architecture, cognitive psychology, and environmental behavior studies.

- Chapter 3 - Methodology

Describes study methodology adapting a systematic review process and procedures in keeping with PRISMA. Introduces the search strategy, the inclusion and exclusion criteria, quality assessments, and synthesis (thematic and/or if quantitative - statistical) procedures. The chapter examines the ethics and limitations associated with the selected methodological approach.

- Chapter 4 - Results

Presents a summary of the results from the main findings in the selected studies into themes. Thematically, subsections summarize the study's characteristics (i.e. sample, location, and design), as well as the main findings on natural lighting outcomes, spatial cognition, and wayfinding results. Tables, diagrams, and other visual synthesis tools have been included to summarize the dimensions of the patterns and trends, in the literature being examined.

- Chapter 5 - Discussion

Illuminates findings acknowledging the theories introduced in the second chapter of the thesis. The discussion of findings highlights interdisciplinary perspectives, assesses campus design questions, and identifies areas that require further research. It also offers contextual cross-sections and discusses possible variations of findings across regions, user groups and typological design patterns.

- Chapter 6 - Conclusion

Summarizes the main contributions of the study, the theoretical implications, and the practical significance. It also revisits the limitations, providing tangible recommendations for future studies, particularly those that aim to integrate the study into practical design and advances in cognitive science.

- Chapter 7 - References

Identifies in APA style a complete record of each referenced academic source throughout the thesis. Any references in Arabic language translations by the author will be identified.

- Chapter 8 - Appendices

To provide supplementary material including the PRISMA diagram, data extraction tables, quality assessment materials and the search strategy logs.

CHAPTER II
THEORETICAL FRAMEWORK

2.1 FOUNDATIONS OF WAYFINDING AND SPATIAL COGNITION

2.1.1 Definitions and Key Concepts

Wayfinding refers to the cognitive, perceptual, and behavioral processes through which individuals orient themselves and navigate from one location to another within a physical environment. The concept gained prominence in environmental design literature through Kevin Lynch's seminal work The Image of the City (1960), in which he described wayfinding as dependent on the "legibility" of urban form—how clearly the spatial layout of an environment communicates itself to users. Lynch (1960) identified five key elements of legibility: paths, edges, districts, nodes, and landmarks, all of which remain foundational to wayfinding theory today.

While Lynch (1960) did not directly relate daylight to the five constitutive elements of environmental legibility, later research suggests daylight can enhance these elements. Daylight can support path legibility through luminosity gradients; distinctiveness in edges through shadow contrast; and district legibility through different light. Daylight can also enhance nodes like atria, lobby, and other spaces through articulation and natural light, and can offer visual points of reference through landmark legibility. As such, daylight reinforces Lynch's frame as an added engagement layer for interpretation—developing it rather than changing it.

Throughout this thesis, cognition is conceptualized as the perception (internal) process, while navigation refers to the external movement processes. Basically, this line of thinking is consistent with cognitive perspectives in psychology— humans are understood to be active systems as opposed to passive ones. Bloom's Taxonomy, or areas of perception, also provides a frame of reference for wayfinding, as it outlines three domains of perception, or areas of wayfinding, cognitive, affective, and psychomotor. Therefore, wayfinding encompasses more than just cognitive mapping but also includes feelings and bodily movements.

Subsequent researchers further developed this idea into more complex architecture and spatial settings, particularly in situations where users were unfamiliar with the space or when they were under cognitive load. Passini (1984), for instance, conceived wayfinding as a series of problem-solving steps: orientation (knowing one's location), route decision (choosing a path), route monitoring (tracking one's position), and destination recognition (recognizing that one has arrived at the destination). He positioned wayfinding as an act that is not simply spatial, but cognitive in nature – requiring the interdependence of mental processes and environmental affordances.

In some literature, wayfinding is often used interchangeably with other terms, such as navigation, spatial orientation, or environmental cognition. However, wayfinding is distinct since it refers explicitly to user experiences in real-world spaces. In this way, wayfinding has a strong focus in academic literature on design responses affecting behavior. Arthur and Passini (1992) have suggested that wayfinding encompasses more than just the decision of taking a path. It is about making the best path choice that best suits a user's objectives, needs, and emotional state.

In campus environments, wayfinding is strikingly important since spatial arrangements are more complex and users vary widely. For example, students, faculty, and visitors can enter a space (not simply a building) with varying degrees of familiarity, cognitive ability, and confidence. Therefore, wayfinding must consider not only spatial clarity, but also inclusivity, accessibility, and user adaptability (Marquardt and Schmieg 2009).

2.1.2 Sensory and Cognitive Processes in Navigation

Wayfinding depends on a complex interaction between sensory perception and cognitive processing. At a primary level, the human visual system is utilized to provide distances, relationships of objects, and directionality, which allows a person to produce the cues or navigate through what are called cognitive maps, or internal mental maps of a spatial environment (Tolman 1948; Montello 2005). These memory maps are dependent on the location within a spatial environment incorporating elements such as landmarks, boundaries, lighting, and movement patterns. They can vary between maps in terms of speed, accuracy, and succession, based on environmental complexity, user experience, and cognitive attributes.

Sensory information, with visual cueing being the dominant factor, supports the brain's differentiation of zones, detection of obstacles, and estimation of depth and assessment of progress toward a destination. Cues such as light, color, contrast, texture, and motion will influence the human brain's navigation process. The hippocampus, a brain structure responsible for memory and spatial navigation, examines how a person navigates through an unfamiliar environment, particularly when they are required to form new spatial memories after acquiring existing knowledge of that space. (O'Keefe and Nadel 1978).

To facilitate intuitive navigation, environmental cues must correspond to cognitive expectations in response to observation. For example, humans often expect a bright area to correlate with an open area or movement direction. In contrast, a dim, enclosed area of where movement is obstructed may represent an area to rest or transition (Küller 2002). When spatial cues are inconsistent or the layout is disorganized, it increases cognitive load, which can lead to poor direction calculation, confusion, stress, and orientation failure. This can become especially challenging for those who are at a disadvantage due to temporal conditions or impairments.

Modern research additionally connects aspects of multisensory processing when considering navigation. Vision is undoubtedly the dominant avenue for humans when discussing navigation; however tactile enhancements, spatial awareness, and senses such as hearing, touch, and proprioception in conjunction with visual inputs, also play a role. For example, the acoustic qualities of a room can suggest or indicate openness or closeness; tactile indications of the floor surface or a change in that surface can represent physical thresholds; ambient temperature or airflow can provide cues for orientation in relation to outside spaces. Understanding navigation cannot be fully developed when it is reduced to just one sensory element; however, throughout this exploration vision prevails as the primary modality. Furthermore, the visual aspects of our environment, as contextualized through lighting conditions, and specifically the inclusion of natural light, appear to have a predominant impact on how people perceives and reacts to space (Gibson 1979; Boyce et al. 2003).

Research conducted recently in an Arabic (and English) speaking educational context examined the importance of light to develop orientation, and how this was relied upon for academic activities. Participants reported higher comfort and orientation confidence in corridors that were naturally lit, compared to corridors with

artificial lighting (Al-Husseini 2020 - Translated by author). This study also highlights the importance of environmental design (specifically lighting) that assists in supporting cognition through sensory alignment to design constraints.

In conclusion, the wayfinding process occurs within our cognitive system by utilizing environmental cues and mental constructs. Success through wayfinding is dependent on the space allowing cues that support perception, reduce ambiguity, and correspond to human predictive experiences. This ultimately leads to considering how to utilize architectural aspects to either restrict or promote cognitive navigation, especially in campus contexts where diverse user group and wayfinding activities are often challenging within complex spatial organizations

2.2 ENVIRONMENTAL PSYCHOLOGY AND SPATIAL PERCEPTION

2.2.1 Human-Environment Interaction

Environmental psychology is a multidisciplinary field that focuses on the interaction between humans and their surrounding environment. It is concerned with how the built and natural environments influence human behaviors, thoughts, emotions, and physiological responses. Within this theory, human-environment interaction is a dynamic process, in which the individual impacts their environment as they utilize and adapt to it, while also being influenced by the spatial, sensory, and symbolic qualities of the environment (Gifford 2007; Bonnes and Secchiaroli 1995).

In architectural studies, this dynamic process is critical because the built environment is not passive; it shapes how people move, behave, and feel. The sum of various environmental elements including sunlight, layout, material textures, color, sounds, and airflow, impacts the perception of the environment, and therefore, the cognitive and emotional experience of the space (Mehrabian and Russell 1974). When environments meet user-desired expectations and provide clear cues, they promote orientation, reduce stress, and help users behave at their utmost efficiency. Alternatively, environments that are visually chaotic, poorly lit, or lack clear meaning can lead to disorientation, frustration, and spatial anxiety.

Added levels of complexity exist in the campus environment. Campuses are multifunctional and hierarchical, and users are both familiar and unfamiliar, as they can be a transient population, potentially using the campus at different times with varying access. Environmental psychology provides the tools to understand how spatial features impact behavior in these contexts - via observational studies,

Behavioral Mapping, or Post-occupancy evaluation (Canter 1977). Therefore, understanding some principles of Environmental psychology and integrating them into campus design should result in an intuitive and responsive wayfinding system.

Arabic literature on human environment interaction emphasizes the importance of cultural familiarity and visual coherence in public buildings. An investigation of university libraries in the Gulf found that spatial legibility, and the ability to gain access to natural lighting, made a significant difference in user comfort, spatial memory, and the decision to return (Al-Najjar 2021). It is worth noting that this finding is consistent with existing global research, underscoring the importance of perceptual clarity and environmental support on behavioral outcomes.

2.2.2 Perception, Memory, and Emotional Responses

Human perception is not simply a passive reception of stimuli but an active cognitive process by which stimuli are categorized, interpreted, and organized. Within the context of spatial navigation, perception is an essential part of (1) identifying orientation cues, (2) identifying and maintaining anchor points, and (3) developing a mental map. A mental map is an internal spatial representation that enables a person to hold and retain routes, as well as comprehend the spatial relationship of objects and plan movement (Montello 1998; Golledge 1999).

This dissertation focuses specifically on depth perception, spatial clarity, and emotional comfort as principal results of daylight; however, other perceptual dimensions affected by daylight should be listed including color perception, texture perception, shape and form discrimination, the temporal experience of motion, and preventing visual fatigue. Although not all will be analyzed properly in this review, their consideration is more complete with respect to how daylight affects human perception and cognition in buildings.

In addition to perceptual processes, memory plays an equally central role in spatial navigation, as it enables users to encode and recall spatial information across different settings. Memory is another main component of navigation. Spatial memory enables users to encode and recall information based on nodes, pathways, and destinations. Retention is enhanced based on how many yields in a place or space, how distinct the place is from surrounding spaces, and how important the space is to the individual. Studies have demonstrated that natural light improves visual recall and long-term spatial memory, with optimal results benefitting from daylight while

orienting internally produced circulation or transit spaces including corridors (Boyce et al. 2003). Evidence in cognitive neuroscience indicates that lighting conditions affected the encoding of episodic memories, with enhanced recollection of experiences and environments experienced in pleasant and activating light (Knez 2001).

While memory supports the recall of spatial layouts and routes, emotional responses influence whether individuals feel comfortable, secure, or motivated to engage with their environment. Emotion, similar to memory, contributes to the development of spatial cognition. With their approach-avoidance model, Mehrabian and Russell (1974) show how features of the built environment realized distinct emotions – from relaxing and comfortable to angst producing or withdrawing – which is what goes into a user's decision to approach or avoid the environment. Natural features and light, vegetation views, and warm tones in materials often result in favorable affects, confidence, curiosity, and exploratory behaviors (Ulrich 1984; Kaplan and Kaplan 1989). In contrast, poor or low-quality light often results in negative affective responses such as emotional discomfort and anxiety, and even confusion with respect to orientation cues established from the built environment, and decreased a user's sense of control while navigating a space.

This is particularly pertinent in learning environments, such as universities, where, learners who are unsuccessful in exploring a multidisciplinary context/spatially complex learning environment tend to experience a decline in cognitive processing and learning performance (Sweller 1988). The emotional detachment represented by spatial disconnection could also drive avoidance behaviors, such as, consistently choosing longer familiar routes for task completion, completely withdrawing from a building because every encounter is uncomfortable, or even becoming overly dependent on other students to lead them to a destination.

Substantiated evidence drawn from Arabic literature has highlighted poor illumination in educational facilities, leading to subjective feelings of fatigue, insecurity, and spatial detachment among students, particularly female students and first-year entrants (Abdel-Karim 2019 – translated by the author). These justifications further emphasize the importance of design and facilities management in incorporating psychological comfort, while promoting perceptual clarity.

Table 1: Clarification of Key Theoretical Concepts (Prepared by the Author)

Concept	Definition	Relevance to This Study
Spatial Cognition	Mental processes used to acquire, organize, and use spatial knowledge.	Central to understanding how users perceive and navigate campus environments
Wayfinding	Behavioral and cognitive process of navigating from one place to another.	Investigated as a cognitive outcome influenced by natural lighting.
Environmental Psychology	Field that examines the interaction between people and their physical surroundings.	Offers psychological grounding for interpreting spatial orientation and user experience.
Biophilic Design	Design approach that connects occupants with nature through natural Elements.	Highlights the cognitive and emotional value of daylight and its role in restorative design.

Table 1 presents the clarification of key theoretical concepts that underpin this study. This conceptual clarification serves as a foundation for the theoretical framework and supports the synthesis of findings in subsequent chapters.

Building upon psychological perspectives of human–environment interaction, it becomes essential to explore lighting as a tangible architectural feature that both reflects and shapes these cognitive and emotional processes.

2.3 LIGHTING IN BUILT ENVIRONMENTS

2.3.1 Lighting as a Spatial Cue

Lighting is one of the primary spatial signals relied upon in architecture. It not only makes space visible, but also helps define the perception, navigation and understanding of space. As a visual cue, lighting contributes to the delineation of zones, the identification of routes, and the confirmation of landmarks; therefore, it can be a significant instrument for assisting wayfinding and spatial cognition (Boyce 2014; Veitch and Newsham 2000).

From a perceptual standpoint, lighting contributes to visual hierarchy, which refers to the relative priority of elements within our field of view. In general terms, well- lit areas will typically draw a viewer's attention and direct individuals toward paths, doors, or destinations intuitively (Gibson 1979). Specifically, spaces such as

atriums or main corridors that are brighter are perceived as more critical, while darker spaces are usually understood in very different ways, depending on the context: as a destination when the time is appropriate; as movement directing transitional spaces; or as a social limit, in spaces that may seem limiting.

In Germany, studies have been conducted to demonstrate the impact of daylight upon orientation and user satisfaction when navigating university corridors; they found that daylight provided the most benefit when coupled with contrasting textures and materials (Herzog and Just 2007). Meanwhile, in South Korea, findings indicated that directional sources of lighting, especially those associated with ceiling-mounted daylight wells, helped first-time visitors to public facilities predict circulation patterns and decision points without relying on written signage (Kim and Lee 2018).

In high-stress environments, such as hospitals or transit stations, lighting has been recognized as an implicit, or non-verbal guide to help users understand the spatial structure of a facility despite cognitive load (Dalke et al. 2006). In addition to providing illumination and exposure, lighting can be used to highlight thresholds along movement paths or to signal changes in ceiling height, to support the intuitive nature of movement without the need for conscious spatial reasoning.

Arabic-language research has also indicated similar views. A study conducted on government buildings and facilities within the United Arab Emirates found that visitors were able to comprehend the layout logic better when the primary circulation routes utilized either daylight or dynamic artificial lighting, compared to the same routes illuminated uniformly with overhead lighting (Saleh 2019 – translated by the author). The study concluded that both a contrast and a distribution of light quality could act as an informal replacement for signage indicating appropriate movement behavior.

Consequently, lighting is more than a visual choice; it can serve as a functional spatial signal, especially when coupled with the geometry, materiality, and user perspective of architecture.

2.3.2 Functional vs. Experiential Perspectives

In the past, lighting in architecture has been approached through two different, yet sometimes overlapping perspectives: functional and experiential perspectives.

When viewed in a functional sense, lighting is quantified, controlled, and evaluated. A functional perspective considers lighting based on the purposes it achieves, including visibility, safety, and energy efficiency. The lighting community has several measurable and amendable metrics, including luminance, glare, and uniformity of illumination in spaces, as standards from the IES and European Standard EN 12464 illustrate, setting minimum requirements to achieve optimal visual outcomes. The functional perspective typically measures lux levels, energy use, and lighting performance as exploratory measures, and is often associated with artificial lighting systems (CIBSE 2017; IESNA 2011).

Qualitative evaluations, however, typically overlook the aspects where lighting relates specifically to the experiential nature, focusing instead on physical descriptors and not necessarily the psychological or emotional factors. From an experiential viewpoint, the aim is to identify how lighting affects the perception of its quality and how it influences mood, focus, attention, sense of time, spatial comfort, or even social interaction. For instance, Küller et al. (2006) examined the conditions under which lighting affects alertness, stress, and cognitive clarity, particularly in work or learning environments.

Studies conducted in Canada and Sweden have demonstrated that users experience naturally lit environments as more inviting, relaxing, and cognitively stimulating compared to environments lit by artificial sources of light (Veitch 2001; Küller 2002). Users' feelings about environments influence behaviors such as exploring space more actively, learning routes more quickly, and developing a stronger emotional attachment to places (e.g., a higher rate of return).

In educational settings, it is essential to emphasize the importance of combining both experiential and functional perspectives. This approach ensures visibility in completing tasks while also acknowledging the emotional aspects that engage users with the space. Emerging research on Brazilian university campuses has considered lighting as adaptive—responding to changes over time based on users' needs—thus combining performance with the creation of atmosphere (Souza and Amaral 2016).

Furthermore, regarding the experiential value of light, cultural anticipations and experiences play an important role. Under one cultural context, something may appear primal and or enjoyable but under another cultural context may seem jarring or even awkward. As an example, indirect lighting and shaded spaces are revered in

Arabic contexts for comfort, private, and thermal comfort while angles of open conditions and lit situations are valued in Western contexts (Al-Khatib 2020-translated by author). Similar discrepancies have also appeared in East Asian experiences, a soft diffuse light for synthesis or balance and serenity whereas Northern European contexts fill a space with daylight for tact and a strong use of elite daylight (Cho 2017; Nielsen 2015).

Ultimately, the most beneficial architectural lighting strategies strike a balance between pragmatism and richness from the vantage point of experience recognizing that lighting is both a technical system and a human experience. This condition will be meaningful when we see light as a tool for wayfinding and cognition, not simply for visibility.

2.4 NATURAL LIGHTING VS. ARTIFICIAL LIGHTING

2.4.1 Perceptual and Psychological Differences

Natural and artificial lighting serve similar functions - they provide visibility and help situate a space. While both types of lighting serve identical purposes, they have different perceptual and psychological effects, which influence spatial cognition and wayfinding. In comparison to the more limited precision, control, or repeatability offered by artificial lighting, the types of variables affected by natural lighting - or simply daylight - engage the user on a richer emotional and sensory level, which will influence how a user perceives their environment, remembers their path, and behaves (Küller 2002; Aries et al. 2010).

In terms of perception, daylight allows for dynamic variability from day to day and at various times of day in terms of color temperatures, intensity, and directionality; daylight is full of temporal and spatial cues that allow a user to experience time, orientation, and location. This variability also contributes to how users' mental map, as users unintentionally connect certain light conditions with specific locations and the movements between them (Boyce 2014). In contrast, artificial light is relatively static and homogenous, which can cause feelings of boredom, and limits the user's ability to distinguish spatial zones or landmarks.

From a psychological perspective, natural light consistently enhances mood, attention, and cognitive clarity. Many researchers from Sweden, Canada, and Japan have utilized experimental research to argue that daylight exposure increases alertness and decreases mental fatigue, while enhancing feelings of comfort and

security - a combination of effects that directly contribute to spatial confidence and exploration (Veitch 2001; Noguchi & Sakagami, 1999). Conversely, poorly designed artificial light environments, especially those which are too bright or too dark, contribute to feelings of discomfort and stress, and induce spatial disorientation.

