Tanta University
Faculty **of** Engineering
Architectural Department

Biophilic Design in Ancient Islamic Architecture

(Toward restorative learning spaces)

A Thesis Submitted in partial fulfillment of the M.Sc. in Engineering (Architectural Engineering) by:

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2022

{وَنَزَعنا ما في صُدورِهِم مِن غِلٍّ تَجري مِن تَحتِهِمُ الأَنهارُ وَقالُوا الحَمدُ لِلَّهِ الَّذي هَدانا لِهذا وَما كُنّا لِنَهتَدِيَ لَولا أَن هَدانَا اللَّهُ لَقَد جاءَت رُسُلُ رَبِّنا بِالحَقِّ وَنودوا أَن تِلكُمُ الجَنَّةُ أورِثتُموها بِما كُنتُم تَعمَلونَ}.

- الآية 43 سورة الأعراف

Dedication

First and foremost, all thanks and gratitude to **Allah**, the most gracious and merciful.

I would like to dedicate my humble work to my mother '**Eman**', and my father '**Usama**' who give me the blessing and happiness. My special thanks also to my dear husband '**Ibrahim**' the source of my strength and support. finally, my sister and my best friend '**Kadeer**', my sister '**Dalia**', my brother "**Mohammed**', and my friends. Without their love, support, and patience, this would not have been possible.

With special gratitude to **Yara**, the best daughter I can imagine. You have been a gift from **Allah**.

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Abstract

Abstract

The new innovative design paradigm "Restorative Environmental Design" has been found to reduce the adverse effects of modern design and development on natural systems and human health. This approach aims to apply two strategies; low-environmental-impact strategy that minimizes the harmful impacts on nature, and Biophilic design strategies that fosters a positive contact between people and nature inside the buildings and in landscapes. Biophilic design can provide people the opportunities to live and work in healthy places and spaces with less stress and greater overall health and well-being. Although the positive impacts of biophilic design, it didn't have big attention such as environmentally friendly designs.

This research employs the hypothesis that biophilic design is not a new phenomenon and the natural-based proportional and aesthetic qualities can be found in historic structures. Therefore, the research validates and recommends characteristics and features influenced by Islamic architecture, which fulfill the biophilic design, to be applied in modern campus design. These features could enhance students' physical health, emotional well-being, and academic performance success.

The sequence of the dissertation explains what the conceptual framework of biophilic design through defining the theories of connecting human well-being and natural systems, then describes the strategy of each attribute of biophilic design, illustrating how it impacts our cognitive function, physical health, and psychological well-being. Thereafter, a suitable example of a madrasa building was analyzed using a guide of eight design elements to examine biophilic design attributes in learning spaces. Finally, the case study of a modern campus was visited and divided into three zones influenced by different Islamic architectural features. The biophilic design qualities and attributes were examined in each zone using a subjective analysis, and an online questionnaire for users focusing on biophilia-relevant qualities, followed by psychological, cognitive, and physiological experiences measurements using a bipolar scale.