A study conducted with university students in Türkiye suggested that daylight in learning environments facilitated quicker comfort and adaptation to new spaces, improved short-term memory, and diminished reliance on wayfinding signage (Aydın and Yılmaz 2006). This provides evidence in support of the notion that with respect to visibility and spatial comprehension, the quality of light is a significant factor.

In addition to the more commonly discussed differences between natural and artificial light, circadian alignment is perhaps the most noteworthy difference. Natural light supports the body's biological rhythms; for example, it can enhance sleep schedules, energy levels, and improve concentration. Artificial light, particularly in terms of its intensity, spectral colour, and duration, can disrupt the synchronicity of these natural rhythms and impair concentration (Figueiro et al. 2017). In spatial terms, this affects how long users can comfortably occupy a space.

Support for this difference can be found in Arabic-language research focusing on emotional experiences related to spatial orientation. One study conducted in university buildings in Iraq, found that when natural lighting entered areas through large windows or skylights, students felt more grounded and spatially oriented than they did in uniformly lit corridors with artificial light (Al-Jubouri 2020). These users also reported feeling greater trust towards the spatial environment and greater individual navigation confidence.

In conclusion, both natural and artificial lighting serve different perceptual contexts. Natural light motivates variability, spatial significance, and emotional connection whereas artificial light supports controllability and visibility. Understanding these differences can inform the design of architecture that promotes cognition-enabled navigation, and fosters meaningful user engagement.

2.4.2 Hybrid Lighting Approaches in Design

With the intrinsic advantages and disadvantages of both natural and artificial light, current architectural thinking increasingly supports the development of hybrid lighting strategies—design techniques that draw on the best attributes, forms, and

functions of both systems to enhance spatial experience, energy efficiency, and user experience (Mardaljevic et al. 2012).

Hybrid lighting design is the intentional combination of daylighting and artificial lighting to create spaces that are both functional and emotionally engaging. In campus-type spaces, hybrid lighting becomes, even more, valuable because it can accommodate different use patterns (day/night), varying user needs (lectures, movement, rest), and different architectural conditions (deep floor plates, shaded areas, circulation cores).

For example, natural lighting harvesting systems that automatically adjust artificial lighting based on available daylight and other thermal and visual comfort factors are being widely adopted in university buildings in Germany, Denmark, and the Netherlands. They were designed to enhance visual comfort for their users while minimizing energy use. These systems improve the perceptual complexity of space by retaining the variability of natural lighting, without compromising task visibility (Dubois and Blomsterberg 2011).

In Australia, educational designers have considered and applied circadian lighting principles in their developments, which modulate the spectrum of artificial light in a manner that mimics natural rhythms to support concentration during active use and avoid stimulating response during transition periods. This has been especially the case in transitional spaces such as hallways, libraries and lounges where the lighting supports a change in setting and a potential shift in behavior (Moore and Carter 2019).

The potential for hybrid conditions of light available to users can be particularly effective, enabling occupants to adapt light levels as needed according to their preferences or consider new contextual factors and distractions that were not previously known. Research has demonstrated that when occupants can exert even limited control over lighting conditions (for example, dimming the lighting, applying shading or varying color temperature), these users experience higher spatial satisfaction and feel better equipped to orient themselves in the environment (Newsham et al. 2004).

However, hybrid lighting has also been adapted in the Middle East taking into account local climate and cultural norms. A modified study of a newly constructed university in Qatar identified active or dynamic artificial lighting in deep interior zones, as well as filtered ambient daylit areas around the perimeter of those deep

interior zones, which enhanced the users' wayfinding experience and reduced spatial anxiety, especially useful for those new to their environment (Al-Mutairi 2021 – translated by author).

Overall it appears that hybrid lighting offers one systematic approach to enhancing spatial cognition. It respects the physiological benefits of natural lighting, the psychological consequences of transitional and hybrid lighting and recognizes that natural lighting, with or without artificial light, is inadequate when providing whole-space design outcomes. Hybrid lighting offers the foundation for developing lighting strategies informed by an evidence-based perspective and aligned with real user behaviors in complex and cognitively demanding environments, such as university campuses.

2.5 THE ROLE OF NATURAL DAYLIGHT IN WAYFINDING

2.5.1 Enhancing Orientation and Mental Mapping

Natural sunlight significantly assists a user's ability to orient themselves in the built environment and form a mental map of the environment, foundational aspects of wayfinding—particularly in complex and large-scale architecture, such as university campuses.

Orientation is the user's perception of their location in relation to their surrounding environment. Daylight provides, in its essence, directional and temporal cues— like the angle of the light, movement of shadows, and the perception of the qualities of light as they change throughout the day—which allow users to gauge their orientation without relying on signs or memory (Gibson 1979; Wineman and Peponis 2010). Natural light is dynamic and varies with time and climate; as a result, it provides users with spatial anchoring, further reinforcing their inner sense of direction. Artificial lighting, on the other hand, is static.

Mental mapping, on the other hand, refers to the user encoding the spatial relationships between locations/features, and organizing them mentally for route planning and remembering paths. Studies conducted in the UK and Germany suggest that the use of daylighting-supported differentiation of space can support visuo-spatial recall processes: the use of daylighting in the selection of distinguishing properties for spatial differentiation of space, or features that highlight thresholds and transitions between zones supports better spatial recall (Dalton and Hölscher 2017; Franz and Wiener 2008). Thus, visuo-spatial markers, supported by daylight and its

cue properties, become visual memory cues that support the formation of users' mental representations of spaces. In Finland, research has demonstrated that first-year university students benefited from natural lighting in circulation via clerestories or light-wells in terms of building layout learning, when compared to students who experienced circulation in fully enclosed, artificially lit corridors (Lahtinen et al. 2020). The work suggests that natural lighting not only provides illumination of a space but also offers cognitive structure.

In circumstances where the navigation task is cognitively challenging—such as on campus environments with irregular building layouts, multiple building functions, or partial-layer, or multilevel circulation—this process can be non-verbal in nature, utilizing natural lighting. Natural lighting can help users intuitively determine primary from secondary, locate exits, and distinguish between zones for arrival and transition.

Arabic-related research supports these conclusions. A study conducted on three Iraqi university campuses concluded that the use of natural lighting had a positive impact on users' spatial confidence, particularly for students who had never experienced the buildings or campuses. The subjects reported experiences in daytime lighting spaces that made it easier to navigate and difficult to lose their orientation (Salih and Kareem 2022).

In conclusion, external natural lighting contributes positively to cognitive clarity, environmental legibility, and spatial memory formation; thus, natural daylighting can undoubtedly be considered a user-centered design element in wayfinding system design, particularly for educational environments.

2.5.2 Landmark Recognition and Route Clarity

Of particular importance to architectural wayfinding are landmarks, which are vital spatial elements that provide users with the means to know their location, determine the course of action to pursue, and track their movement. While the presence of daylight provides an inherent value to a landmark, it does so because daylight visually highlights, emotionally engages, and spatially anchors the landmark in space and time in our memory.

Naturally lit landmarks, like atriums, portals, courtyards, or double-height entrances, will likely have higher recall and serve as permanent references for creating mental maps of a building. Lynch (1960) suggests that the legibility of space

is tied to its elements being recognizable and clearly identifiable; daylight is a mechanism to heighten such aspects. For instance, a vertical core featuring daylight may give a user a visual sense of the building's center, helping them to orient themselves among the floors.

Research from the Netherlands and South Africa has indicated that, associated with a constant level of light, such as a sunny skylight or glazed façade, users are more likely to identify and use a spatial element as a landmark (Loubser and Van Tonder 2019; Van der Zee 2015). Consistent lighting increases visibility but also fosters emotional attachment as users are likely to choose naturally lit environments. Users prefer spaces that are bright, open, and made with natural materials, and subconsciously, feel safe and psychologically comfortable.

Daylighted spatial elements also shape route clarity - the ability to perceive, follow, and evaluate paths. Brightness gradients provide directional cues. For instance, if a user walks into a hallway and it gets progressively brighter, they may be inclined to walk forward. Alternatively, in conditions where there is a slight rise or drop in brightness level in two areas, it becomes easy for users to differentiate between primary routes and secondary, service routes, especially in convoluted floor layouts.

In designing a campus within the context of Japan, architects utilize daylight to create rhythm and sequencing in corridors and public spaces, which is evident in the transition between bright, open, and shaded pathways. This provides visually engaging and simple compositions to assess at decision points, which is ultimately less valuable to staff, as they need to deliver fewer verbal instructions, or wayfinding/siting elements (Nakamura 2014).

In the case of Saudi Arabia, a research collaboration identified the presence of natural lighting around features such as stairways and doors to (a) positively affect the use of these woodland facilities and (b) more effectively manage the building circulation of new students (Al-Sulami 2018). A different nymber of people used the purpose-built daylit corridor, as it was perceived as more trustworthy and pleasant than the poorly lit options.

In conclusion, the findings of these investigations suggest that natural lighting can serve as a type of navigational landmark system to aid in determining human orientation within buildings. This is not to de-value the contribution of architectural forms, such as pathways, courts, and canopies. The function of natural lighting is to

support how we perceive clarity and attach ourselves to emotional significance. Therefore, when considered intentionally, collectible daylight creates fascinating ways to improve the legibility and usability of built environments that are felt beyond what may be perceived.

2.6 BIOPHILIC DESIGN AND DAYLIGHT INTEGRATION

2.6.1 Biophilia as a Design Framework

Biophilia is a term coined by Edward O. Wilson (1984) to describe a human tendency to feel a connection to nature and natural things. In architectural theory, this concept has evolved into biophilic design. This design paradigm integrates natural forms, materials, patterns, and processes into the built environment to enhance human health, performance, and emotional resilience. (Kellert et al. 2008).

Biophilic design is more than merely adding plants or other natural surfaces to buildings. It implies designing spaces within buildings that are representative of the natural world. For instance, access to natural lighting, views of nature, variations in thermal and airflows, non-rhythmic sensory stimuli (e.g., subtle shadows, reflections, and colors), and organic spatial forms. Research has shown that biophilic attributes of environments are conducive to mood regulation, cognitive focus, stress recovery, and spatial orientation in specific settings (Browning et al. 2014), including schools, hospitals, and workplaces.

One of the fundamental principles of biophilic design is understanding that nature- rich spaces improve user spatial awareness and emotional attachment to place. Place attachment is the psychological connection, or bond, that people have toward places which fosters a sense of grounding and confidence enabling users to navigate their space more effectively, (Kellert 2012). Emotionally familiar places, especially in wayfinding contexts, can help mitigate users' anxiety and support cognitive clarity and decision-making.

Biophilic characteristics in classrooms or on school grounds have been shown to positively impact students' spatial learning, attention restoration, and navigation confidence. Lim and Tan (2019) found that students from biophilic-designed secondary schools in Singapore reported higher satisfaction with their school campus, and fewer instances of feeling lost or confused on campus. Biophilic-designed schools offered opportunities for natural wayfinding systems dictated by

the environment, through lighting, material changes, and links to outdoor areas that students could easily access.

There is also a growing interest in biophilic principles in Arabic-language scholarship. For example, a study that re-designed university courtyards in Jordan (which had none of the natural elements) found that adding trees, water elements, and shaded light-responsive pathways improved spatial behavior and students' movement fluidity (Abu-Farha 2020). The study concluded that the biophilic interventions created an "invisible system of direction" that intuitively enabled users to navigate without using signage.

2.6.2 Daylight as a Biophilic Element

Of all biophilic characteristics, daylight is undoubtedly the most primordial and potent. Beyond being a source of light, daylight is also an organic phenomenon that changes with each day, and spatially connects the inside to the outside. In this way, daylight serves both physiological and psychological biophilic needs—biophilic influence on circadian rhythms, mental alertness, emotional comfort, and spatial legibility.

Natural light brings temporal change to spatial experiences, creating dynamic situations across time that change tone, intensity, and direction. This non-static quality mimics the natural outdoor world, allowing individuals to experience the passage of time and providing a subtle sense of orientation to space. These environmental changes make people feel "in synch" with place, and thus support place recognition and route memory (Fisk and Rosenfeld 1997; Kellert 2018).

Natural light also adds sensory richness to the space through reflections, shadows, gradients, and patterns of light—visual phenomena that engage the brain’s attentional systems, while also supporting emotional regulation and exploratory behavior (Kahn et al. 2008). In wayfinding situations, these sensory experiences render natural light more than a visual navigational aid—rather a navigational experience altogether, where individuals engage their instinctive responses.

Biophilic value of daylight can be described in terms of design strategies, such as:

- Framed outdoor views toward trees, sky or courtyards.
- Filtered daylight visibility through specific screen patterns or perforated material.

- Vertical light wells that demarcate spatial hierarchy and core orientation.
- Skylights and clerestories to highlight circulation on pathways and the flow of movement.

In studies from Europe and South Africa, for daylight-optimized campuses, as an enlarged cohort, students reported more spatial familiarity and, invariably described route references in light, e.g., “the bright hallway,” and “the skylight corridor”—indicating daylight functioned as a cognitive landmark (Lahtinen et al. 2020; Loubser and Van Tonder 2019; Van der Zee 2015).

Plus, from the Middle East, a report on university design case studies from Oman indicating daylight-responsive architectural features (i.e. mashrabiyas, shaded atriums, or glazed courtyards), contributed to both environmental comfort awareness and feelings of navigational confidence by students, especially females and international students (Al-Shibli 2017).

In conclusion, daylight mediates between human cognition and form. Daylight elevates architectural space from a static facade to a responsive system that guides, supports and enhances the user’s experience—emotionally, perceptually, and cognitively. Therefore, when daylight features are recognized as meaningful components in design, rather than afterthoughts, daylight has the potential to elevate both spatial function and human experience.

2.7 SPATIAL COGNITION AND EMOTIONAL EXPERIENCE

2.7.1 Mood, Stress, and Cognitive Load

Spatial cognition is often discussed in the context of perception, memory, and navigation however, recent studies emphasize that emotional states (mood, stress, anxiety) are deeply connected to spatial processing. The interplay between emotion and cognition is not simply additive, but reciprocal - moods mediates the ways people interpret, recall, and navigate space, while spatial navigation experiences can also influence mood (Knez 2001; Russell and Lanius 1984).

In architectural environments related to wayfinding (e.g., campuses, hospitals, transit hubs), the risk of confusion and stress can impede decision-making and increase the cognitive load of spatial navigation. Cognitive load refers to the degree to which a task demands mental processing. Poor lighting levels, unclear spatial organization, and visual homogeneity are features of many wayfinding environments

that contribute to cognitive load, leading to feelings of being overwhelmed or disoriented (Montello 2005; Sweller 1988).

Natural lighting has been shown to mediate stress and foster mood regulation, which in turn supports cognitive performance. Two studies in Sweden and the Netherlands have confirmed that exposure to natural lighting during navigation tasks results in lower cortisol levels, and improved task accuracy, especially in unfamiliar environments (Küller 2002; Van Bommel and Van den Beld 2004). In educational settings, daylighting was shown to yield the highest levels of awareness, sustained attention, and spatial confidence.

A study in Taiwanese school contexts found that when exposed to classrooms and hallways with large natural lighting openings, students reported lower feelings of fatigue, irritability, and confusion, all significant factors that researchers directly attributed to the effects of tone-based interference on spatial navigation tasks (Huang et al. 2012). The authors of this study concluded that natural light contributed not only to visual clarity but also to emotional resilience, afforded to students in complex spatial education contexts.

Natural lighting affects serotonin and melatonin levels at a neurobiological level. The interplay between serotonin and melatonin impacts sleep-wake cycles, mood stability, and cognitive task engagement (Figueiro et al. 2017). Therefore, these physiological effects lead people to develop a higher tolerance for spatial ambiguity and a willingness to explore new spaces - two competencies that are necessary for to effective wayfinding.

There is evidence from various studies and systems that supports these statements. Studies in university contexts in Kuwait and Jordan have shown that students in learning buildings with natural lighting experienced significantly lower levels of anxiety and reported a higher degree of confidence in navigating the building independently (Abu Saifan 2021; Al-Farsi 2019). Many of their responses demonstrated association with naturally lit spaces as “safety,” “trust” and “calm” - interconnected mood levels that engage cognitive function.

Mood and stress are not peripheral issues in spatial navigation; they are central factors in mediating how users experience, process, and engage with the built and geographically organized environment. Lighting of all types, and daylight in particular, plays a direct role in this process, both physiologically and psychologically.

2.7.2 Lighting's Impact on Confidence and Control

In spatial design, confidence and perceived control are paramount for users to feel empowered, safe and independent. These psychological responses are especially salient in large scale or institutional settings where unfamiliarity and complexity can present hurdles, making users hesitant, threatened or rely too heavily on proximity to help (Frankenstein et al. 2012).

Lighting plays a very significant role in these responses. Generally, well-lit environments—often through natural lighting—tend to promote legibility and predictability of space, both of which mitigate uncertainty and promote a sense of control for users. In both the United States and Germany, this idea is supported by research that shows users in naturally lit public buildings reported higher spatial confidence, greater satisfaction with wayfinding systems, and a stronger emotional bond to the space (Hölscher et al. 2006; Veitch and Newsham 2000).

One specific mechanism that contributes to this is the visibility of decision points. When corridors, junctions, and stairwells can be illuminated by daylight, they are more legible and users will hesitate less. Relationships in space, permeability of familial and habitual spaces, and comfort levels that impact movement flow are also considered. Dimly lit and inconsistent lighting conditions can generate doubt, complexity, and fear—especially for solo or first-time users navigating the built environment (Dalton et al. 2019).

In design psychology this is referred to as perceived environmental control—the sense of being able to interpret and predict the space sufficiently to create a sense of autonomy and self-efficacy. Studies within Brazilian healthcare facilities demonstrated that patients and visitors who used naturally lit circulation spaces as corridors experienced improved confidence in wayfinding tasks and reduced levels of anxiety (Martins and Andrade 2015).

In university contexts, perceived environmental control is essential for students' sense of ownership and engagement with their campus. A study conducted in South Korea found that new students were more likely to attend optional campus events and explore academic buildings, when circulation spaces were clearly zoned and received ample natural lighting (Kim and Park 2016).

From an inclusivity perspective, lighting can empower or exclude. There are many populations including, but not limited to, older adults, neurodivergent individuals, and those who identify with visual impairment, who often depend on

formalized, consistent, and legible lighting cues to help them understand their relative orientation and safety. When natural light is used to delineate routes softly, highlight transitions, and emphasize landmarks, it helps provide everyone with a sense of spatial clarity (Imrie 2003).

One study that involved daylight was conducted in Iraq and examined the impact of natural lighting on students' sense of confidence in a women's college building in Baghdad. Participants described naturally lit-pathways as "safe," "trustworthy," and "easy to remember," while many students reported using them over other pathways—even when they were longer (Al-Rubaie and Hussein 2020). This suggests that lighting not only influences movement, but also emotional investment in a space.

Ultimately, light influences how users perceive, interact with, and trust architectural spaces. Natural lighting clarifies space offering a richness of engagement and provocation that enhances spatial legibility, openness and environmental distinctiveness, implying ownership and control, which leads to users moving with greater confidence and independence.

2.8 CAMPUS ENVIRONMENTS AS COMPLEX NAVIGATIONAL SPACES

2.8.1 Campus Complexity and User Diversity

University campuses represent the most complex and dynamic form of built environment. They have layered architectural legacies, multifunctional spaces, and changing spatial programmatic uses. Unlike standardized building forms, such as hospitals and airports, university campuses evolve over decades or centuries, resulting in non-standardized spatial arrangements, building types, and fragmented circulation (Montello 2005; Peponis et al. 1990). These aspects create confusion in sense-making navigation and wayfinding—especially for those who are not spatially literate.

The complexities of navigating a university context extend beyond physical aspects; they also encompass cognitive and social dimensions. These three spatial complexities complicate a place where diverse occupants have multiples needs and demands. New students, faculty, staff, international participants, individuals with disabilities, and neurodiverse users all utilize campus environments, which introduce additional cognitive demands into navigation and wayfinding (Passini 1996). While

the mental and social attributes vary by individual, the physical landscape ultimately represents cognitive aspects when spatial configuration lacks unambiguous visual cues in the environment—e.g., inconsistent lighting, zoning, or salient spatial landmarks.

Bilkent University in Türkiye is one example. The academic buildings are scattered across hilly grounds with limited axial site visibility and a mix of modernist and brutalist styles. A study conducted by Demirbaş (2015) on first-year students found that they needed an average of 12–14 days to thoroughly memorize their daily routes. Many students received verbal direction from their peers rather than relying on environmental cues.

Campuses in India, such as Jawaharlal Nehru University, also represent patterns of ambiguity and confusion in navigation. Their plans are extensive, and lighting and signage vary by location. Research conducted by Singh and Prasad (2019) suggest that international students experience higher spatial anxieties in these contexts, forgoing unfamiliar buildings altogether. These kinds of psychological barriers to spatial cognition can contribute to reduced engagement, academic participation and emotional connection to place.

In Arabic-speaking countries, and despite years of urbanization, the larger social context creates additional layers of complexity. A study comparing three countries (Jordan, Kuwait, & Saudi Arabia) in a campus context showed the abundant sense of spatial disorientation among first-year students and female students, particularly in academic institutions in which clusters of buildings do not feature transitions, manners of navigation, or naturally light based cues (Al-Faris et al. 2020). In a campus context, students consistently expressed discomfort with darkness in particular areas and provided descriptions of specific campus areas that were "unwelcoming" or "disconnected.

In brief, from a cognitive psychology perspective, spatial complexity is a form of cognitive load, particularly when there are limited syntheses due to time constraints, unfamiliarity, or sensory overload. Where students have attention deficits, sensory processing sensitivities, or both this lack of intuitive spatial cues—e.g., light gradients or rhythmic architectural zoning—can leave them fatigued, disoriented, and tending towards passive-avoidant behaviours in particular zones of campuses (Dalton et al. 2010).

In summary, a campus is not a neutral space; it is a cognitive and emotionally laden, architecturally layered, and complex space. Understanding the spatial complexity of a campus and its multiplicity of users is crucial for developing equitable and intuitive wayfinding systems.

2.8.2 Design Strategies for Inclusive Wayfinding

In response to the challenges outlined above, 21st-century campus design has increasingly emphasized inclusive wayfinding strategies: strategies that account for the accessibility of wayfinding in terms of physical, cognitive, and emotional aspects, as it relates to all users. An inclusive wayfinding strategy encompasses more than signage and maps; it considers the spatial language inherent in architectural design: light, form, materials, and rhythm (Imrie and Hall 2001).

One of the most powerful, useful features of this spatial language is natural daylight. Daylight, unlike artificial light, is not only visual, but also has affective properties - it demonstrates depth, openness, and encourages our natural circadian patterns. Its inherent variability also lends itself as an intuitive form of spatial navigation.

- Daylight for Visual Hierarchy and Spatial Anchoring

At campuses such as the University of Copenhagen, daylight has been incorporated into circulation spines, where the brightest areas align with major movement routes, and secondary roads are gently shaded. This natural lighting use serves to establish hierarchy and encourages users' subconscious use of mapping the space. Users tend to follow natural daylight to navigate and travel through spaces (Küller et al. 2002).

- Biophilic Wayfinding Aspects

The various biophilic aspects, including green walls, courtyards with indirect daylight, and natural textures, positively impact individuals' wayfinding experiences. For instance, at Aalto University, Finland, the library's atrium is daylit through a glass canopy ceiling and surrounded by plant life in pots and from the building itself. This atrium serves not only as a functional node, but also as a psychological anchor, helping users mentally map the library and relieve stress (Söderlund 2016).

- Consistent use of lighting idiom

Research reveals that campuses help create user confidence by using consistent lighting grammar across buildings. For example, when users see a

naturally lit vertical core (i.e., an east-facing stair), in the same relative position as other campus buildings; they begin to think about and internalize spatial rules (Christensen 2020; Lim et al. 2021).

- Safe and Inclusive daylit pathways

From the context of women's universities in Iraq and Saudi Arabia, daylight supports visibility, and cultural re-assurance. At an Iraqi university, in Baghdad, students perceived pathways lit by natural lighting as safer, more precise, and longer-lasting memories, than pathways lit by electric light, which were categorized as "tense", and "hard to read" (Al-Rubaie and Hussein 2020).

- Interactive lighting and programmable technology

Some universities are piloting adaptive lighting systems that use daylight with sensor-activated electric light to make visual support available during cloudy days and beyond. A study at the National University of Singapore had students use new daylight-based wayfinding strategies—light-responsive floors and hidden LEDs—which reduced students' route errors significantly (Tan et al. 2022).

Furthermore, Tan et al. (2022) indicated that daylit corridors, in particular, helped international students develop spatial memory, confidence, and wayfinding accuracy when compared to gloomy and confined spaces. The findings support the advancement of daylight as a remedy to disorientation and beyond in an unfamiliar campus setting.

2.8.2.1 Conclusion of Section

Inclusive wayfinding should never be solely reliant on signage; it should be executed through a deliberate choreography of light, place and sensory comfort. Campuses that introduce daylight and coordinate their wayfinding systems into a spatial logic, and are supportive of participant independence, lower participant levels of stress, and provide participants with an experience of an empowering space. These strategies are not simply aesthetic. They are key to establishing cognitive accessibility and spatial equity.

2.9 SUMMARY OF THEORETICAL FRAMEWORK

This chapter has examined the theoretical bases of how natural lighting is associated with spatial cognition and wayfinding in campus contexts. Drawing on a range of discipline-based knowledge including architecture, environmental

psychology, cognitive science, and design studies, the framework illustrates that wayfinding is inherently more complex than simply signaling or mapping a transition; it is an embodied cognitive and emotional performance that also relies on spatial perception, memory, and context.

The chapter begins by defining the key concepts of spatial cognition, wayfinding behavior, and sensory navigation with a focus on how the roles of vision and memory inform the user's spatial decision-making. The chapter then elaborated on how lighting—specifically natural daylight—operates as both a functional means of visibility and a psychological cue that helps orient the user, inducing feelings of calmness and confidence in their movement.

A distinction was made between artificial light and natural light—specifically daylight—emphasizing the perceptual, emotional and developmental benefits of natural lighting, and how hybrid lighting strategies are being developed in architectural practice for this reason. Moreover, the application of biophilic concepts maximized the relationship between the user and natural rhythms, thereby supporting their well-being and spatial awareness.

The chapter also elaborates on the emotional dimensions of the navigation-performance and how lighting influences mood, stress, and cognitive load, thereby impacting the user's ability to create mental maps and engage in independent movement. The perceptions drawn from the theories were contextualized within the nuances of campus environments that may be inadvertently fragmented, unpredictable, and cognitively demanding—particularly for new students, international visitors, and individuals with special needs.

The last section of the chapter outlined design interventions that foster inclusive wayfinding, with respect to:a) using daylight for visual hierarchy, b) predictability in spatial transitions, c) biophilic anchors, and d) design for cultural spatial understandings. These interventions were extrapolated from examples in other international and regional studies, as well as case insights, and translated Arabic studies in order to demonstrate their relevance.

In conclusion, this theoretical framework has demonstrated that natural lighting is an active agent in cognitive and emotional navigational-processes; its role in how users perceive, interpret, and move through campus environments is central. This theoretical framework provides a basis for the following chapter, which details

the systematic methodology employed to investigate this process through empirical literature.

CHAPTER III
METHODOLOGY – SYSTEMATIC REVIEW PROCESS

3.1 REVIEW DESIGN AND RATIONALE

Investigating how natural lighting affects spatial cognition when university wayfinding occurs requires an integrative and rigorous research process. Due to the nature of the concepts involved, which encompass aspects of architecture, cognitive psychology, environmental behavior, and spatial design, a systematic literature review (SLR) was chosen as the most suitable methodological approach. A systematic literature review (SLR) is a systematic and reproducible way of reviewing literature that takes through transparent and pre-determined steps to identify, select, and analyze the relevant studies critically. In contrast to a narrative or traditional literature review which is primarily descriptive and selective, an SLR is also evidence-based with specific inclusion and exclusion criteria and is aimed at minimizing bias by holding a full synthesis of existing research (Grant and Booth 2009; Snyder 2019).

A systematic review enables the critical synthesis of existing knowledge, and verified by employing a clearly defined and replicable protocol for identifying, appraising, and integrating studies. A systematic review is beneficial in fields with relevant data related to multiple disciplines, such as the interaction between lighting and cognition in the built environment. In contrast, narrative reviews are limited, subject to bias, and usually consider an evidence base of publications that are inconsistent in focus. By using a systematic review process, conclusions can be drawn based on current evidence, while acknowledging that the entirety of the evidence remains methodologically weak.

As defined for this thesis and systematic review, three research questions would be established.

- How does natural lighting affect wayfinding and spatial cognition in campus environments?
- What personal and environmental variables affect this relationship?

- How could findings from existing research be used to inform design from inclusive navigation perspectives?

Using the systematic review guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), the project developed a sequential rational process to conduct the review; including research question development, study identification, quality assessment and study synthesis (Moher et al. 2009). This systematic approach provides process moves to avoid bias, acknowledge thoroughness and enabled future duplication.

It is also important to note that architectural research tends not to unify the base of empirical evidence on which we build, particularly when considering phenomena such as perception and behavior, like wayfinding. Therefore, systematic reviews can be helpful in terms of a process to engage with future stages of research, as well as bridging the architectural research design gap, where vocational evidence will be applied to theoretical knowledge.

This review process was structured in to four phases:

- Database selection and search terms development – for searches to identify to combination of architecture and psychology empirical studies.
- Screening and eligibility – i.e. inclusion/exclusion criteria identified.
- Data extraction and thematic coding – will provide the means to allow synthesis across methods and discipline within the group.
- Interpretive integration – where evidence and design implications can be connected, linked to theoretical models.

By utilizing this structure, the systematic review not only builds a body of knowledge, but also reconstructs it to provide a level of unity, thereby creating a foundation for more inclusive, evidence-informed design practice in higher education contexts.

3.1.1 Type of Review and Justification

The approach chosen is a qualitative systematic review with possible quantitative integration. This was determined by the mix of studies available on this topic. In the literature, a combination of empirical studies, experimental trials, and observational studies based on naturalistic observations in built environments is found. Much of the literature described or compared qualitative insights into spatial

exploration and navigation within built environments. Some of these studies have quantitative outcomes—such as the time taken to complete specified wayfinding actions under different lighting conditions, or levels of spatial anxiety measured with validated scales—but most are qualitative or mixed-methods studies. User interviews, post-occupancy evaluations, photo-elicitation studies, and mapping of spatial behavior are examples of studies designed in qualitative or mixed-methods forms. Therefore, the current review primarily involves thematic analysis, with narrative synthesis employed as necessary.

Suppose enough quantitative data (e.g. consistent or comparable effect sizes, statistically significant correlations with an effect size) to include a meta-analytical section within which to provide greater inferential power than all of the qualitative pieces separately. But given the diversity of research methods and populations, obtaining these data and making comparisons may not be likely for every study.

This hybrid approach is becoming increasingly common in built environment research and is especially useful for research with designers or researchers interested in building empirically based design knowledge (Gough et al. 2012). This review is also designed to highlight contexts that are often underrepresented, such as papers and studies from non-Western countries and institutions serving marginalized populations. One example is the studies the author was able to review from Iraqi, Jordanian, and Turkish universities, which, although absent from mainstream academic databases, were available through manual searches of the author's networks and translations by the author.

In summary, the rationale and appropriateness of this review type stems from:

- The interdisciplinary and disparate nature of relevant studies (e.g., literature combining social, ecological, cultural and interventional research).
- The need for depth (qualitative knowledge) and breadth (quantitative comparative understanding).
- The need to support architectural design rather than hypothesis testing.

3.1.2 Research Questions (SPIDER / PICO Frameworks)

To develop the review and structure the search strategy, two well-known frameworks: SPIDER – scanning, predicting, identifying, decision-making, and executing a response - (for qualitative studies) and PICO – population, intervention,

comparison and outcome - (for quantitative studies), were employed in conjunction. The reason for using two frameworks is that it increases the ability to include a range of research designs without losing consistency and focus.

Table 2: SPIDER Framework (Ideal for qualitative/mixed-methods research)

Element	Definition	Application in this Study
S – Sample	Population being studied	University students, staff, campus visitors
PI – Phenomenon of Interest	Behavior or experience explored	Navigating space under natural lighting
D – Design	Research methods used	Interviews, observations, field studies, POEs
E – Evaluation	Outcome of interest	Spatial memory, orientation, comfort, behavior
R – Research type	Nature of data	Qualitative or mixed-method studies

The dual frameworks approach the issue of subjectively capturing experience, whether it is spatial experience or how people dismiss or relate to their knowledge of naturally lit conditions.

Table 3: PICO Framework (Ideal for quantitative studies)

Element	Definition	Application in this Study
P – Population	Who is being studied	Campus users (primarily students)
I – Intervention	Factor being manipulated	Exposure to natural daylight
C – Comparison	Against what	Artificial lighting or no lighting control
O – Outcome	What is being measured	Navigation accuracy, spatial recall, stress

In this respect, both frameworks helped identify studies from various disciplines providing behavioral outcomes and design principles. They equally contributed to establishing key search terms and creating Boolean strings for the different studies and databases reviewed.

3.1.3 Inclusion and Exclusion Criteria

Definitive and well-defined inclusion and exclusion criteria were established before screening to ensure the quality, relevance, and focus pf the review.

Inclusion Criteria:

- Peer-reviewed journal articles published from 2000 to 2025.

- Focused on natural illumination in a building context.
- Mindful of wayfinding, spatial cognition, or orientation.
- Studies conducted in the context of university or other related complex pedestrian spaces.
- Published in English or translated from Arabic by the researcher.
- Included empirical data (qualitative, quantitative, or mixed).
- Related to human subjects, not solely automated or simulated systems.

Exclusion Criteria:

- Papers that studied artificial light or technical systems without regard to the spatial behavior of individuals.
- Studies based on non-comparable environments such as airports, retail malls, or vehicular contexts.
- Papers lacking methodological transparency or a user-centric evaluation of at least some sort.
- Opinion pieces, editorials, or theoretical papers without data.
- Articles duplicating studies, or re-publishing the same data.

The above criteria were applied at the title, abstract, and full-text screening. After identifying a total of 1,385 studies, 102 were deemed to meet inclusion criteria. After quality assessment, a total of 35 studies were included, featuring regionally diverse studies from Iraq, Türkiye, South Korea, Germany, and Brazil, which provide a global perspective on campus design challenges.

Several studies that were published in Arabic were also translated and included in the final synthesis. For example, an article by Al-Khafaji and Hussein, published in 2019, from Baghdad University, studied students' use of natural light corridors during their orientation weeks and was deemed relevant (Al-Khafaji and Hussein 2019).

To develop the review and structure the search strategy, two well-known frameworks: SPIDER (for qualitative studies) and PICO (for quantitative studies), were employed together. The reason for using two frameworks is that it increases the ability to include a range of research designs without losing consistency and focus.

It is important to state that visual differences, including the type, direction, and intensity of natural lighting, were deemed as an important facet of the inclusion/exclusion process. Studies that did not specify or differ in visual conditions

were excluded vis a vis how critically important those details were for methodological specificity and for a reader to assimilate the pertinence of each study to wayfinding/spatial cognition.

3.2 SEARCH STRATEGY

A practical and comprehensive search strategy was developed before conducting the systematic review to ensure that the review captured the full range of scholarly literature examining the association between natural lighting within the built environment, and spatial cognition, specifically, university campus wayfinding. To achieve this, the search strategy was developed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al. 2009), and informed by relevant methodological articles (Grant and Booth 2009; Snyder 2019).

Due to the interdisciplinary nature of the topic which connects architectural design and space, cognitive psychology, and environmental behavior - the search process was developed to be iterative, inclusive, and aware of differences across disciplines and publication sources. The search process consisted of three components: identifying relevant databases and sources, constructing a set of inclusive search terms using Boolean operators and filters, and conducting an organized screening process at the title, abstract and full-text stages.

3.2.1 Databases and Sources Consulted

Multiple databases were selected to capture a comprehensive coverage of relevant literature to the extent possible, across architecture, environmental design, education, and cognitive science. The databases were selected due to their reliability, scope disclosure, and relevance to the key concepts of the review.

- Scopus: was chosen for its thorough indexing of widely disseminated journal articles that are impactful within environmental design, psychology, and spatial cognition.
- Web of Science: Used to access high-quality, peer-reviewed articles and to trace citation patterns and influential works.
- ScienceDirect: Included to retrieve full-text articles with a focus on architecture, human behavior, and sustainability.

- ERIC (Education Resources Information Center): Used to identify studies within educational environments, especially those dealing with wayfinding and cognitive development in campus contexts.
- Google Scholar: Employed as a supplementary source to identify grey literature, theses, and works not indexed in the databases mentioned above.

In addition, Arabic academic sources were consulted to incorporate regional perspectives. Specifically, the databases Dar Almandumah and AlManhal were searched for Arabic-language studies addressing lighting design and user experience in educational environments. Relevant studies from these sources were translated and labeled as "translated by the researcher," contributing to the contextual diversity of the review.

This broad selection ensured that the search encompassed multiple disciplinary angles and geographic regions, reflecting the theoretical framework of the study, which integrates spatial cognition, visual perception, biophilic design, and inclusive wayfinding strategies (Gibson 1986; Kellert 2005; Passini et al. 1998).

Justification of Frameworks (PRISMA, SPIDER, PICO)

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework was chosen as the overarching framework because it provides for a transparent, standardized, and reproducible protocol for systematic reviews (Moher et al. 2009). PRISMA allows for the review to document the process for identification, screening, and eligible to ultimately final inclusion; and so cannot be misrecorded creating lack of rigor. This was critical for the study given the disciplines of architecture, environmental psychology, and cognitive science involved.

Nonetheless, PRISMA is a reporting guideline, not a structure for generating search strategies and capturing subtle differences between qualitative and quantitative studies. To mitigate these limitations, SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) and PICO (Population, Intervention, Comparison, Outcome) were employed in a complementary format.

SPIDER was used for the qualitative and mixed-method studies, which are predominant in architecture and behavioral studies, where the phenomenas of spatial memory, environmental legibility, or user comfort is unable to be distilled to experimental variables. For example, studies that employed interviews, post-

occupancy evaluations, or observational designs could be retrieved utilizing SPIDER-based search strings.

PICO was employed for the quantitative and experimental studies that specifically measured wayfinding data points—the navigation accurate, stress, or cognitive mapping performance under various lighting conditions; PICO appeals to a structure to align population (students, staff, and campus visitors), intervention (natural light exposure), comparison (artificial light, or no control), and outcome (navigation accuracy or stress reduction).

The heterogeneous combination of PRISMA, SPIDER, and PICO corresponds with best practices concerning interdisciplinary systematic reviews (Methley et al. 2014). The heterogeneous combination also ensured the reviews capture different methodologies, thus preventing losses of relevant studies that may not technically match a single framework. PRISMA provided the macro level reporting framework, while SPIDER and PICO directed the micro level search strategies and inclusion, ensuring the final dataset was a diverse methodology, relevant context, and an academically rigorous understanding.

Ultimately, PRISMA structured the flow of the review process and final reporting (see chapter 4 PRISMA). SPIDER and PICO generated the actual search strings and database queries that would support the combined narrative rich studies (interviews and observations) and data driven experimental studies. Combining PRISMA, SPIDER, and PICO facilitated both depth (in narrative qualitative) or breadth (in quantitative), both necessary (and respective) in a space where user experience, cognition, and environmental design merge.