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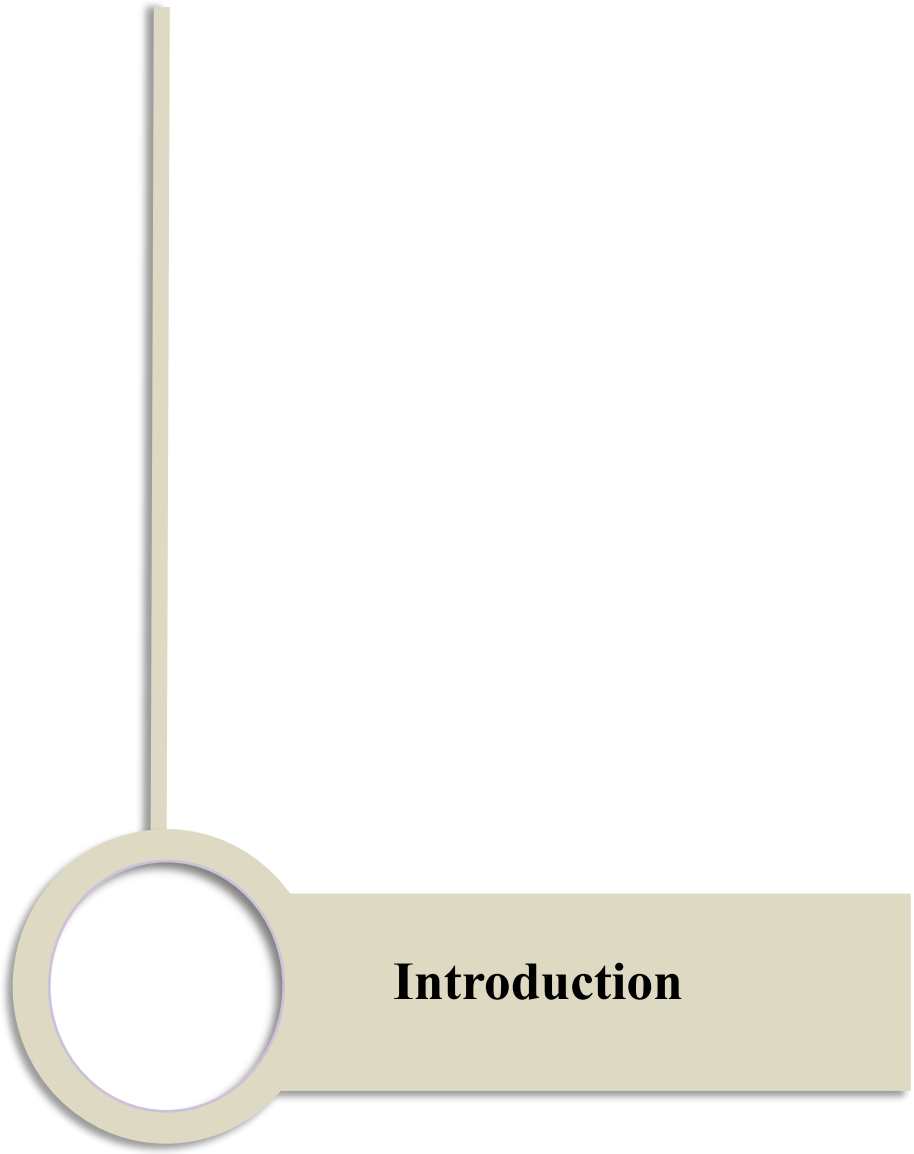


Introduction

Introduction

Humanity has been strongly connected with nature from the beginning of time. The relationship between nature and mankind has always played a significant role in our evolution, we have depended on nature for our essential needs to survive. Over time, humans developed more formal and sophisticated ways of living, they attempted to build habitats away from the natural environment. After 'Industrial revolution' and the increase of population density in urban areas, the requirement for buildings also increased, thus the architects began to experiment huge structures with new materials like steel and glass to build tall buildings, but the inner environment of these buildings was dark and cramped. Therefore, in the late 1970s it was noted that many symptoms such as breathing difficulties, headaches, and fatigue, were reported by occupants in the newly constructed buildings. The World Health Organization (WHO) used the term "Sick Building Syndrome" to describe these situations. Sick buildings have a long-term effect on their occupants, it is affecting their productivity and health, and they have a much higher level of stress, anxiety, and confusion in comparison to those who worked in non-sick building syndrome buildings (Modi and Parmar, 2020). For solving this problem, the new approaches of architectural designs that connect people with nature has been found.

Biophilia concept is humankind's innate biological connection with nature, and the biophilic design applies this concept into building's design. It is an attempt to introduce the outside nature to the inside of the building for a more efficient and effective built environment. Biophilic design can reduce stress, anxiety, improve our well-being, and improve productivity and creativity (Browning *et al.*, 2014). It works side by side with the environmental design to achieve the restorative environment (Kellert, 2005). Apply biophilic design in healthcare buildings and hospitals enhances patients' psychological status and ensure speed healing process (AbdelMeguid, 2014), and enhances the employee's psychological state and increases their productivity in businesses offices (Tahoon, 2018). Moreover, integrating biophilic design in learning spaces has a positive impact on student's physical health, psychological well-being, and social relationships (Peters and D'Penna, 2020).

Biophilic design is not considered a new phenomenon, ancient architects inspired their designs from natural creatures (Browning et al., 2014). Therefore, historical architecture and our heritage are not only a reference to the environmental design, but also one of the important

resources for designs that connect people with nature. In this context, it is observed that the ancient Islamic architecture features fulfil biophilic design strategy, the issue that will be investigated in this thesis.

a) Research Problem

University students and instructors face many health problems such as stress, anxiety, and depression, due to academic challenges. Consequently, it is essential to incorporate biophilic design in the learning environment to make restorative spaces and places. The research problem is that there is a lack of research on applying biophilic design in university settings that did not pay much attention, as much as applying environmentally friendly designs strategies.

b) Aim and Objectives

The thesis attempts to enhance psychological, cognitive, and physiological performance of the university students through applying the biophilic design strategy to connect the buildings with nature, which will reduce stress, restore attention, and increase their productivity. Hence, the aim of the thesis is to fulfill biophilic design attributes in modern learning environment using architectural features influenced by historical Islamic architecture.