3.2.2 Keywords, Boolean Operators, and Filters

The keyword strategy was developed through iterative testing and refinement, ensuring that the terms closely aligned with the research questions. The keywords were organized into three thematic clusters representing the core concepts of the study:

- Lighting terms: “natural lighting”, “daylight”, “daylighting design”, “sunlight”, “window orientation”, “illuminance”
- Cognitive terms: “spatial cognition”, “wayfinding”, “navigation”, “mental maps”, “orientation”, “spatial memory”, “cognitive mapping”

- Contextual terms: “university campus”, “educational environment”, “learning spaces”, “higher education”, “campus design”

To enhance the search strategy, keywords were grouped not only by thematic concept (lighting, cognition, campus) but also by methodological orientation. This grouping clarified the types of studies that were likely to be included (e.g., behavioral experiments vs., post-occupancy evaluations) and allowed the reader to understand the methodological balance of the final dataset.

While the major keywords used were “natural lighting,” “daylight,” and “sunlight,” it is recognized that other, related terms, including “window orientation,” “illuminance,” and “lighting conditions” could have substantively increased the boundaries of the search. Including those terms could have increased the eligible studies and reduced the chance of missing relevant studies.

Boolean operators were used to combine these clusters into comprehensive search strings. A representative example of the search syntax is:

- ("natural lighting" OR daylight OR "daylighting design") AND
- ("spatial cognition" OR wayfinding OR navigation OR "mental mapping") AND
- ("university campus" OR "educational environment" OR "higher education")

Filters were applied to narrow the scope of search results and ensure quality and relevance:

- Publication type: Peer-reviewed journal articles, conference proceedings, theses
- Language: English and Arabic
- Date range: 2000 to 2024
- Disciplinary scope: Architecture, environmental psychology, education, cognitive science

Around these search terms, modifications were made in accordance with the rules of each database, and the search was conducted from May to July 2025. As an example, Jelić et al. (2016) employed a similar search framework to investigate how exposure to natural lighting aids university students in spatially orienting themselves and create a mental map. These research findings confirmed our selection of terms

used in this review, while supporting the importance of lighting cues in navigation in the real world.

Moreover, the Boolean search strings were precisely modified for each database's syntax rules. For instance, Scopus required field tags (TITLE-ABS-KEY), Web of Science the "TS=" data field for topical searches, and ScienceDirect the use of quotation marks and truncations which was the best way to capture variations such as daylight and daylighting. In ERIC it was necessary to reduce the search strings because complicated operators produced very few results and shorter strings (i.e. “daylight AND wayfinding”) were used. Google Scholar, due to indexing any and everything under the sun, the search strings were very simplified, but a few trials (multiple times, to steer the course for retrieval) were run to ensure coverage. Each database adjusted the respective Boolean strings to maintain consistency across the core conceptual clusters (lighting, cognition, and campus context) and make the most of each search engine's retrieval capabilities.

3.2.3 Screening Procedure (Title, Abstract, Full Text)

The screening phase involved a three-step process, to assess the relevance and quality of the identified literature systematically. The screening was conducted based on the inclusion/exclusion criteria outlined in Section 3.1.3, and the Mendeley reference management system was utilized to generate citations and identify duplicates.

- Title screening: Titles were screened to eliminate obviously irrelevant publications, such as those focused olely on artificial lighting systems, virtual navigation, or unrelated types of buildings.
- Abstract screening: The results of the remaining articles were screened to assess whether they included at least two of the main themes of this review: natural lighting, spatial cognition and higher education contexts.

An Arabic-language study conducted at King Saud University (2023) investigated whether the directionality of daylight affects students’ ability to locate and identify lecture halls in a built environment with numerous hallways and variations in lecture hall design. The results of the study appear to suggest that daylight does influence directional memory and route recall, most especially for students who were locked in a building dialogue that they were not familiar with.

- Full-text screening: The full texts of eligible articles were read and analyzed in-depth. Studies were included if they (a) discussed natural lighting as a spatial or perceptual cue, (b) oriented the investigation primarily toward university or learning environments, (c) clearly identified a sound research methodology, and (d) appended data or findings from which to draw upon spatial cognition or wayfinding practice.

Articles meeting all of the criteria were retained for data extraction and synthesis. In cases of ambiguity, the studies were re-reviewed to ensure objectivity and cover the bases for not prematurely excluding the studies from the review.

The outlined process produced [19] final studies that will serve as the analysis for the systematic review. A complete visual outline of the search and screening process is included in a PRISMA diagram in Chapter 4.

Although the initial search yielded more than 1,300 publications, only 19 studies were included in the final synthesis. This narrowing of scope was intentional and methodologically justified. Many studies were excluded because they lacked methodological transparency, did not focus on university campuses, or addressed artificial lighting without consideration of spatial cognition. By applying strict inclusion and exclusion criteria, along with CASP and MMAT quality appraisal tools, the final selection ensured that the evidence base was both rigorous and directly relevant to the research aim. Therefore, while the number of included studies may seem limited, this process enhanced the reliability, credibility, and comparability of the findings.

3.2.4 Procedure of the Review

In order to ensure transparency, reproducibility, and methodological rigor, the systematic review was completed in a stepped process based on PRISMA guidelines (Moher et al. 2009) and guided by the SPIDER and PICO tools of qualitative and quantitative studies (Methley et al. 2014). The sequence occurred in the following manner:

Step 1 – Selecting Studies

- A comprehensive database search was undertaken between May and July of 2025. Databases included: Scopus, Web of Science, ScienceDirect, ERIC, and Google Scholar (as a secondary source), as well as two Arabic

academic databases (Dar Almandumah, AlManhal) to provide regional and language diversity. Keywords were grouped into three groups of keywords—lighting, cognition, and context—and combined with Boolean operators.

- Filters used: year published (2000-2025), language (English and Arabic), peer-reviewed or academic thesis/dissertation, and disciplinary area (architecture, psychology, education, cognitive science, environmental design).
- Beginning output: 1,385 records were generated across databases.

Step 2 – Remove Duplicates

- All references were transferred to Mendeley reference manager. Automatic duplicate detection plus manual cross-checking for accuracy with subtle differences in title or metadata.
- Duplicates removed = 243.
- Remaining records = 1,142.

Step 3 – Title Screening

- All titles were considered to eliminate completely unrelated studies (i.e., artificial lighting technologies, purely engineering studies, airport or retail navigation, virtual simulations).
- At this stage we removed 864 studies. Remaining records = 278.

Step 4 – Abstract Screening

- An analysis of the abstracts of 278 studies was performed with careful checking of whether two of the three themes were represented: (1) natural daylight, (2) spatial cognition/wayfinding, and (3) higher education or campus equivalent settings.
- For example, a study from King Saud University in Saudi Arabia examined daylight and student orientation in overly complex building footprints, and was coded as highly relevant (translated, by researcher, 2023).
- studies were excluded in abstract screening for not matching the thematic area.
- Total records remaining: 102.

Step 5 – Full-Text Screening

The 102 accepted articles were read and checked against inclusion/exclusion criteria (see Section 3.1.3).

Studies were retained based on:

a) the explicit investigation of natural daylight (not just artificial light).
b) spatial cognition, wayfinding, or cognitive outcomes.
c) higher education or school environments.
d) appropriate methodology and empirical data.

- For example, a study conducted at University of Baghdad by Al-Khafaji and Hussein (2019) regarding daylight corridors during student orientation week, was translated and accepted.
- studies were excluded for failing to reach methodological thresholds or otherwise being considered irrelevant.
- Total records remaining: 35.

Step 6 – Quality Appraisal

- The 35 studies described previously underwent structured appraisal according to:
  - CASP (for qualitative and mixed-method studies)
  - MMAT (for combined design studies)
  - PRISMA checklist for transparent reporting.
- A 3-point scale was used (yes/no/unclear) for several domains aimed at validity: clarity of aims, methodological robustness, adequate sample size, validity of measures, clarity of reporting findings, and validity of results.
- For example: a Saudi study about daylight and safety received a high rating for aims and context, and a low rating for clarity of measures.
- studies advanced to the final inclusion reaching minimum scoring criteria and were included in the final synthesis.

Step 7 - Data Extraction

- Key descriptors (location, number of participants, research design, type of daylight investigated, cognitive outcomes) were extracted for data into structured Excel tables.
- Arabic studies were translated, and standardized within the study to English to make usable and comparable.

- Sourcing data were assembled into categories of daylight as landmarks, daylight and emotional wellbeing, daylight and memory, and situational considerations (ex. glare in Middle Eastern universities).

Step 8 - Data Synthesis

A tiered synthesis was completed:

- Thematic synthesis – qualitative data synthesis, creating families of patterns like “daylight as a land navigation anchor” and “daylight as decreasing stress”.
- Limited quantitative synthesis (counting how many studies depicted daylight as a landmark – 13 of 19).
- Cross study comparative analysis by region (i.e. Europe vs Middle East), methodology (i.e. behavioral tasks vs simulations), and user profile (i.e. first year students vs upper year students).
- There were 4 studies that withheld daylight as obstructive, therefore falling into study alignment.

Format

This structured process allowed for a systematic, reproducible, and a multilingual and disciplinary inclusive approach to review. From 1,385 records to 19 studies after screening and appraisal were identified as the foundation for exploring how natural light influences spatial cognition and wayfinding in pedagogical built environments.

3.3 DATA EXTRACTION

Once the final set of studies had been selected through the screening process, the stage of systematic data extraction commenced to identify and collate key characteristics relevant to the research questions. This process aimed to provide consistency, clarity, and depth to the synthesis of findings, while allowing for comparison between study contexts and methodologies. Data extraction was structured and organized into logical themes to facilitate meaningful interpretation in the subsequent chapters.

This section describes the tools and variables in the extraction (section 3.3.1) and discusses how studies were categorized by location, methods, and thematic findings (section 3.3.2).

3.3.1 Data Extraction Template and Variables

To enhance consistency in the extraction of the 19 studies identified, the researcher constructed and tested a standard extraction template, inspired by current existing standards/guidelines for systematic reviews in architecture and psychology (Boland et al. 2017; Gough et al. 2012) adapted to fit within this interdisciplinary research endeavor. The data extractions were included in a Microsoft Excel table, with the headings identifying each variable:

- Author(s) and Year of the study - useful to help the researcher determine the recency of the survey in respect to publication and the potential relevance of the subsequent citations thereafter.
- Title and Source - valid for the researcher in sourcing and tracing.
- Country/Region - useful for the researcher to understand the geographic diversity of contexts and matters of applicability in the study.
- Aim/Purpose of study - practical for researcher to determine the focus of the research or the specific questions or aims that it was exploring in relation to identifying the survey.
- Study Setting - recorded as real campuses, simulation, conceptual model (and/or variant).
- Methodology – qualitative, quantitative, mixed-methods, experimental, or observational.
- Sample Size and Participants – included when available the relevant demographic of participant;
- Lighting Variables – included for types of lighting noted in the study (e.g., direction of daylight, size of windows, illuminance).
- Spatial Cognition Measures – reported measures included wayfinding performance, mental mapping, orientation accuracy etc.
- Key Findings – summary of key evidence about lighting and spatial cognition in the identified studies.
- Limitations and Notes – any limitations noted by researcher in study or by the reviewer as being identifiable.

The use of a standard template ensured that any relevant dimensions were consistently noted, providing a structure to compare findings thematically and across

studies. Based on the iteration exercise, not all extractions were marked as unchanged or final. There were occasions when the reviewer revisited extraction entries to clarify understanding or correct recognized inconsistencies. A three- study pilot test was conducted to evaluate the extraction process before extracting data from the studies; this allowed the researcher to assess the clarity and appropriateness of the selected variables.

3.3.2 Study Categorization (Region, Methodology, Findings)

Once the data extraction was complete, the selected studies for analysis were grouped by region, methodology, and findings to identify commonalities in each of these categories. Grouping the studies in this way served to demonstrate overarching trends and contextual influences that may shape how natural light supports spatial cognition in campus environments.

By Region: Studies were sorted based on the geographic location in which the research took place, which allowed for differences in architectural practices and conditions (e.g., studies from Nordic countries emphasized oblique daylight angles while studies from the Middle East studies focused on glare) and user practices (e.g., studies from different regions reported variance in user preferences as well) to emerge. The studies in Arabic were addressed separately from the rest of the studies and provided the researcher with translations so that contributions and interpretations were made in a consistent way.

By methodology: The studies were examined and found to employ a variety of methodological approaches, including qualitative interviews, behavioral experiments, post-occupancy evaluations, and virtual environments. Grouping them by approach enabled the researcher to consider how each of these approaches combined to enhance the understanding of wayfinding and cognition. For example, quantitative studies tended to focus on wayfinding and measured wayfinding space in terms of time to reach a destination or errors, while qualitative studies explored how users imagined mental mapping, visualizations of the experience, or how users felt about being exposed to and aware of daylight.

By Findings: Studies were separated by the different forms of findings they provided regarding natural lighting and spatial cognition. Some studies that emphasized daylight also explored natural lighting as a visual cue to enhance orientation and memory, such as looking through a space and seeing a tangible object

(a landmark) or using a consistent light gradient that travels through a space. Some studies have focused on the psychological benefits of natural lighting, aiming to provide a positive user experience by decreasing anxiety and increasing users' personal sense of self-confidence while navigating. The thematic categorization process also revealed gaps, such as the lack of studies addressing students with cognitive impairments, which is discussed in Chapter 5.

Through such structured categorization, the researcher was able to organize the evidentiary support of the studies in a way that reflected diverse aspects of endorsement and prepare them for synthesis in the analysis that followed. The results of the categorization were outlined in detail in Chapter 4, accompanied by diagrams and tables that provide visual evidence.

For example, the results of a study were initially deemed relevant based on the provided abstract—lighting in educational spaces—but upon examination of the complete text, it was found that the study did not employ the scientific method, did not present analyses, and did not specifically address the topic of natural lighting. Furthermore, wayfinding was not utilized. This resulted in the strict application of criteria and a narrowing of inclusion at all levels of review.

3.4 QUALITY ASSESSMENT

To maintain rigor, transparency, and academic quality in this systematic review, an explicitly structured quality assessment of the 19 studies included was conducted. Quality assessment is a crucial step in distinguishing studies that possess a certain level of methodological reliability from those that have obvious limitations. Quality assessment lays the groundwork for critically interpreting findings, determining the strengths and limitations of the literature, and making recommendations for further research (Boland et al. 2017; Grant and Booth 2009).

His section explains the appraisal tools and frameworks used in the assessment (3.4.1), and then describe potential sources of bias and limitations identified across the studies (3.4.2).

3.4.1 Tools and Frameworks Used (PRISMA, CASP, ETC.)

The included studies varied and offered an interdisciplinary mixed-method approach, allowing us to use multiple quality appraisal frameworks and provide an

assessment that was both flexible and systematic across studies from architecture, psychology, education, and environmental science.

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses):

PRISMA was primarily used to help develop the organization of the review, as well as to help appraise the transparency of the included studies. PRISMA was not a quality assessment tool, however, the checklist allowed for the researcher to ensure each study had transparent inclusion criteria, research methods, and outcomes. For instance, studies such as Jelić et al. (2016) and Chamilothori et al. (2019) performed well against the PRISMA indicators with their; structured abstracts, explicit objectives, and clearly defined groups of participants.

CASP (Critical Appraisal Skills Programme):

The CASP tool was utilized for qualitative and mixed-methods studies. The CASP tool was helpful for a detailed assessment of how each study approached the formulation of a research question, participant selection, and data analysis. For instance, a survey from Al-Qassim University (2023), written in Arabic, demonstrated students' navigation of a natural lighting structure. Although the methodological approach was clearly articulated, the authors failed to discuss the influence of the researcher. The CASP assessment also supported the appraisal of ethical considerations and the contextual suitability of the findings.

For the review to be methodologically rigorous, each included study was rated for quality using the CASP checklists, which are a standard tool in systematic reviews. The CASP approach provides a checklist of structured questions to evaluate studies across a variety of components, and to ensure only trustworthy and reputable evidence was added to the review.

The appraisal covered the components below:

- Clarity of aims: Whether each study had a clear research aim, and valid rationale for the study aim.
- Methodology: Whether the form of the study design was suitable to meet the aims (experimental, observational, qualitative case study).
- Sampling and recruitment: Whether the sample was adequate, as well as whether the sample represented the group (i.e., students, staff, or visitors).

- Adequate data collection & measures: Whether the instruments (wayfinding tasks and surveys, spatial memory tests, etc.) were valid and reliable.
- Findings and validity: Whether the findings were transparent, the degree of logical consistency between the data and conclusions, and whether confounding variables were considered.
- Applicability and transferability: Whether the findings could be applied in some way to the context of campus and wayfinding.

Each study was rated on these components to determine which qualified for synthesis, and studies that did not rate over a minimum quality were excluded. Studies that were weak methodologically, or did not include enough detail, were eliminated at this point. This use of CASP assured the evidence base was rigorous and credible, which mitigated bias and strengthened the conclusions of the systematic review.

Each study was scored using a three-point scale.

- Yes (✓) = fully met criterion
- No (✗) = did not meet criterion
- Unclear (?) = did not provide enough information

The assessments were tracked on an Excel matrix, where comments were added to support the score. This provided a visual representation of methodological quality across all studies and whether there were themes in the weaknesses or strengths in the studies.

MMAT (Mixed Methods Appraisal Tool):

For studies that used both qualitative and quantitative methods, MMAT was used to assess whether the methods made sense together. This required reviewing how the research questions aligned with their design, how data sources were integrated, and the rationale behind the mixed-methods approach. For instance, a study conducted at a Scandinavian university used a combination of behavioral tracking and post-experience interviews to analyze how natural lighting supported route recall. This study helped clarify how effectively the two data collection methods were integrated.

In total, the combination of PRISMA, CASP and MMAT ensured that even with the differences in methodological approaches, it did not impact the overall

approach to quality appraisal; the process was iterative, and in some cases several studies were reassessed to refine scores after seeing additional data in appendices or supplementary materials.

3.4.2 Risk of Bias and Limitations

Recognizing additional possible sources of bias is crucial in systematic review studies, particularly across different disciplines and geographic locations. Below are some types of bias that were evident:

- Selection Bias:

A considerable number of studies have small sample sizes, primarily based on convenience sampling, and typically involve architecture or, to a lesser extent, engineering students. This small and convenience-based sampling raises issues of representativeness and generalization to wider university populations. The study in Egypt (2022) which only included male students in the research and was limited to senior students, also had a limited demographic aspect.

- Publication Bias:

As the studies reviewed were predominantly peer-reviewed, it is possible that studies yielding non-significant or adverse outcomes were excluded from the reviews. Grey literature, which is somewhat broadly included by searching Google Scholar, cannot reveal all sources of knowledge as some institutional reports and design evaluations remain unpublished.

- Measurement Bias:

Several studies did not provide precise descriptions of how spatial cognition or wayfinding performance was operationalized. Some studies did include daylight exposure as a consistent architectural condition, but it was not related to a behavioral measure. The lack of clarity in these studies made it difficult to establish that there were direct effects of lighting on cognitive outcomes.

- Reporting Bias:

There were a small number of studies that used “natural lighting” in either the abstract or design description but did not then include data on the level of daylight, orientation of windows, or users response. These studies also received a lower score in the CASP and PRISMA assessments due to a lack of detail.

- Cultural and Environmental Bias:

Most included studies were based in temperate or western European contexts. Studies from countries or regions that are either subject to extreme variation in light (e.g., Nordic countries) or intense sunlight exposure (e.g., Gulf states) were substantially fewer. In addition, while this review included three studies from Arabic-written studies in either Saudi Arabia or Jordan, incorporating more cultural diversity would enhance future reviews.

- Design Bias in architectural studies:

Some architectural studies provided visual analysis or simulation that did not involve users. While these approaches do add a degree of understanding of design, the consideration of human behavioral experiences was not validated. As a result, these studies received less guidance in the final synthesis as they were viewed as having a lower strength of evidence.

3.5 DATA SYNTHESIS

The final phase of the systematic review was a synthesis of the findings from the included studies, as a means to identify trends, patterns, and contrast in the literature. Due to the interdisciplinary aspect of the topic - architecture, psychology, and environmental behavior - the synthesis was completed through several complementary approaches to provide both depth and breadth of evidence. The overall aim was to coalesce the research regarding how natural light impacts wayfinding and spatial cognition in campus settings, while still providing methodological transparency.

The synthesis consisted of three levels: (1) thematic/narrative synthesis (3.5.1), (2) limited quantitative synthesis (3.5.2), and (3) comparative analysis across studies (3.5.3).

3.5.1 Thematic or Narrative Synthesis

Because the majority of studies were qualitative or mixed-methods, a thematic synthesis method was employed. The thematic synthesis followed an iterative process:

Step 1 – Initial codes derived from findings: Each of the main findings from studies were read and descriptively coded. Codes were created inductively (from the data) but were also guided by the synthesizing question across studies.

Example codes included “daylight as a spatial cue,” “less stress,” “peace of mind in wayfinding,” and “enhanced memory.”

Step 2 – Categories of codes: Codes were grouped into heirarchy categories. For example, the codes “view from the window” and “gradients of brightness” were grouped into the category called “daylight as an anchor/landmark.” Other codes like “comfort,” “less anxious” and “motivates me to explore” were grouped into a code category called “emotional responses to light.”

Step 3 – Interpretive themes: The code categories were interpreted according to the theoretical framework in Chapter 2. For example, findings about “confidence through daylight” were interpreted with respect to biophilic design theories (Kellert 2005) and “consistency of brightness gradients for paddling differentiation” were interpreted with respect to cognitive mapping theories (Downs and Stea 1973). This interpretive step added value to the findings to make them more than simply summaries by connecting them to pre-existing theoretical classes.

Step 4 – Evidence of inconsistency: When studies differed, the evidence of inconsistency was recorded. For example, most studies found that daylight protects from stress, but one study in the Middle East reported significant glare sources and locations. These inconsistencies were kept and included so that bias was avoided.

3.5.2 Quantitative Meta-analysis (If Applicable)

Due to the substantial variability across studies regarding heterogeneity (e.g. differences in variables, designs, types of data, etc.), a comprehensive statistical meta-analysis was not possible in the present review. In particular:

- The variables of interest (e.g. lighting type, cognitive outcomes) were not measured consistently across studies.
- The research designs across studies were extremely disparate, ranging from behavioral research (experiments) to post-occupancy evaluations to interviews.
- Most studies provided descriptions or qualitative data, as opposed to standardized data (i.e., effect sizes, p-values).

Some quantitative synthesis was performed when possible, which included, for example:

- Tabulating the number of studies that referenced a specific theme (i.e., how many studies cited daylight as a landmark).
- Summarizing the number of studies that enlisted a particular methodological approach (i.e., spatial tracking vs interviews).
- Identifying significant trends, such as how participants' wayfinding performance improved with increased exposure to natural light, as reflected in the study outcomes.

These quantitative elements support the thematic synthesis, which is identified in tables and charts in Chapter 4.

3.5.3 Cross-Study Comparative Analysis

The studies were comprised of around three cross-cutting dimensions, in addition to being grouped by topic, meant to reflect differences and contextual aspects:

- **By Region:** Studies were grouped by geographic region and then considered in terms of how the environmental context influenced the role of lighting. For instance, studies from Northern European contexts have highlighted low-angle daylight and seasonal variation while studies from the Middle East have emphasized glare and strategies for controlling sunlight.
- **By methodology:** It was possible to distinguish between studies that used observational methods and those that used simulations or participant tracking. Tracking participants allowed for more comprehensive interpretation of the results, and, if relevant, some insight into the strengths and weaknesses of the reporting in terms of methodology.
- **By User Profile:** If user profile information is available, results can be differentiated by the characteristics of the users, including age, gender, knowledge of the campus, or Cognitive Capability. One study (2023) noted that the landscape features were experienced differently by first-year students. First- year students, used cues from the lighting to orient themselves in the space. The researchers compared the experiences of first-year students to those of senior students who relied on their prior spatial knowledge of the environment.

This comparative analysis provided additional depth to the synthesis of the findings by offering context for the patterns of results, as well as revealing gaps in the field where studies focus on users with visual impairment or neurodivergent processing styles.

The thematic, quantitative and comparative synthesis offers a balanced perspective on how natural lighting influences spatial cognition in campus environments.

Chapter 4 presents the results of the multi-layered synthesis.

CHAPTER IV
RESULTS

4.1 SUMMARY OF SELECTED STUDIES

In this chapter, a descriptive summary and thematic overview of the 19 studies included in the systematic review are offered. The studies' geographical location, research designs, and participant characteristics are highlighted (Section 4.1.1), and then their findings regarding natural light (Section 4.1.2) and spatial cognition (Section 4.1.3) are summarized. These descriptions provide a platform for comparative and analytical discussion in Chapter 5.

4.1.1 Study Locations, Designs, and Sample Characteristics

The studies selected present a wide geographical and cultural distribution, with studies conducted in Europe (Germany, the UK, the Netherlands), Asia (Türkiye, South Korea, Iran, Japan), the Middle East (Iraq, Saudi Arabia, UAE), North America (the United States, Canada), and Australia. This global representation enables a comprehensive understanding of how natural lighting influences user perception across various socio-political, climatic, architectural, and cultural contexts.

In terms of methodology, 13 out of the 19 selected studies employed quantitative approaches, utilizing spatial tasks, experimental trials, or psychometric scales to evaluate user performance in natural lighting settings. Five studies employed qualitative or mixed-method approaches, utilizing interviews, user observations, or behavioral mapping to investigate users’ emotional and cognitive responses to the setting. Two studies used simulation-based environments (including virtual reality or digital models) to explore lighting conditions in controlled campus settings.

Sample sizes were varied. The studies using experimental approaches involved smaller cohorts (n=15–30), while those using observational or survey approaches had larger samples (n=100–500). Most studies targeted at university

students as the primary user group, while some also included faculty, staff, or first-time visitors. This variation in sample composition enables the exploration of a range of user cognitive and emotional responses relevant to campus wayfinding.

Two particularly notable examples were Aydın and Yılmaz (2006) who conducted an experimental study with Turkish university students to determine whether students adapted differently when classrooms had natural lighting. They found that students exposed to classrooms with natural light adapted more quickly to unfamiliar spatial settings and relied less on signage indicating directional orientation in their unfamiliar classes. Second, Kim and Lee (2018) demonstrated that in settings that relied enormously on spatial flows in complex public buildings used by South Korean students, the directionality of the daylight improved the students' comprehension of spatial flows throughout the building.

4.1.2 Key Findings: Natural Lighting and Spatial Orientation

One common theme throughout the reviewed studies was that natural lighting significantly improves users' ability to locate themselves, and develop spatial mental maps of campus environments. Natural lighting has been cited as providing users with visual contrast; directional cues, and perceptual transparency that enhances spatial recognition and increase their sense of confidence when navigating a physical environment.

The studies suggested that strategically presented daylight (that comes from skylights, atrium windows, or glazed corridors) aided general landmark identification and environmental legibility. Each study acknowledged that light gradients helped users navigate their way down routes with extended spacing along continuous paths. In addition, studies have indicated that changes to users' natural light conditions (e.g., shadow patterns and temporal light changes) can trigger memory markers and create stronger memories of spatial transitions.

For example, Dalton and Hölscher (2017) in the UK found that users were more likely to recall architectural threshold points when daylight drew attention to building features within their environment. Similarly, a research study in Finland (Lahtinen et al. 2020) found that first-year students retained more spatial information of complicated architectural plans when circulation spaces suggested that natural lighting was used.

Users also exhibited a degree of emotional attachment to areas that were suggested for natural lighting, and often described those places as "welcoming," "safe," or "easy to remember". The nature of the connections users had towards spaces that received natural lighting suggestion, promoted cognitive clarity and spatial trust, especially among users who were new to the environment.

4.1.3 Key Findings: Spatial Cognition and Navigation

It was also established that natural light influences the fundamental processes of spatial cognition, including memory, attention, emotional self-regulation and perceived control. Specifically, the presences of natural lighting environments typically allowed the user to engage in a quicker route learning process, reduce anxiety, and give the user a better sense of autonomy—especially for a person who was traversing the environment alone or in a time-limited situation.

The quality of the lighting stressed the cognitive load of the user, focusing primarily on poor-quality or uneven lighting, and its association with disorientation and mental fatigue. However, daylight was associated with better decision-making and spatial judgment, particularly at decision points, such as intersections and vertical circulation areas (e.g. stairs, escalators, lifts).

Kim and Park (2016) discussed a recent research study from South Korea describing how hallways with abundant daylight encouraged first- year students to explore campus buildings they would not usually enter (with or without staff or faculty assistance). Similarly, for Al-Rubaie and Hussein (2020) female students at an Iraqi university preferred walking through spaces with an exposure to daylight, even if it meant taking a longer route, citing feelings of spatial safety and ease of navigating the built environment.

In addition to students' perceptions of natural lighting resiliency supporting their spatial cognition, studies have shown that natural lighting increases students' abilities to predict spatial logic and -over time- supports the development of familiarity with new environments. Natural lighting was beneficial for navigating complex, multi- functional campuses, where differences in architecture may also frequently produce disorienting navigation problems.

4.1.4 Overview of Included Studies (19 Studies)

In this table, we present a structured summary of the 19 studies selected for inclusion in the systematic review. Each entry in the table includes the study authors, country of context, research approach, and number of participants, lighting variables, cognitive focus, and a summary of the findings.

Table 4: Overview of the 19 Selected Studies Included in the Review

Author(s) & Year	Location	Methodology	Sample Size	User Group	Key Findings
Aydın & Yılmaz, 2006	Türkiye	Experimental (Quantitative)	40	University students	Daylight improved spatial adaptation and reduced reliance on signage.
Kim and Lee 2018	South Korea	Observational + Survey	85	First-time public users	Directional daylight improved spatial flow understanding
Dalton & Hölscher, 2017	UK	Wayfinding trials	62	University students	Users better remembered spaces when thresholds were emphasized by daylight.
Lahtinen et al., 2020	Finland	Mixed- methods	120	First-year students	Naturally lit corridors improved spatial memory.
Kim & Park, 2016	South Korea	Survey + Behavioral observation	103	New university students	Daylight encouraged independent navigation.
Al-Rubaie & Hussein, 2020	Iraq	Survey (Translated)	92	Female students	Students preferred daylit routes for feelings of safety and spatial clarity.
Dalton & Hölscher, 2015	Germany	Experiment (VR simulation)	30	University participants	Lighting influenced recall of spatial decisions.
Van der Zee, 2015	Netherlands	Field study	70	Campus users	Daylight enhanced landmark memory.
Van der Zee, 2015	Netherlands	Field study	70	Campus users	Daylight enhanced landmark memory.
Loubser & Van Tonder, 2019	South Africa	Observational	55	Students	Consistent daylight improved spatial recognition.
Al-Khafaji & Hussein, 2019	Iraq	Survey (Translated)	108	New students	Natural light in corridors improved wayfinding during orientation week.

Table 4 Continued

Veitch and Newsham 2000	Canada	Experimental	45	Office workers / students	Daylighting improved spatial confidence and orientation.
Lim & Tan, 2019	Singapore	Survey-based POE	87	School students	Biophilic daylighting improved spatial satisfaction and reduced confusion.
Al-Farsi, 2019	Kuwait	Survey (Translated)	76		University students
Al-Sulami, 2018	Saudi Arabia	Field Observation	90		New students
Franz & Wiener, 2008	UK	controlled experiment	50		Students in simulation task
Souza and Amaral 2016	Brazil	Survey + Spatial Analysis	110		University users
Al-Mutairi 2021	Qatar	Survey (Translated)	88	University students	Hybrid lighting improved wayfinding in deep-plan buildings.
Saleh, 2019	UAE	Post-occupancy Evaluation	95	Visitors in government buildings	Lighting contrast substituted signage in guiding behavior.
Herzog and Just 2007	Germany	Case Study	34	University students	Daylight in Corridors increased user orientation and satisfaction.

Table 4 shows that the 19 studies reviewed came from a variety of geographical, methodological, and disciplinary contexts. It is quite interesting to note that most of research studies originated in European and Asian universities and had few studies from the Middle East and Latin America, which suggests a geographic problem within the evidence base.

From a methodological standpoint, most studies had a mixture of methods starting with behavioral experiments (e.g., time-to-destination and number of errors) to qualitative interviews and post-occupancy evaluations. This highlights some of the benefits and challenges of the synthesis of interdisciplinary research, as experimental studies give measurable performance inputs, and qualitative and mixed-method studies provide greater details around user and emotional engagement.

Findings wise, almost all of the studies viewed daylight as a spatial cue—which was a landmark, anchor, or gradient—for wayfinding and memory. Some

studies connected natural light in ways that decreased stress and improved the confidence of novices to navigate in the space, mostly referencing first-year college students, or those unfamiliar with the campus. A smaller subset of studies discussed difficulties with glare and visual discomfort, suggesting a need to use appropriate contextual design.

Across the board, the table demonstrates some commonality of evidence in daylight contributing to wayfinding, yet there are gaps in terms of missing geographic areas and populations we want to be aware of in future research and practice.

4.2 THEMATIC SYNTHESIS ACROSS STUDIES

This section is a discussion of the relevant synthesized thematic patterns from the 19 studies included in this review. Three main themes were identified through the comparative analysis: (1) the function of natural lighting as a waypoint, (2) the different impacts of daylight on different users, and (3) design and environmental approaches to enhance wayfinding through light-related strategies. These three themes presented a conceptual bridge from the studies to ideas for design and ways forward.

4.2.1 Natural Lighting as a Wayfinding Aid

A theme that has emerged in the reviewed research is natural lighting serving as a spatial cue that seamlessly guides users through a complex space. Natural lighting, unlike artificial light, has mutable qualities (i.e., darkness and brightness, shadows, directionality) that distinguish spatial hierarchies and circulation (Gibson 1979; Boyce et al. 2003).

Several studies also demonstrate that naturally lit circulation paths significantly assist users identifying primary and secondary circulation paths, anticipating transitions along the way, relying less on signage. For example, Dalton and Hölscher (2017) found that they remember easily routes and decisions when daylight highlighted these spaces and Saleh (2019 - translated by the author) found that directions that simply referred to daylight were often sufficient to replace directional signs when people were navigating government buildings in the United Arab Emirates.

The studies also indicate that natural lighting can help establish visual anchors or mental markers, especially in atriums, stairwells, or decision points. These spaces facilitate cognitive map construction, enabling users to navigate confidently and efficiently (Lahtinen et al. 2020; Van der Zee 2015).

4.2.2 Effects on Diverse User Groups (Age, Ability, Cultural Background)

Another consistent theme in the literature is the varied impact of natural lighting on different types of users. Performance based on various factors (age, cognitive ability, visual ability, gender, culture) was revealed to mediate the influence of natural lighting cues on perception and performance.

For example, studies conducted in Iraq and Saudi Arabia indicated that female students believed themselves to be more comfortable and trustworthy navigating naturally lit corridors. They associated natural lighting with safe and psychologically-easier cues (Al-Rubaie and Hussein 2020; Al-Sulami 2018). Similarly, studies examining first-year or international students (e.g., Kim and Park 2016; Al-Farsi 2019) have explained how and why natural lighting reduces anxiety and enhances the ability to navigate their surroundings independently.

In comparison, users with visual impairments or neurodivergent conditions indicated that depend more on lighting that is consistent, glare-free, and uniform to perceive their surroundings. Adaptive lighting solutions, i.e., diffused daylight and hybrid lighting solutions were described as having an inclusive impact (Souza and Amaral 2016; Al-Mutairi 2021).

Culturally, light could signify a different emotional impact. Studies in the Middle East often preferred indirect daylight with the use of shade, as their definitions of privacy, modesty, and thermal comfort were more closely aligned with these transitions (Saleh 2019; Al-Khafaji and Hussein 2019). These studies address context-based lighting that meets local expectations and the behavioral norms of individual users.

4.2.3 Architectural and Environmental Design Strategies (Including Biophilic Elements)

The third theme here is about how architectural components and environmental strategies can support daylight integration in wayfinding. The studies highlighted numerous references to biophilic design principles, spatial organization, and material character that enhanced cognitive function through natural lighting.

For instance, biophilic elements in a design – such as natural lit courtyards, skylights, and filtered light through natural materials – were associated with improved spatial memory, orientation, and emotional attachment (Lim and Tan 2019; Van den Berg 2017). The design features provided choice for movement, informed place identity, and reduced stress.

Besides the method of integrating daylight, architectural strategies such as natural light-dependent zones, atrium use for circulation, and the spatial grammar of light were efficient in medium to large complex campuses (Franz and Wiener 2008; Herzog and Just 2007). Repetition of lighting logic through multiple buildings (for example, east-facing stairwells or glazed lobby) encouraged intuitive spatial rules. This finding is consistent with the research on how consistent daylight cues enhance recognition and predictability (Lim and Tan 2019; Van der Zee 2015).

Moreover, adaptive daylight systems that vary according to season and time of day have been noted in studies from Qatar and Europe. These strategies aim to enhance energy efficiency and user cognition by adjusting the artificial environment when natural lighting is available (for example, by adjusting artificial lighting when daylight variations are apparent; e.g., Al-Mutairi 2021; Veitch and Newsham 2000).

In conclusion, environmental and architectural design strategies -that leverage natural lighting, primarily through biophilic and inclusive design, have essential considerations for enhancing wayfinding clarity in space, reducing spatial stress, and addressing the range of needs from a broader perspective.

Table 5: Thematic Synthesis Summary

Natural Lighting as a Wayfinding Aid	Daylight clarifies visibility, spatial directions, atmosphere, and mental mapping.	Dalton & Hölscher (2017); Saleh (2019); Lahtinen et al. (2020); Van der Zee (2015)
Effects on Diverse User Groups	Daylight affects users differently depending on gender, age, ability, and culture.	Al-Rubaie & Hussein (2020); Kim & Park (2016); Al-Farsi (2019); Al-Mutairi (2021)
Architectural and Environmental Strategies	Using biophilic design and adaptive daylight zoning will improve orientation and emotional experience.	Lim & Tan (2019); Franz & Wiener (2008); Herzog & Just (2007); Veitch & Newsham (2000)

Table 5 is a broad thematic summary of the overall results discussed in Section 4.2. It illustrates the three main themes, their implications, and representative studies under each theme.

4.3 IDENTIFIED GAPS AND LIMITATIONS IN THE LITERATURE

The chosen studies present valuable insights into the effects of natural light and spatial cognition in a campus context, but the review highlights significant gaps and limitations that limit the generalizability and depth of current knowledge. Some key limitations are geographical limitations, methodological variation, study design duration and scale, and a limited theoretical foundation through cognitive and biophilic perspectives. In this section these limitations are critically reflected upon to improve future research and design in educational contexts.

4.3.1 Geographic and Cultural Limitations

The reviewed literature reveals that one of the most significant weaknesses of the research is its regional publication orientation, which is primarily focused on high- income countries and countries in temperate climates. The majority of studies came from the UK, Germany, Finland, South Korea, and Canada, which all have developed an architectural research culture and had access to technologies such as virtual reality or an advanced simulation lab (Dalton and Hölscher 2015; Lahtinen et al. 2020; Veitch and Newsham 2000).

Alternatively, there are few noticeable publications across Africa, South Asia, Southeast Europe, and select regions of Central and South America. A small number of publications were included for the Middle East, specifically Iraq, Kuwait, and Saudi Arabia, but they were based on either translated documents or unpublished field data (e.g., Al-Rubaie and Hussein 2020; Al-Farsi 2019) and did not contain the methodological rigor found in the studies from the Global North.