To attain this aim, it is intended to achieve the objectives of the thesis that could be listed as follows:

- Explaining the theories of the restorative environment and the biophilia and the relationship between them.
- Explaining biophilic design concept, principles, and strategies, as well as highlighting the significance of biophilic design to students' physical health, emotional wellbeing, and academic performance success in educational buildings.
- Describing the concept, strategies of Islamic architecture, as well as discuss the sustainability and connecting to nature from the Islamic architecture point of view.
- Examine the biophilic design attributes in the architectural features of a madrasa building as an example through

analyzing the important elements of design the learning spaces.

- Evaluate the students' psychological, cognitive, and physiological performance and the biophilic design qualities of different educational zones in a new educational campus, containing different Islamic architectural features.

c) Research Question

What are the architectural features influenced by Islamic architecture help to fulfill biophilic design qualities in learning spaces?

d) Research Methodology

The research depends on the theoretical and applied approach: the theoretical approach present literature review and theoretical background, while the applied approach depends on the analytical study and case study assessment to gain information and the research goals.

(1) Theoretical Part:

This part is reviewing all the theories of connecting human well-being and natural systems and the restorative environment theory, and all the previous literature and studies of the science of the biophilia and the biophilic design and exploring the importance of biophilic design in learning spaces. The research represents the most essential elements of design a learning space incorporate biophilic design attributes. It also shows the concept of Islamic architecture, and the sustainability, connecting to nature, and the most important environmental features in Islamic architecture.

(2) Analytical part:

Example analysis approach is used for this research to understand the architectural features in the madrasas building that respond positively to biophilic design qualities. The research used the proposed important elements of design a learning space as guidelines in analysis to examine biophilic design attributes.

(3) Case Study part:

This part studying a modern campus in Cairo containing three modern learning spaces zones influenced by Islamic architecture using varying amounts of Islamic architecture features and examining the biophilic design attributes in every zone using the proposed guide in analysis, then evaluate users respond to the biophilic design quality in each zone and assesst the psychological and physiological impacts on the users. The purpose of doing this is to suggest some architectural features that fulfill biophilic design attributes in design future learning spaces.

The methods which were used in studying the case study are:

1. Data were collected from observation, documentations, websites, books, pictures, and scientific references.
2. Online questionnaires: almost 80 respondents between 20-40 years old, almost equally between male and female, two groups of people were responded:
   a) Academic architects that visited the campus many times for academic purpose.
   b) Undergraduate students in the campus.

e) The Structure of the Research

The research consists of seven chapters, as the following:

Chapter one: Theories of Connecting Human Well-Being and Natural Systems

This chapter displays definitions, concepts, and the theoretical framework of different theories of connecting human well-being to nature, the restorative environment design approaches, and the environmental preferences theories.

Chapter two: Biophilic Design

This chapter will focus on understanding the biophilic design approach and the important attempts by researchers to determine the conceptual framework of biophilic design. Furthermore, it represents biophilic design attributes and discuss the psychological, physiological, and cognitive benefits of each attribute.

Chapter three: Biophilic Design at Learning Spaces

This chapter displays the definition and components of learning sapces, and the factors that influence the academic performance of students. It also discusses the importance of incorporating natural elements in learning spaces, and the indoor environmental quality in educational buildings. The chapter determine the important elements of design a learning space to incorporate biophilic design attributes as a guideline in the analytical part of the research.

Chapter four: Islamic Architecture

This chapter represent a brief introduction to Islamic architecture and discuss the concept of sustainability and connecting to nature, and the most important environmental features in Islamic architecture. It also represents the evolution of madrasa design and the significant architectural features.

Chapter five: Analytical Study: Biophilic design in Islamic Educational Buildings

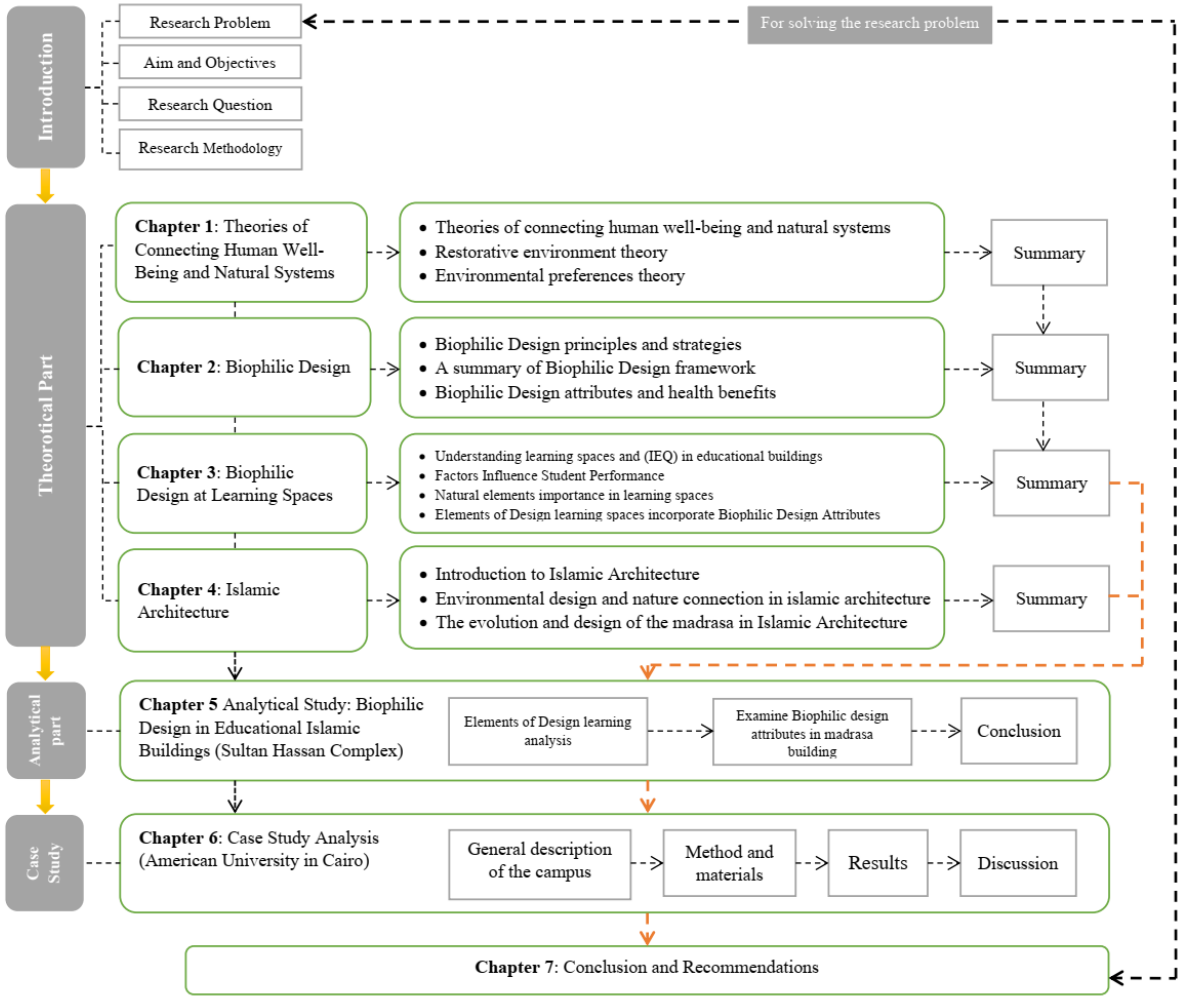
This chapter use a local example of the madrasa in Egypt from the Mamluk Bahri period to examine the biophilic design attributes through analyzing the design elements to find out some features in historical Islamic buildings that responds to the criteria of biophilic design used in the complex.

Chapter six: Case Study

The ultimate purpose of this chapter is to assess the biophilic design qualities of different Islamic architectural features when it used in a modern learning space. Therefore, this chapter studying three modern educational zones in a new campus containing varying amounts of Islamic architecture features. The study using two stages; first examine the biophilic design qualities on the three zones, second using online questionnaires to evaluate the biophilic attributes in the three zones, and the psychological, cognitive, and physiological performance of the spaces is also evaluated.