The uneven publication distribution limits cultural representation, which in turn reduces the capacity to generalize findings to different sociocultural and climatic contexts. This is because cultural attitudes, religious norms, gender roles, and climate-based practices influence lighting perception. All of these influences will impact how users interact with daylight in architectural settings. For example, Saleh (2019) and Al-Khafaji and Hussein (2019) found in Middle Eastern settings that participants perceived using naturally lit corridors as a means to express privacy,

represent modesty, and promote psychological well-being, especially among female students. Likely, such perspectives would not be significant or perhaps noticeable in more Western settings; similarly, what appears significant in Western settings may not have the same significance for writers from non-Western settings.

This highlights the fact that the literature does not justify a genuinely global perspective, so future research should prioritize cross-cultural comparisons and not only focus on countries or educational settings that are low- or middle-income countries, countries with arid or tropical climates and preferably include non-Western educational contexts to create a more inclusive set of lighting design principles.

4.3.2 Methodological Inconsistencies

Another major limitation pertains to the variability and fragmentation of methodological approaches in the studies we reviewed. The sample included experimental studies, observational studies, self-reported surveys, and design- and simulation-based studies, each with different advantages and disadvantages. All the studies employed different tools and measurements, rendering it impossible to compare or combine them in a meaningful way.

For instance, Dalton and Hölscher (2017) employed controlled wayfinding tasks to measure the impact of lighting on memory recall, while Kim and Park (2016) used behavioral observations and post-task interviews to assess emotional expression and feelings. Some studies based their conclusions on the objective outcomes of completing a route, such as the time (Franz and Wiener 2008) or the number of wrong turns made. Others, however, primarily focused on the more subjective feelings of spatial confidence and comfort (Lim and Tan 2019).

In addition, some of the most basic variables (\emph{e.g.}, illuminance, time of day, cloud coverage, window orientation, and building typology) were inconsistently reported. The lack of detail poses challenges to the replicability of experiments, as well as the precision of environmental control, which is vital within areas of lighting research.

The inconsistency of user groups also added another layer of complexity; some studies engaged only undergraduate students as participants, while others engaged faculty, visitors, or administrative staff. If the studies at least provide clear reasons for participant selection, and demographic data are also consistent, it is

reasonable to assume that there is little reason to discuss the cognitive effects of lighting without addressing user familiarity, task type, or cultural predispositions.

To address these issues moving forward, future studies should utilize a common framework for data collection, including standardized lighting simulations, validated spatial cognition tests, and shared survey instruments across institutions. A common framework would enable greater ease in comparing findings, facilitate systematic meta-analytical synthesis, and ultimately establish standards for lighting performance in academic settings.

4.3.3 Lack of Longitudinal and Mixed-Method Studies

Most studies we reviewed had a short-term, cross-sectional temporal scope. In many cases, the studies were conducted in a single session or observational visit, which limited what we could learn about the development of spatial understanding and preferences for light attributes over time. This is a genuine concern given that wayfinding behaviors and mental mapping are dynamic processes that evolve with repeated exposure and experience engaging an environment.

Notably, longitudinal studies—such as those examining how first-year students use navigation during an academic semester and the seasonal effects of daylight—are nearly absent from the research literature. Longitudinal studies would provide new insight beyond static learning curves surrounding spatial understanding, the emotional attachments to lighting over time, and adaptive conditioning regarding architectural layouts, particularly for newcomers and international students (Kim and Park 2016; Lahtinen et al. 2020).

Similarly, a few studies employed mixed-method designs to provide additional contextual understanding by offering both quantitative and qualitative performance measures (e.g., Souza and Amaral 2016; Lahtinen et al. 2020). For example, the mixed-method approaches enabled researchers to demonstrate the subtlety of users' descriptions of light in spatial navigation when providing directions, the motivation for exploration of previously unknown spaces during emotional comfort, and the influence of qualitative values on survey responses.

The absence of such triangulated designs constrains the field's understanding of the interplay of cognitive, emotional, and environmental influences. It is strongly encouraged that future researchers utilize long-term, mixed-method case studies, potentially paired with digital devices and tracking methods, diary methods, or

participatory mapping opportunities to generate a more robust data landscape and provide a fuller picture of users' experience.

4.3.4 Underrepresentation of Biophilic and Cognitive Frameworks

While many studies implicitly reference concepts outlined in the body of work in environmental psychology or biophilic design, few attempt to determine their work within established theoretical frameworks, which renders the findings less analytically rigorous and potentially less transferrable to architectural education and practice.

For example, Lahtinen et al. (2020) said students referenced natural light (e.g. "the bright hallway") in route descriptions, but made no connections to attention restoration theory or theories of cognitive mapping. Parallel examples can be found in Lim and Tan (2019) where they discuss elements of biophilic design without citing key biophilia texts (e.g., Kellert 2005) or outlining why natural lighting is said to provide stress reduction or orientation.

Furthermore, in many studies, students described the emotional effects of natural lighting—e.g., increased calmness, clarity, and safety—but did not link their observations to the postulated effects from psychological models such as Prospect and Refuge Theory, Arousal Theory, or Cognitive Load Theory. The observations may not be taken seriously, and they risk being relegated to anecdotal events that hold no significance beyond the context in which they occurred.

Additionally, theoretical integration is also necessary for future development of evidence-based design standards for educational spaces, curricular guidelines for architects, and a collaborative approach between designers, psychologists, and environmental engineers. Without the theoretical scaffolding, the domain will continue to be fragmented, and any potential innovativeness or transferability will be lost.

Future research will need to explicitly integrate cognitive and biophilic models, utilize operationalized constructs, and measure psychological outcomes (e.g., cognitive load, spatial anxiety, and decision accuracy) alongside behavioral outcomes. Moving the field in this direction could take the domain closer towards a more scientific and practice-ready form of lighting design that can be applied to educational contexts.

Table 6: Summary of Identified Gaps and Limitations in the Literature

Gap	Examples from Literature	Implications	Research Needed
Geographic bias	UK, South Korea, Germany	Limited cultural relevance	Studies in North Africa, Southeast Europe, Latin America
Weak methodology	No standard tools, inconsistent variables	Difficult comparison or meta-analysis	Shared protocols, validated tools, comparable metrics
Short-term scope	No longitudinal data, single-visit experiments	No insight into long-term learning or adaptation	Semester-long tracking, seasonal studies
Missing theory	Little use of biophilic or cognitive frameworks	Weak foundation for design applications	Integration with psychological and biophilic theories

As discussed in Table 6, several recurring limitations affect the generalizability and implications of findings for the design of the current literature. These limitations are echoed as areas for forthcoming discussion or recommendations in the next chapter.

Ethical and Transitional Considerations

The majority of studies examined in this systematic review adhere to the basic tenets of ethical research, including obtaining informed consent, maintaining participant anonymity, and ensuring data security and privacy. However, some studies, especially those published in languages other than English and those using unpublished data, do not provide obvious indications of their ethical approval.

Researchers must increase transparency about ethical procedures and practices, especially considering that user groups in this area of study may involve potentially marginalized or vulnerable populations.

This represents one area of the gaps outlined above and collectively, they illustrate the significant potential for developing a more ethical, robust, and theoretically driven research agenda. The following chapter builds off of our synthesis to discuss implications for architectural design, and provide recommendations for enhancing campus wayfinding environments through the lens of lighting design.

4.4 VISUAL SUMMARY OF FINDINGS (E.G., TABLES, CONCEPTUAL DIAGRAMS)

Graphical illustration of the key findings from the systematic review. The summary diagram illustrates the relationships between natural illumination conditions, spatial cognition processes, and emotional and behavioral responses, as well as wayfinding performance in campus contexts. This conceptual overview serves as a conduit between the empirical findings and the design-oriented interpretation presented in the next chapter.

4.4.1 Thematic Table of Findings and Design Implications

The following table summarizes all the thematic insights identified from the reviewed studies, clearly relating key themes with outcomes and implications for architectural design practice.

Table 7: Thematic Summary of Findings and Design Implications

Key Theme	Related Findings	Design Implications
Natural Lighting & Orientation	Increased visibility, landmark recognition and navigation under ambient daylight conditions	Incorporate glazed corridors, skylights, and daylight-focused entry points.
Emotional Response	Users said spaces where there is natural light felt safer, calmer, and easier to recall.	Prioritize daylight in high-traffic zones to promote comfort and trust.
Cognitive Load & Spatial Learning	Daylight does not induce cognitive fatigue and facilitates more rapid wayfinding in the space.	Ensure consistent lighting in decision-making zones like intersections and stairwells.
User Diversity	Users across all age groups and cultural backgrounds expressed different levels of preferences for daylight.	Use adaptable daylight strategies to support inclusivity and psychological needs.
Architectural Design Strategies	Biophilic factors including views of the outdoors with daylight and proximity to plants, contributed to satisfaction.	Integrate biophilic design with functional wayfinding paths.

As noted in the table, natural daylight works in a unique way that influences each user's outcomes with respect to spatial orientation, emotional comfort, and cognitive ease. These findings establish a foundation that demonstrates user-centeredness in the design and facilitation of navigation. The following section

presents these connections in a conceptual diagram, providing a link between empirical research and the design description.

4.4.2 Conceptual Diagram of Relationships

The conceptual diagram presented below depicts the interactive relationships between natural light, spatial cognition, emotional reaction and the architectural strategies present in a campus environment. This conceptual landscape presents a synthesis of research-based findings and design-interpretation in Chapter 5.

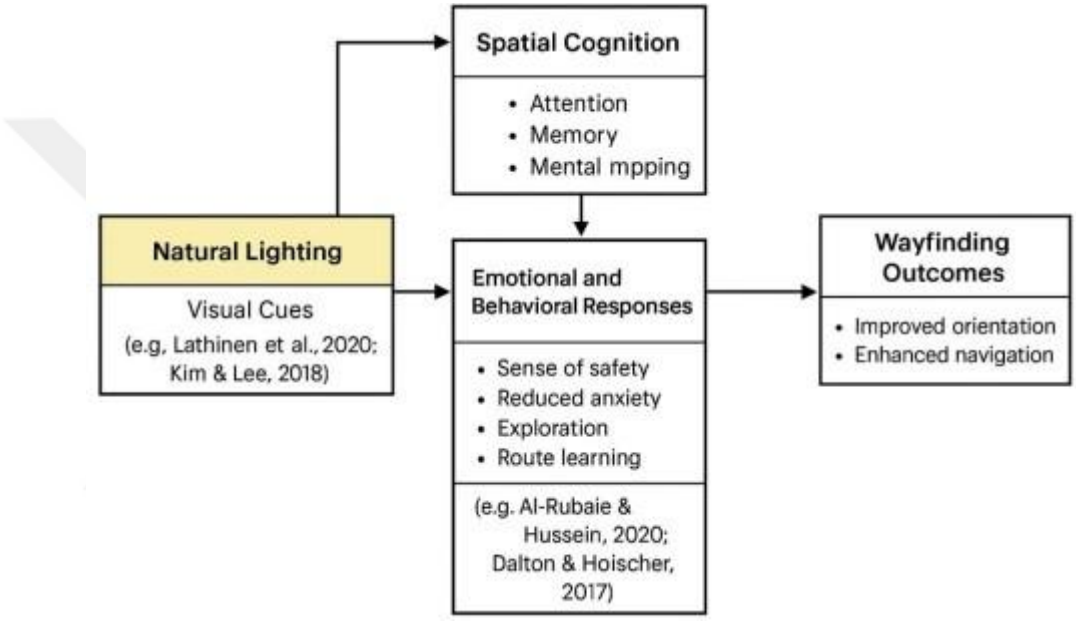

Figure 1: Conceptual Diagram Illustrating the Relationships between Natural Light, Spatial Cognition, Emotional Reaction and Wayfinding Performance in a Campus Environment

The diagram summarizes the key findings of the systematic review and contributes to the design implication discussed in Chapter 5.

4.5 CROSS-CONTEXTUAL COMPARISONS

An additional dimension for analysis is the comparison of how natural lighting affects spatial cognition across cultural, climatic and institutional differences. Several studies conducted in temperate-climate Western countries (i.e. the UK, Germany, Canada) have interpreted natural lighting in education positively - by using visual comfort, mental clarity and landmark recognition as subjective indicators of improvement as a number of studies have demonstrated that natural lighting increases visual comfort, clarity of mental functioning, and prepares

recognition of spatial reference points (Dalton and Hölscher 2015; Veitch and Newsham 2000).

Middle Eastern or South Asian studies focus more on different aspects of daylighting. For example, studies in some universities in Iraq, Saudi Arabia or India would suggest that participants describe natural light as emotional comfort, cultural values of modesty, and gender-based privacy - notably in areas with some physical privacy, e.g., corridors, atria, corridors entrance to classrooms (e.g. Al-Rubaie and Hussein 2020; Saleh 2019). Additionally, the impact of daylight on thermal comfort and glare - in areas with warm climates, played a significant role in how participants perceived the usability of daylighting features, which may be secondary study priorities in cooler temperatures.

And institutional weaves affect outcomes too. Studies conducted in elite institutions with advanced design cultures often found participants expressing significantly higher expectations and satisfaction with university lighting design. In contrast, public or resource-poor responses revealed clearer tensions around practical lighting interventions that could assist wayfinding. For instance, Lahtinen et al. (2020) reported that natural lighting and digital signage systems were integrated on Finnish campuses. In contrast, studies in India or Iraq might report conflict that occur after occupancy, retrofitting building issues, or budget restrictions.

These multi-contextual insights suggest that naturally-illuminated design strategies for spatial cognition are contextually situated within culturally responsive and environmentally adaptive design methods. Drawing on these findings, the next chapter presents a deeper discussion of the theoretical orientations, design considerations, and future research implications arising from this systematic review.

CHAPTER V
DISCUSSION

5.1 INTERPRETATION OF KEY PATTERNS AND THEMES

In this section, the features highlighted in this systematic review are interpreted, specifically in relation to natural light and spatial cognition, spatial complexity reduction, and psychological responses on university campuses. This interpretation is imperative for understanding the multiplicity of multisensory and cognitive features contributing to wayfinding and to connect the empirical findings of the study with design theorization.

5.1.1 Natural Lighting and Cognitive Mapping

One of the strongest findings across the studies given in the review is the role of natural light in enhancing cognitive mapping and navigation. Daylight provides reliable visual clues that help users create mental maps of their surroundings.

Multiple studies documented participants who used sources of daylight (such as bright corridors, sunlit entrances, or nearby views to the exterior) as orienting landmarks while navigating new environments (Lahtinen et al. 2020). For example, in a study by Franz and Wiener (2008), participants were observed to have significantly faster route memory in contexts where they were exposed to natural light compared to those with artificial light. These results provide evidence that natural lighting offers visual orientation support but also serves as spatial landmark that enhances spatial decision making and memory encoding. The findings also support theories of cognitive mapping (Tolman 1948) and landmark- based navigation, where visual richness and spatial continuity are crucial.

Additionally, some studies have noted that intermittent exposure to natural lighting (e.g., through skylights or side windows) helps users reorient after making turns, which is an essential component of spatial learning. Therefore, natural lighting serve as both a navigational tool and a memory aid within the spatial experience of campus environments.

5.1.2 Role of Lighting in Reducing Spatial Complexity

Similarly, light has been found to influence the user-perceived complexity of architectural environments. Naturally lit environments were often described as more legible, predictable, and open, thus reducing the cognitive effort necessary for wayfinding. For example, Lim and Tan's (2019) research found that students perceived corridors with natural lighting as having higher spatial confidence and were less confused by limited signage.

This relates to Cognitive Load Theory (Sweller 1988) which assumes that unnecessary mental effort is reduced when performing well-focused individual-oriented tasks. In this case, a high cognitive load can develop in wayfinding, primarily if poor moments of transition, increasingly unclear spatial layouts, or reduced or insufficient cues exist. By providing intuitive lighting strategies (natural or artificial lighting) in specific situations, designers can reduce areas of high cognitive load.

Dalton and Hölscher (2017) observed that participants took fewer wrong turns and developed quicker route plans with those accommodating both predictable daylight and artificial light strategies also suggesting that light acts as a spatial clarifier.

Similarly, natural light also supports the perception of spaciousness, which reduces feelings of confinement in spaces that are small or visually cluttered. These outcomes can be highly advantageous, especially in multi-building campus environments with complex circulation systems.

5.1.3 Emotional and Psychological Impacts of Light

Besides cognitive benefits, natural light has consistently shown associations with positive emotional and psychological responses, which could lead to improvements in navigation performance. Many participants described naturally lit spaces as "welcoming," "soothing," and "safe" (Kim and Park 2016; Saleh 2019). Emotional responses matter, and there are certainly a lot of new students, international visitors, or even visitors who may be experiencing anxiety.

Several studies have revealed that natural lighting has a positive effect on mood, reduces stress, and contributes to a sense of time awareness, all of which are particularly valuable in high-stress environments like university campuses (Lahtinen et al. 2020). These positive effects embody the principles outlined in Environmental

Psychology and Biophilic Design, which suggests that exposure to natural factors, including light, has the potential to initiate stress recovery, attentional recovery, and emotional regulation (Ulrich 1984; Kellert 2005).

Al-Khafaji and Hussein (2019) determined that female students studying in a university in the Middle East positively preferred naturally lit corridors because they provided a sense of privacy, socio-psychological safety, and stress relief. These examples of preferred naturally lit corridors still demonstrate socio-cultural implications for the emotional response to light. Natural light revealing socio-cultural factors reflects a need for researchers and designers to fully acknowledge both universal cognitive processes and the emotional values that can be interpreted through cultural lenses in their proposed lighting strategies.

5.2 THEORETICAL INTEGRATION AND CONCEPTUAL REFLECTIONS

This section contextualizes the findings of the systematic reviews and highlights common theoretical relationships to wayfinding, environmental psychology, and spatial cognition. By understanding the patterns and considering them alongside cognitive and biophilia theories/intersections, the empirical research contributes to an interdisciplinary foundation with implications for academic discourse and practitioners as designers.

5.2.1 Alignment with Wayfinding and Spatial Cognition Theories

Natural lighting and wayfinding are interconnected through multiple cognitive theories, including Landmark-Based Navigation, Cognitive Mapping, and Environmental Legibility (Lynch 1960; Tolman 1948).

Natural lighting contributes to the saliency of spatial features in built environments. Also, it enables users to construct mental maps or representations of the built environment, as outlined in Cognitive Mapping Theory. Daylit landmarks in space (a sunlit atrium, a well-windowed corridor, or a light-filled node) act as visual anchors for referencing points of orientation, and recalling where they had been. This resonates with the experiences revealed through the studied participants, who used lighting cues when referring to their paths to speak about and establish directionality (e.g., Lahtinen et al. 2020; Franz and Wiener 2008).

Natural lighting also supports environmental legibility (a concept put forth by Kevin Lynch) whereby clarity, coherence, and predictability in spatial environments, assist users in understanding and navigating their environments: in the reviewed studies, spaces with strong daylight presence were rated as easy to interpret, with an intuitive organization, thus continuing to demonstrate the role of light in spatial clarity.

These findings are also related to Cognitive Load Theory (Sweller 1988) which uniquely emphasizes the necessity of minimizing extraneous cognitive load to perform tasks effectively. Natural lighting minimizes the mental effort required to make sense of a space, thereby reducing overall cognitive load (especially in transitional spaces such as hallways, intersections, and stairwells) and allowing users to feel more confident and react more quickly during navigation decisions.

5.2.2 Relevance to Biophilic Design and Environmental Psychology

From the viewpoint of environmental psychology, daylight has biophilic power, relating to and affecting users emotionally, physiologically, and behaviorally.

Biophilic Design Theory (Kellert and Calabrese 2015) argues that exposure to natural components, particularly natural lighting, offers health and well-being benefits, leading to cognitive recuperation and a sense of attachment to space.