Chapter seven: Conclusion and Recommendations

Diagram of Research Methodology



01

Chapter

Theories of Connecting Human Well-Being and Natural Systems

Chapter 1:

Theories of Connecting Human Well-Being and Natural Systems

Introduction

6.6 **The Human-Nature Relationship**

- 6.6.1 Nature definition
- 6.6.2 Human relationships to the natural world
- 6.6.3 Values of human attachment to the natural world

6.7 **Theories of Connecting Human Well-Being and Natural Systems**

- 6.7.1 Ecosystem services
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- 6.7.3 Spirit of place

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Summary

Introduction

> *"Unfortunately, the prevailing approach to design of the modern urban built environment has encouraged the massive transformation and degradation of natural systems and increasing human separation from the natural world."* (Kellert, 2008)

Humans have evolved in the natural environment context, and they have developed to responding to these natural surroundings. Throughout the years, the rapid population growth, and the industrial revolution, cause a transformation toward urbanization, fabrication, isolation from the nature world, and loss of natural spaces. As a result, this degradation of the natural world health promoted the development of the modern sustainable or green design movement. This sustainable design approach has almost focused on the low environmental-impact objectives of avoiding and minimizing harm to natural systems, while this focus is insufficient, because it is ignoring the importance of achieving the long-term sustainability to restoring and enhancing the positive relationship between human and nature in the built environment.

The main purpose of this chapter is to understand specific approaches for designing built environment connected to the natural world. To accomplish this task, we need to know definitions, concepts, and the theoretical framework of the theories of connecting human and natural system. Accordingly, this chapter is divided into four parts: the first part presents the definitions, dimensions, and values of the human nature relationship. The second part presents the important theories of connecting human well-being and natural systems; Ecosystem services, Biophilia, and Spirit of place. The third part explores the definitions, theories, and framework of the restorative environment, and discuss its design approaches; first, low-environmental-impact design strategies, and second positive environmental impact or biophilic design approach. Furthermore, it displays the relationship between the three theories of connecting human well-being and natural systems, and restorative environmental design strategies. The last part presents the environmental preferences definition, paradigms, and display four theories of environmental references, which related to restorative value of natural and urban environments.

1.1 The Human-Nature Relationship

The relationship between human and nature is an important sub-field of social ecology, its importance comes from the world growing concern of the disconnection from nature that effects human health and wellbeing, as well as contribute to an unhealthy environment (Chen, 2017). It is proposed that technology is the cause of this disconnection between nature and human (Chen, 2017). Technological advances allowed people to settle and farm the land first, but further advances eventually made people leave the villages for an industrial life in cities and towns. Therefore, the working and living are no longer driven by the ecological context, resulted a changing in lifestyle (Chen, 2017).

1.1.1 Nature definition

The term "nature" comes from “asci” (the Latin word which meaning to be born). “Nature” refers to physical features and processes of nonhuman origin that people ordinarily can perceive, including the “living nature” of flora and fauna, together with still and running water, qualities of air and weather, and the landscapes that comprise these and show the influence of geological processes (Hartig *et al.*, 2014). Environmental psychologist Joachim Wohl defined nature as “vast domain of organic and inorganic matter that is not a product of human activity or intervention” (Kellert, 2005). Nature also defined as living organisms and non-living components of an ecosystem, inclusive of everything from the sun and moon, to fishbowl habitat (Browning *et al.*, 2014). “Natural environments” were broadly described as places absent from any human interference, as such, “nature” overlaps substantially with “natural environment,” and the two terms have been used interchangeably (Arias-Maldonado, 2015).

1.1.2 Human relationships to the natural world dimensions

Human relationships to the natural world occur along two broad dimensions (Kellert, 2005)

- *First:* The varying people's degree in closeness to nature; ranging from highly familiar settings and domesticated animals, such as pet animals and roof gardens, to wilderness-dependent wildlife and pristine environments, such as captive zoo animals or a national park.