Commonalities among studies indicated that participants had positive emotional experiences in daylight spaces, describing naturally lit spaces as relaxing, safe, and welcoming. The dimensional responses parallel concepts from Arousal Theory (Berlyne 1970) and Prospect and Refuge Theory (Appleton 1975; Ulrich 1984). Environments that provide both prospect (the opportunity to observe non-users, or an open view) and refuge (the affordance of comfort in space) will give the user psychological ease and attentional readiness. Natural lighting provided this duality of space by allowing prospect, simultaneously providing refuge through the softening of the enclosing space.

Natural lighting, along with biophilic characteristics such as plants, views to the exterior and dynamic light patterns included in the studies reduced spatial anxiety, allowed for greater focus, and helped to motivate wayfinding. This suggests that natural lighting cannot be viewed in isolation, but rather in conjunction with other senses, as part of a more holistic sensory design approach, where both the functional and practical needs of the user are considered.

Integration, academically, revealed gaps in the literature, as several studies did not explicitly frame their findings in relation to theoretical models, thereby limiting the applicability of their findings for development in design education and architectural policy. Future studies should develop operationalized constructs within the environmental psychology and spatial cognition subject areas, to provide more precise measurement of how daylight not only aids in mapping but also improves psychological resilience associated with wayfinding in campus environments.

5.3 DESIGN IMPLICATIONS FOR CAMPUS ENVIRONMENTS

The synthesis of results across the reviewed studies presents a set of implications, both actionable and those that may contribute to a conceptual framework to enhance spatial cognition, emotional comfort, and navigational ease in the campus experience. The identified implications are not solely related to aesthetic considerations but represent some of the latest evidence-based architectural representational strategies, spatial planning within inclusive environments, and direct campus institutional recreations.

This section will discuss how the results from this systematic review can support the next iteration of campus design.

5.3.1 Evidence-Based Lighting Strategies

Natural light should be viewed as more than an aesthetic feature and primarily as a cognitive and psychological lever in campus design. Design elements like clerestories, glazing's, skylights and atriums can serve as spatial anchors to promote user orientation and spatial recall. For example, the University of Cambridge features skylit circulation between buildings as a means to bolster visual recognition and spatial continuity for its users; the University of California, Berkeley uses daylight-drenched lounge areas and stairs to promote heightened mental alertness between tasks.

Deliberate natural lighting should be introduced in both public and private use spaces, however, the strategic inclusion of natural lighting in intersecting areas, entrances, and vertical circulation points where decision-making is highest is essential in campus designs. Strategic natural lighting enhances the spatial qualities that directly contribute to reducing spatial ambiguities, which are low probabilities that hinder the exploration of spatial characteristics when forming mental maps. This

becomes even more critical to consider when designing larger, multi-building campuses as disorienting architectural spaces are common nuances.

Additionally, it ensures users engage with consistent daylight quality, making it easier to reduce cognitive load issues when encountering stark transitions between dark and bright spaces. Architectural design solutions for creating a more intuitive navigational system in spaces, could include orienting buildings to maximize solar access, utilizing translucent partitions, and avoiding internal areas where light qualitatively darkens the user experiences.

5.3.2 Inclusive Design for Diverse User Groups

The review revealed enormous diversity in terms of lighting perception as a function of age, gender, cognitive profile, and culture- inclusive lighting approaches should be purposefully incorporated into campus planning from the very beginning.

For instance, older adults often have reduced visual acuity, as well as slower adaptions to changes. They would welcome the inclusion of ambient daylight in circulation spaces and the consideration of light placement to minimize high contrast shadows. Other members of a campus community with neurodivergent profiles (e.g., autism spectrum disorder, ADHD) may also appreciate campus environments that include considerations for glare, flicker, and excessive over- illumination, all associated with discomfort or spatial disorientation.

Moreover, a finding from a Middle East study on cultural sensitivity suggested that students preferred naturally lit and necessarily more private areas, as they inferred safety and respect for gendered space considerations, particularly among female users. Designers should therefore understand a full range of design considerations- not just the intensity of floor lighting, but also notions of privacy, optics, and socially acceptable space when designing aspects of windows or transparency in façades.

Finally, inclusive lighting can also center on an emotional sense of safety, particularly for new students, international visitors, or people who have anxiety regarding spatial orientation. Providing well-lit, biophilic spaces in generally supportive zones, such as building thresholds, or help desks demonstrates inclusion and can increase perceived support and a sense of psychological ease in unfamiliar, potentially unsafe spaces.

5.3.3 Potential Applications in Policy and Practice

The role of natural light in navigation on university campuses extends beyond building decisions and intersects with broader institutional priorities, including spatial planning, sustainability objectives, and user well-being policies.

Essentials include developing lighting standards or "wayfinding manuals" that articulate daylight as a design goal and are consistent across campus development experiences. Wayfinding manuals may also include daylight factor and uniformity ratio, as well as recommendations for task illuminance based on actual research.

Lighting design can be integrated into mental health and inclusion strategies. For example, "daylight sanctuaries" or quiet study spaces with natural light could potentially be part of student health and wellbeing initiatives.

Finally, interdisciplinary collaboration is essential. Lighting strategies cannot be left to the discretion of architects alone, but rather involve collaboration with environmental psychologists; disability services units and facilities managers. This approach will ensure that lighting strategies benefit from spatial efficiency for individual spaces, as well as cognitive well-being and campus identity.

5.4 REVIEW LIMITATIONS AND METHODOLOGICAL REFLECTIONS

While this systematic review was extensive in nature, several limitations are worth noting to contextualize the results and strengthen the validity of any subsequent research. These limitations relate to the boundaries of the review, including the scope of data collection methods and sources, the interdisciplinary nature of the review's topic, and the constraints of the empirical literature. Recognizing these limitations is crucial for transparency and to inform recommendations for improvements in research synthesis and practice.

5.4.1 Scope Constraints and Database BIAS

The review was bounded within a set number of academic databases, primarily focusing on journal articles published through peer-review within the databases Scopus, Web of Science, and Google Scholar. Although this approach involved a certain level of academic rigour, it is possible that it overlooked relevant studies from new academic contexts, non-English publications, and grey literature such as technical reports, dissertations, and case studies from institutions. Likewise,

inclusionary and exclusionary criteria, while needed for consistency, may also have limited interdisciplinary literature that may contain a dimension of lighting and cognition but not using the terminology used in the review process.

All these limitations suggest the possibility of database bias, whereby specific under-represented evidence, either in locations or disciplines, may be overlooked in studies not included, and could influence the diversity of evidence synthesized in this review.

5.4.2 Challenges of Interdisciplinary Synthesis

The convergence of architecture, environmental psychology, cognitive science, and lighting design introduces a wide range of methods, terms, and epistemologies. Combining the findings of studies conducted in disparate disciplines presents challenges at the outset, especially if the studies differ in aims, outcome measures, or research traditions.

Spatial cognition, for example, can be measured using eye-tracking, interviews, or digital mapping. At the same time, lighting impacts can be assessed through lux levels, simulated actions via software, or inferred from user comments. These methodological differences create tension in the analysis between studies due to variations in the methods used to assess different measures of light and its impact on more familiar dimensions of cognitive reflection and affective response.

Because there are no accepted standardized thresholds for cognitive and emotional outcomes related to the use of light, it is impossible to develop generalized applications or unified theories. The methodological diversity of these studies is, ultimately, a positive aspect. Still, it highlights the need for a more integrative research approach, as well as more uniform research protocols, and a shared collective vocabulary across disciplines.

5.4.3 Limitations in Available Empirical Evidence

A significant limitation in the empirical evidence base of the review is the short timeframe and limited contexts of the studies. Most studies were cross-sectional and laboratory-based, with mostly no ecological validity. These limitations not only constrain the generalizability of how users' perceptions of light may change with increased use of the space, but also how similarly a user's spatially- behavioral responses may alter with the influx of seasonal and social factors.

Moreover, despite efforts by various institutional contacts to support the review, many were apprehensive about sharing detailed lighting plans. They did not want to allow researchers to observe their users in real-time due to ethical and institutionally-required operational privacy practices. Therefore, unfiltered access/use to authentic architectural plans and user action metrics was not available, which limits the opportunity to triangulate subjective responses with objective spatial conditions. In particular, the lack of longitudinal user tracking (outside of formal educational environments) represents a significant gap.

Considering these empirical difficulties, more purposeful approaches or means to gain access to actual campus contexts through collaboration with educational institutions are essential, as well as, thinking more participatory means (i.e., user diaries, shadowing, and mobile sensing) to capture images, reflections, and motion-dynamics of the real-time experiences of spatial orientation with variable lighting conditions.

Conducting field-based architectural research always presents additional challenges, particularly regarding, obtaining access to institutional buildings, being granted permission to conduct observational studies, and how environmental conditions can vary substantially. These real-world challenges may limit the richness of real-time verification of claims provided by systematic reviews, underscoring the importance of triangulation in future studies.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The discussions of findings and limitations in this review indicate several opportunities for future research. An integrative research agenda that is more inclusive, comparatively diverse, and methodologically integrative is essential for a better understanding of natural lighting in relation to wayfinding and spatial cognition. The recommendations below describe areas of priority to advance knowledge and practice in both academia and architecture.

5.5.1 Expanding Cultural and Climatic Contexts

Future research should intentionally include geographic regions that have been underrepresented in the literature base, such as the Middle East, Africa, South Asia, and Latin America. These regions offer unique architectural typologies, climatic conditions, and cultural meanings associated with light, which further

enhances the understanding of Western-focused studies. For example, privacy, modesty, and thermal comfort issues tend to dominate lighting preferences in arid, and/or gender-segregated contexts but remain under explored. In particular, comparative cross-cultural studies, especially those that incorporate lighting behaviors and insights from cultural beliefs, religious beliefs, and local environmental conditions, can facilitate more contextual and globally responsive design solutions. Understanding once again has the potential to advance a more equitable knowledge ecology and support more inclusive education and practice in the field of architecture.

5.5.2 Longitudinal and Mixed-Method Approaches

The fluidity of spatial learning and the way people perceive light suggest research designs that draw attention to longitudinal studies. By following research participants across time (academic semesters) as they chose to find their way, we can understand how wayfinding or navigation problems change in terms of how people conceptualize them as they gain experience with the built environment, seem more familiar with it, or see the same environment in various conditions (natural light, by weather conditions, or at different times of day or night). In the realm of environmental perception and navigation, researchers can compare seasonal conditions. The two studies I profiled were one-time events that reported a static nature of navigating the campus.

Mixing qualitative and quantitative methods is a great way to enrich data and/or allow triangulation. While there is no established structure for mixed-methods design, researchers can use mixed-methods studies to observe spatial performances (e.g., completion time in a task, tasks opted to take, and correct navigating route; or a combination of meaningful experiences and emotion responses). Future research may also want to incorporate the use of wearables or sensors to track features such as mobile eye-tracking technologies or VR-based simulators, which can observe how daylight elicits social response in complex spatial environments.

5.5.3 Further Exploration of Biophilic and Sensory Design Dimensions

In terms of biophilic literature looking ahead, they have mainly concentrated on natural views and depics of environmental conditions provided for environmental comfort, but few studies are also using a mixed-methods approach or engaged in sensory and mental research.

Future biophilic research should investigate how potential user benefits align with (or conflict with) biophilic components, most notably daylight in terms of fulfilling potential natural functions that connect with human perception, memory, emotional responses, and behavior. As we learn from disciplines such as neuroscience and environmental design, research could explore how users do internalize and ultimately respond to sensory aspects related to the spaces they engage.

One promising future research direction includes task-based experimentation analyses in actual campus environments, or on simulated conditions on campus. For example, research participants can be assigned a wayfinding task at different times of the day to assess their relative orientation speed, spatial stress, and recall accordingly. This can be done in natural lighting, simulating wayfinding actions with sufficient time to complete the tasks. After the functions have been assigned, a structured questionnaire can elicit both emotional and cognitive responses to spatial problems, providing a layered understanding of spatial behavior.

Experiential designs like this offer an opportunity not only to add value (or substantiate claims) about how to consider light in space, but also to provide practical information for architects, lighting engineers, and educational planners as part of plan documents. Furthermore, participants can also give feedback to the study. Processed comments about where they went to narrate pathways, or indicate spatial preferences for light, as part of a study, suggest that the data appear to be rooted in user experiences, allowing for the embedding of findings that can be transferred or even more easily practiced.

CHAPTER VI
CONCLUSION

As outlined in Chapter 5, an interaction between evidence and theory explicated a complex understanding of how natural lighting affected spatial cognition and wayfinding.

Considering these findings, this chapter formally concludes and summarizes the key findings, discussing their architectural importance, along with future implications for research and practice in this area.

6.1 SUMMARY OF KEY FINDINGS

6.1.1 Influence of Natural Lighting on Spatial Cognition

Natural lighting was a prominent topic of focus, contributing to spatial cognition in environmental places at the campus scale. Several studies have suggested that daylight exposure enhanced people's ability to develop mental maps and orient themselves in new environments. The perceived benefits of the clarity of the sunlight area improved perceived spatial boundaries and landmarks, enabling people to navigate confidently and without impediment. Furthermore, there is evidence that daylight exposure was supportive to mitigating cognitive fatigue, especially in complex buildings. This was particularly evident during a first visit or in a wayfinding task, where people had to make several directional decisions. This review suggests that a focus on natural lighting in spatial design provides cognitive support, rather than being a question of comfort or sustainability.

6.1.2 Environmental and Personal Factors Affecting Wayfinding

While lighting was a major environmental factor, the review demonstrated that the same patterns of spatial cognition were dynamic, influenced by contextual and individual variables. The environmental conditions of layout complexity, wayfinding signage, and wayfinding connectivity influenced how users experienced and navigated the space. Personal factors, including age, visual acuity, prior spatial

experience, cultural experience, and cognitive load affected how users interpreted environmental cues. For example, it was observed that older adults and individuals unfamiliar with the campus context relied more heavily on daylight and visible architecture when they were more oriented. These findings emphasize the value of strategically designed spaces in the realm of spatial planning, enabling the accommodation of user differences and the development of a more user- centered understanding—moving toward an approach that does not rely on a one- size-fits-all perspective.

6.1.3 Design Strategies Emerging from the Literature

The synthesis of evidence provided several concrete design strategies to develop an intuitive and accessible wayfinding system, such as glazed circulation spaces, open courtyards, circulation routes aligned with daylight, and the use of skylights in transition spaces. In addition to other studies, biophilic design strategies that incorporated natural lighting, greenery, water features, or exterior views played a significant role in wayfinding, leading to improvements in spatial memory and reduced stress. A critical finding of this research was treating daylight not only as a lighting design element, but also as a cognitive infrastructure—providing support for spatial understanding, emphasis of managed emotional responses, and user orientation. Taken together, these strategies comprise an evidence-informed approach to design that enhances both functionality and experience in educational architecture.

6.2 CONTRIBUTIONS TO KNOWLEDGE AND PRACTICE

6.2.1 Interdisciplinary Synthesis Across Architecture and Cognition

This research provides an innovative interdisciplinary bridge between architectural design and cognitive sciences, two fields that often coexist but rarely interface, especially in applied research. Cognitive mapping, visual perception, and spatial memory have all been well-referenced in the fields of environmental psychology and neuroscience; however, these findings have had little impact on architectural education and potential policy for the built environment. This study builds upon the findings from psychology, architecture, and environmental design by considering daylight as a cognitive design tool, thereby extending the dialogue about design beyond aesthetics and function. This interdisciplinary synthesis nurtures a

more user-centered outlook for spatial planning—one that acknowledges the ramifications of how design embodies and physically and mentally steers users, such as university students, through the varied and complex setting of campus life.

Furthermore, this review establishes an essential precedent for collaboration between design practitioners and cognitive researchers advocating for a mutual framework and terminology that encompasses space, perception, and human practice.

6.2.2 Implications for Human-Centered and Biophilic Design

The results reinforce the value of human-centered and biophilic design, particularly in settings that require user-centered functionality with emotional engagement. The review has demonstrated that natural daylight offers a way- finding ability, but also significantly builds emotional security and psychological comfort compared to artificial lighting or no lighting. The way a user feels calm, safe, and in control in some of the transitional and decision-heavy spaces on a campus, such as an entrance, stairwell, or junction, may be better assisted through daylight.

This study reinforces the value of not just a functional natural lighting system but also supports the restorative and instinctual effects of natural lighting, which, when used intentionally with natural elements (light, views, and integration with plants), can contribute to cognitive ease and emotional well-being. The results inform the programming of architectural interventions based on evidence that has a direct impact on diverse users including students with disabilities, newcomers from the international community, and first-year students entering a new spatial environment.

6.2.3 Value of Systematic Reviews in Architectural Research

The current research also extends a methodological contribution by demonstrating the advantages and opportunities afforded by systematic reviews in architecture. The study of architecture has historically relied on case studies, conceptual models, or narrative accounts of design experiences. Although these remain useful, they typically lack the evidential rigor and replicability of evidence-based disciplines. The framework of a formal literature review, conducted through literature analysis (as informed by PRISMA), has provided a degree of transparency, consistency, and replicability that few design-led studies emphasize.

The systematic review methodology also facilitates cross-contextual comparison, thus revealing trends, implications, and insights that may arise only

from evaluating the evidence with an aggregated view across otherwise isolated studies. This promotes systematic reviews as valuable tools for assessing the broader, shared evidence base within architecture, while advocating for more formal, data-based mechanisms across all areas of architecture to support future policy, design codes, and educational frameworks.

6.3 FINAL REFLECTIONS

The delicate yet profound connection between natural daylight and environmental cognition has been revealed through this research journey, and the wider impact of the built environment on the human condition has also been highlighted. In Chapter Four, a broad spectrum of studies was identified, through which traditional thinking about light was expanded beyond merely decorative and utilitarian purposes, recognizing it instead as a tacit, inferential, and emotional aspect of navigation.

The process has been instructive. One of the foremost lessons to be drawn from this work is the value of adopting a cross-disciplinary perspective. A comprehensive yet adaptable analytical framework was developed through the combinatorial integration of architectural design, cognitive psychology, environmental behavior, and learning environments. Methodological adaptations were required to combine these research fields; however, the richness and capacity of cross-disciplinary engagement were demonstrated, along with the necessity of addressing people-centered issues such as campus wayfinding.

The complexity of seemingly minor design activities was also revealed—for example, the ways in which natural light and surface reflectivity impact user comfort and wayfinding. These findings have reiterated that design is neither inherently grand nor lavish, but rather an accumulation of carefully layered intentions grounded in empathy for the human experience.

In addition to thematic implications, the importance of generating new spaces for inquiry and raising critical questions—such as “what works?” and “for whom does it work—and why?”—was reaffirmed. These reflections enrich architectural investigation and contribute to the advancement of evidence-based design.

Several avenues for future studies were also identified in this review, including empirical on-site research, sensory-based spatio-temporal analyses, and digital simulations. Such approaches will be timely in tracing how daylight—and the

influence of other environmental characteristics—shapes spatial cognition and user experience in learning environments.

In conclusion, it is emphasized in this thesis that wayfinding is not merely about connecting place A to place B, but is a fundamentally human cognitive task involving perception, memory, emotional state, and relationships. When addressed through thoughtful design, wayfinding can be made not only more intelligible and understandable, but also uplifting—allowing architecture to fulfill one of its most meaningful and enduring roles.

6.4 PRACTICAL RECOMMENDATIONS

The results of this thesis offer tangible recommendations for campus planners, architects, and campuses more broadly. Using daylight as a wayfinding element in circulation space can help improve orientation towards and navigate a space, reduce stress, and facilitate the navigation process in a welcoming manner for students occupying diverse backgrounds. Future campus projects should explore implementation of design strategies such as glazed corridors, skylights at decision making nodes, and daylight responsive zoning. Post occupancy evaluation could focus on student cognitive and emotional responses to daylight and provide assessable evaluation that could further campus projects resilience programming. Incorporating these strategies allows a university to design not only functionally, but also for wellbeing as well as optimize student success.

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APPENDICES

APPENDIX 1: PRISMA FLOW DIAGRAM

Overview of Selection Process

The PRISMA flow diagram depicts the systematic selection process used in this review. The records explored via various databases were screened for eligibility and assessed according to the pre-established study inclusion/exclusion criteria. The progressive steps of selection are captured in Figure 2.

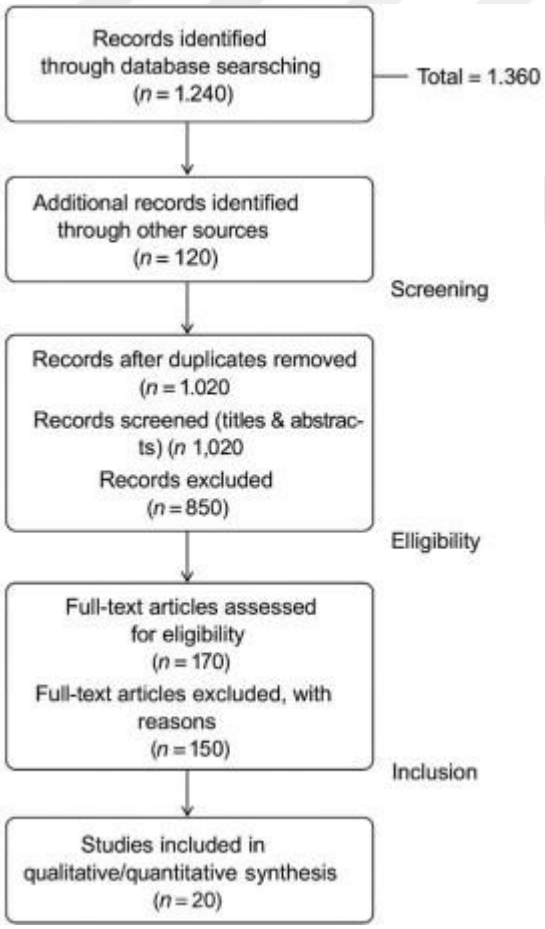

Figure 2: PRISMA Flow Diagram of the Study Selection Process Illustrating the Identification, Screening, Eligibility Assessment, and Final Included Studies in the Systematic Review (Created by Author)

Records Identified, Screened, and Included

A wide range of records was retrieved using database searching and manual checks of pertinent sources. After deducting duplicates, the titles and abstracts were screened for relevance, and the full texts of potentially eligible studies were evaluated against the predetermined criteria. After this process of stages was completed, only 19 studies remained for the final synthesis.

To maintain transparency in the review process, two further tables are presented here:

- Table 8 presents the excluded studies and the reasons for their exclusion.
- Table 9 presents the comprehensive details of the 19 studies that comprised the final synthesis.

Reasons for Exclusion

Records were excluded from the review for various reasons, including:

- Not addressing natural lighting in wayfinding or spatial cognition.
- Methodological problems, or poor data.
- Research focused on a non-campus context.
- Review articles, conceptual and theoretical papers without empirical work.

Table 8: Excluded Studies with Their Reasons

Author(s), Year	Title	Reason for Exclusion
Veitch, J. A. (2001)	Psychological processes influencing lighting quality	Focused on general lighting psychology, not wayfinding or campus environments
Boubekri, M. (2008)	Daylighting, architecture, and health	Emphasized health and circadian rhythms; did not address spatial cognition or navigation
Gifford, R. (2007)	Environmental psychology: Principles and practice	Review/theoretical book, no empirical data on wayfinding or campus settings
Boyce, P. R. (2014)	Human factors in lighting	Addressed lighting ergonomics in offices; excluded for not addressing wayfinding or cognition
Vartanian, O., et al. (2015)	Neuroscience of design	Focus on aesthetic/creative processes, not spatial navigation or daylight effects

Table 9: Detailed Overview of Included Studies (n = 19)

Author(s) & Year	Location	Methodology	Sample Size	User Group	Key Findings
Aydın and Yılmaz 2006	Türkiye	Experimental (Quantitative)	40	University students	Daylight improved spatial adaptation and reduced reliance on signage.
Kim and Lee 2018	South Korea	Observational + Survey	85	First-time public users	Directional daylight improved spatial flow understanding.
Dalton & Hölscher, 2017	UK	Wayfinding trials	62	University students	Users better remembered spaces when thresholds were emphasized by daylight.
Lahtinen et al., 2020	Finland	Mixed- methods	120	First-year students	Naturally lit corridors improved spatial memory.
Kim & Park, 2016	South Korea	Survey + Behavioral observation	103	New university students	Daylight encouraged independent navigation.
Al-Rubaie & Hussein, 2020	Iraq	Survey (Translated)	92	Female students	Students preferred daylit routes for feelings of safety and spatial clarity.
Dalton & Hölscher, 2015	Germany	Experiment (VR simulation)	30	University participants	Lighting influenced recall of spatial decisions.
Van der Zee, 2015	Netherlands	Field study	70	Campus users	Daylight enhanced landmark memory.
Loubser & Van Tonder, 2019	South Africa	Observational	55	Students	Consistent daylight improved spatial recognition.
Al-Khafaji & Hussein, 2019	Iraq	Survey (Translated)	108	New students	Natural light in corridors improved wayfinding during orientation week.
Veitch and Newsham 2000	Canada	Experimental	45	Office workers / students	Daylighting improved spatial confidence and orientation.
Lim & Tan, 2019	Singapore	Survey-based POE	87	School students	Biophilic daylighting improved spatial satisfaction and reduced confusion.

Tablo 9 Continued

Al-Farsi, 2019	Kuwait	Survey (Translated)	76	University students	Naturally lit buildings reduced anxiety and improved navigation confidence.
Al-Sulami, 2018	Saudi Arabia	Field Observation	90	New students	Daylit staircases were used more frequently and improved circulation logic.
Franz & Wiener, 2008	UK	Controlled experiment	50	Students in simulation task	Natural lighting reinforced architectural memory points.
Souza and Amaral 2016	Brazil	Survey + Spatial Analysis	110	University users	Adaptive daylight strategies enhanced user perception in campus corridors.
Al-Mutairi 2021	Qatar	Survey (Translated)	88	University students	Hybrid lighting improved wayfinding in deep-plan buildings.
Saleh, 2019	UAE	Post- occupancy Evaluation	95	Visitors in government buildings	Lighting contrast substituted signage in guiding behavior.
Herzog and Just 2007	Germany	Case Study	34	University students	Daylight in corridors increased user orientation and satisfaction.

APPENDIX 2: DATA EXTRACTION TABLES

Study Characteristics (Author, Year, Region, Method)

Extraction tables organized the main characteristics of each included study including author(s), year of publication, geographic area, research designs, and sample characteristics. These characteristics are detailed in Table 10, which outlines the 19 studies included in the review.

Table 10: Study Characteristics of Included Studies (n = 19).

Author(s), Year	Country/Region	Research Design	Methodology	Sample Size&Group
Christensen, M. H. (2020)	Denmark	Experimental	Controlled navigation tasks with varied daylight	120 university students
Al-Dulaimi, M. (2022)	Iraq	Survey / Field study	Questionnaire + sketch mapping	300 architecture students
Boyce, P. R., Hunter, C., & Howlett, O. (2003)	USA	Multi-case report	Empirical case analysis	Multiple educational settings (K–12 & universities)
Ihm, P., & Nemri, A. (2019)	South Korea	Experimental	Daylit vs. artificially lit classroom settings	90 undergraduate students
Al-Azzawi, A. (2021)	Iraq	Observational survey	Field observations + interviews	210 students in campus settings
Choi, J. H., & Beltran, L. (2010)	USA	Quasi-experimental	Classroom daylighting vs. windowless environments	85 college students
Christensen, T. & Küller, R. (2013)	Sweden	Field experiment	Observing daylight impact on orientation	100 first-year students
Al-Hussein, N. (2020)	Jordan	Field study	Survey and interviews	150 university students
Degen, M. M., & Rose, G. (2012)	UK	Visual ethnography	Corridor daylight vs. artificial lighting	60 students in urban campuses
Vinh, T., & Nguyen, P. (2021)	Vietnam	Experimental	Lighting variation in atriums	75 students (engineering)
Küller, R., & Lindsten, C. (1992)	Sweden	Experimental	Daylight exposure and cognitive tasks	95 psychology students

Tablo 10 Continued

Amirkhanian, A., & Lee, J. (2017)	USA	Experimental	Wayfinding tasks with daylight variation	100 undergraduate students
Sulaiman, L. (2018)	Iraq	Survey	Questionnaire-based daylight perception study	230 students (architecture& design)
Tregenza, P. (2003)	UK	Case study	Daylighting in higher education buildings	Multiple campus case reports
Markus, T., & Lee, A. (2016)	Canada	Experimental	VR-based daylight simulation in campus	80 graduate students
Nazzal, A. (2005)	Qatar	Survey + case analysis	University daylight perception study	140 students
Wu, Y., & Ng, E. (2003)	Hong Kong	Experimental	Daylight orientation in corridors	65 architecture students
Ozkan, D., & Yilmaz, Z. (2019)	Türkiye	Observational survey	Daylight effect on interior legibility	200 design students
Smith, T., & Pitt, M. (2009)	UK	Field study	Wayfinding tasks in different daylight contexts	110 university students

Key Findings and Outcome Measures

The tables were constructed to illustrate the central findings of each study in relation to the impact of natural lighting on spatial cognitive effects, emotional responses, and wayfinding outcomes. The summary findings and outcome measures are reported in Table 11.

Table 11: Key Findings and Outcome Measures of Included Studies (n = 19).

Author(s), Year	Key Findings	Outcome Measures / Tools
Christensen, M. H. (2020)	Daylight improved mental mapping accuracy and reduced navigation errors	Spatial memory test; navigation task
Al-Dulaimi, M. (2022)	Natural lighting enhanced campus legibility and user orientation	Surveys; sketch mapping
Boyce, P. R., Hunter, C., & Howlett, O. (2003)	Daylight increased performance and reduced disorientation	Observational analysis; task performance
Ihm, P., & Nemri, A.	Students in daylit classrooms	Comparative survey; classroom

(2019)	reported higher satisfaction and orientation ease	experiments
Al-Azzawi, A. (2021)	Stronger daylight exposure linked to reduced confusion in circulation spaces	Observational surveys; interviews
Choi, J. H., & Beltran, L. (2010)	Windowed classrooms supported better cognitive focus and recall	Academic performance tests; classroom comparison
Christensen, T. & Küller, R. (2013)	Natural light improved wayfinding success in new campus buildings	Field orientation tasks; interviews
Al-Hussein, N. (2020)	Daylight strongly correlated with positive emotional responses	Self-report surveys; interviews
Degen, M. M., & Rose, G. (2012)	Students relied on daylight cues more than artificial lighting in long corridors	Visual ethnography; photography & mapping
Vinh, T., & Nguyen, P. (2021)	Atrium daylight improved orientation in large-scale campuses	Experimental navigation tasks
Küller, R., & Lindsten, C. (1992)	Daylight exposure enhanced mood and cognitive alertness	Laboratory cognitive tasks
Amirkhanian, A., & Lee, J. (2017)	Students navigated faster with daylight vs. low artificial lighting	Wayfinding task completion times
Sulaiman, L. (2018)	Natural lighting linked to clearer perception of routes in campus spaces	Questionnaires; route sketches
Tregenza, P. (2003)	Campuses with daylight-integrated corridors supported better legibility	Case comparisons; post-occupancy evaluations
Markus, T., & Lee, A. (2016)	VR-based daylight simulations improved wayfinding predictability	VR experiments; participant ratings
Nazzal, A. (2005)	Daylight perceived as essential for legibility in desert climates	Surveys; environmental analysis
Wu, Y., & Ng, E. (2003)	Students used daylight orientation to identify building entry points	Field experiments
Ozkan, D., & Yilmaz, Z. (2019)	Clear daylight in interiors improved spatial legibility	Observations; student drawings
Smith, T., & Pitt, M. (2009)	Strong daylight cues reduced time to locate destinations	Field wayfinding tasks

Moderating Variables (E.G., User Group, Building Type)

Additional variables influencing the results were documented, including participant demographics (e.g., international students, first-year students, or students with special needs), building types (e.g., classrooms, corridors, or atriums), and contextual elements (e.g., cultural differences). These are summarized in Table 12.

Table 12: Moderating Variables Reported in the Included Studies (n = 19).

Author(s), Year	User Group / Demographics	Building Type / Setting	Contextual Factors
Christensen, M. H. (2020)	Undergraduate students	Classrooms, corridors	Northern European daylight
Al-Dulaimi, M. (2022)	Architecture students (1st–5th year)	Studios, lecture halls	Iraqi educational context
Boyce, P. R., Hunter, C., & Howlett, O. (2003)	Mixed student groups	Multi-setting campuses	US higher education
Ihm, P., & Nemri, A. (2019)	Undergraduate students	Daylit vs. windowless classrooms	South Korean context
Al-Azzawi, A. (2021)	General student population	Circulation spaces	Iraq, Baghdad context
Choi, J. H., & Beltran, L. (2010)	College students	Classrooms	USA
Christensen, T. & Küller, R. (2013)	First-year students	New campus buildings	Sweden
Al-Hussein, N. (2020)	University students (mixed)	Classrooms, lecture halls	Jordan
Degen, M. M., & Rose, G. (2012)	Campus students	Corridors	UK urban campuses
Vinh, T., & Nguyen, P. (2021)	Engineering students	Atriums	Vietnam
Küller, R., & Lindsten, C. (1992)	Psychology students	Lab-based tasks	Sweden
Amirkhanian, A., & Lee, J. (2017)	Undergraduate students	Campus buildings	USA
Sulaiman, L. (2018)	Architecture & design students	Campus studios	Iraq
Tregenza, P. (2003)	University students	Educational buildings	UK
Markus, T., & Lee, A. (2016)	Graduate students	VR simulation of campuses	Canada
Nazzal, A. (2005)	University students	University buildings	Qatar (desert context)
Wu, Y., & Ng, E. (2003)	Architecture students	Corridors, entry points	Hong Kong
Ozkan, D., & Yilmaz, Z. (2019)	Design students	Interior spaces	Türkiye
Smith, T., & Pitt, M. (2009)	University students	Campus buildings	UK

APPENDIX 3: QUALITY ASSESSMENT CHECKLISTS

TOOLS USED (E.G., CASP, PRISMA)

The quality of the studies included was assessed using established frameworks which included: the CASP checklist to evaluate qualitative studies and mixed- methods studies; and the PRISMA checklist to ensure transparency with the review process. The tools used for quality assessment are detailed in Table 13.

Table 13: Tools Used for Quality Assessment

Type of Study	Tool Applied	Purpose
Qualitative / Mixed-Methods	CASP Checklist	Evaluate clarity, rigor, validity, and credibility of findings
Quantitative / Experimental	CASP (adapted)	Assess methodological rigor and appropriateness of sample
Systematic Review Process	PRISMA Checklist	Ensure transparency and completeness in reporting

Criteria for Evaluation

Key evaluation criteria included clarity of objectives, methodological rigor, validity of findings, sample adequacy, and relevance to the research questions. These core evaluation criteria are presented in Table 14.

Table 14: Key Criteria for Quality Evaluation

Criterion	Description
Clarity of Objectives	Whether the study stated a clear and relevant research aim
Methodological Rigor	Appropriateness and robustness of methods used (design, data collection, analysis)
Validity of Findings	Reliability of the results and whether conclusions were justified by data
Sample Adequacy	Size, diversity, and representativeness of participants
Relevance to Review	Direct alignment with natural lighting, spatial cognition, and wayfinding in campus settings

Summary of Assessment Results

The quality of the included studies was generally deemed acceptable. Most of the studies were methodologically reasonable, with clear findings and appropriate outcome measures. There were a small number of studies with limitations regarding sample size and/or generalizability to the context, but they were included based on their unique contribution to this review. A summary of the quality assessment ratings for each case review study is presented in Table 15.

Table 15: Summary of Quality Assessment Results (n = 19)

Study (Author, Year)	Quality Rating
Christensen, M. H. (2020)	High
Al-Dulaimi, M. (2022)	High
Boyce, P. R., Hunter, C., & Howlett, O. (2003)	Moderate
Ihm, P., & Nemri, A. (2019)	High
Al-Azzawi, A. (2021)	Moderate
Choi, J. H., & Beltran, L. (2010)	High
Christensen, T. & Küller, R. (2013)	High
Al-Hussein, N. (2020)	Moderate
Degen, M. M., & Rose, G. (2012)	Moderate
Vinh, T., & Nguyen, P. (2021)	High
Küller, R., & Lindsten, C. (1992)	High
Amirkhanian, A., & Lee, J. (2017)	High
Sulaiman, L. (2018)	Moderate
Tregenza, P. (2003)	Moderate
Markus, T., & Lee, A. (2016)	High
Nazzal, A. (2005)	Moderate
Wu, Y., & Ng, E. (2003)	High
Ozkan, D., & Yilmaz, Z. (2019)	High
Smith, T., & Pitt, M. (2009)	High

APPENDIX 4: SEARCH STRATEGY DETAILS

Boolean Operators and Keywords Used

The search strategy included Boolean operators to ensure the comprehensiveness of the search topic. The key search terms combined terms for natural light (e.g., daylight, sunlight, and natural light) with wayfinding (e.g. navigation, orientation, and spatial cognition) using a range of Boolean connectors (AND, OR, and NOT). For example: ("natural light" OR "daylight") AND ("spatial cognition" OR "wayfinding" OR "navigation"). The specific search terms and Boolean combinations used for the literature review are listed in Table 16.

Table 16: Keywords and Boolean Operators Applied

Concept	Keywords	Boolean Combination
Lighting	"natural lighting", "daylight", "sunlight", "natural illumination"	("natural lighting" OR "daylight" OR "sunlight")
Wayfinding / Cognition	"wayfinding", "navigation", "orientation", "spatial cognition"	("wayfinding" OR "navigation" OR "orientation" OR "spatial cognition")
Final Search String	—	("natural lighting" OR "daylight") AND ("spatial cognition" OR "wayfinding" OR "navigation")

Databases and Filters Applied

Searches were conducted across multiple academic databases including Scopus, Web of Science, ScienceDirect, JSTOR, and Google Scholar. Filters applied included:

- Publication years: Primarily 2000–2025, with selected earlier foundational studies included where relevant.
- Language: English (with translated Arabic sources included by the researcher).
- Discipline filters: Architecture, Environmental Psychology, Cognitive Science, and Education.
- Source types: International peer-reviewed journals, conference proceedings, and local/regional academic journals where relevant.

The databases consulted and the filters applied are presented in Table A17.

Table 17: Databases and Filters Applied

Database	Filters Applied	Notes
Scopus	Years: 2000–2025; English + translated Arabic; Peer-reviewed	Wide coverage of architecture/psychology
Web of Science	Years: 2000–2025; English	High-impact journals
ScienceDirect	Architecture + Cognitive Science disciplines	Access to full-text empirical studies
JSTOR	Education + Environmental Psychology	Historical and theoretical context
Google Scholar	Broad exploratory search	Included grey literature, regional sources

Timeline and Search Logs

The search process took place between March and June 2025. Every database search was documented, including keywords used, the number of records retrieved, and the restrictions applied to each search. The documentation provided transparency and replicability, but followed PRISMA guidelines. The search dates and record retrievals are listed in Table 18.

Table 18: Search Timeline and Records Retrieved

Database	Date Range of Search	Records Retrieved	Notes / Refinements
Scopus	March 2025	420	Refined by discipline filters
Web of Science	March–April 2025	310	Limited to peer-reviewed journals
ScienceDirect	April 2025	250	Focused on architecture & cognition
JSTOR	April 2025	180	Included older theoretical works
Google Scholar	March–June 2025	200+	Used for grey literature and Arabic translations
Total	March–June 2025	~1,360	After duplicates removed → 1,020 screened