- *Second:* The varying kinds of people's experience contact with the nonhuman world, ranging from direct and indirect contact to symbolic contact (Kellert, 2008).
    a) *Direct contact*: refers to relatively unstructured contact with self-sustaining natural features and processes, such as daylight, plants, animals, natural habitats, and ecosystems.
    b) *Indirect contact*: involves contact with elements of nature that require ongoing human input to survive, such as a potted plant, a water fountain, or a fish aquarium.
    c) *Symbolic or vicarious contact:* involves no actual experience with real nature, but rather the natural world representation through image, mimic, or simulation, such as botanical and animals' motifs

1.1.3 Values of human attachment to the natural world

Human has an inherent inclination to affiliate with the natural world (Kellert, 2008). According to Kellert, people respond to the natural environment from a blend of nine basic ways or values. However, these nine values are "weak" genetic tendencies that depend highly on individual learning and experience within a cultural and community context (Kellert, 2005). These nine values are; Utilitarian, Dominionistic, Naturalistic, Scientific, Symbolic, Aesthetic, Humanistic, Negativistic, and Moralistic (Kellert, 2005; Kellert *et al.*, 1993).

1.2 Theories of Connecting Human Well-being and Natural Systems

Many researchers have proved that the interaction with nature provides a physical, psychological, and cognitive benefits. Thus, human well-being and development affected with all the previous forms of contact with the natural world. Kellert has examined three theories that help elucidate the interdependency of human well-being and the natural world; Ecosystem services, Biophilia, and Spirit of place (Kellert, 2005).

1.2.1 Ecosystem services

Ecosystem services are the benefits that people obtain from ecosystems, which are critical to their well-being and survival. Some of these essential ecological services include the following (Kellert, 2005):

- Oxygen production
- Soil formation
- Remediation of chemical and biological pollution
- Plant pollination
- Water supply and purification
- Crop and livestock production
- Products from wild animals (e.g., honey, finfish, shellfish), and plants (e.g., wood, paper, lubricants)
- Pharmaceuticals and other medical materials
- Decomposition of waste
- Control of injurious organisms

1.2.2 Biophilia

The term “Biophilia” is derived from the Greek word “bios” means organic life, and “philia” an ancient Greek word for love. It literally means (love of life or living systems). The term biophilia was first mentioned by Erich Fromm, a German social psychologist, in his book (The Heart of Man,1964). Fromm hypothesized that people have a “passionate love of life and all that is alive; it is the wish to further growth, whether in a person, a plant, an idea, or a social group” (Fromm, 1974). After that biophilia hypothesis popularized by Harvard Biologist Dr. Edward Wilson in his book in 1984, he described biophilia as our innate tendency to focus on life and life-like processes, to affiliate with other life-forms, and according to his hypothesis there is a bond rooted in our biology between us and other living systems.

Thus, the concept of biophilia can be simply defined as the inherent human inclination to affiliate with natural systems and process, especially life and life-like features of the nonhuman environment, which are instrumental in human physical, mental, emotional, intellectual, and moral well-being. The inherent inclination to attach with nature, however, is a “weak” genetic tendency whose full and functional development depends on sufficient experience, learning, and cultural support (Kellert, 2008) and (Kellert, 2005).

1.2.3 Spirit of place

The third concept that illustrates the relationship between nature and human well-being is a secure, satisfying connection to the places where the people work and reside, which called “The spirit of place”. Many researchers have found that when people feel tied to their places, they convert them from a group of lifeless physical materials to a living entity. Thus, these places become a source of personal identity with a unique spirit (Kellert, 2005).

A spirit of place signifies the following (Kellert, 2005):

- The comfortable, compatible connection between the cultural and the history of the place
- The successful fusion of culture and ecology of the place.
- Constructed buildings and landscapes that reflect the distinctive natural and social characteristics of a particular setting.

People in the modern society seeks chances for mobility and exploring the new and unfamiliar, but most people appreciate the return to the secure, reassuring place they call home. This relationship and connection to a particular place sometimes referred to "possessing roots,” which is a concept that reflecting both social and biological significance and considered as a fundamental aspect of human existence (Kellert, 2005).

In contrast, a phenomenon of growing people in an unfamiliar, disconnected setting, has been called "placelessness", which described as the “weakening of distinct and diverse experiences and identities of places”. The sense of placelessness makes people less responsible toward the places where they work and reside and rarely committed to maintaining the cultural or ecological features of their places. There are many aspects of modern life that contribute to a sense of placelessness like transience, the loosening of neighborhood and community ties, economic and cultural globalization, loss of open space, environmental and biological degradation and pollution, and an anonymous and alienating architecture (Kellert, 2005).

The various concepts support the relationship between human and the natural world experience. When people experience a healthy environment with iterative contact with nature in a secure, satisfying, and reinforcing local settings, they are more able to recognize their biophilic tendency and reap its benefits, they are also more able to derive the ecological services of their environment. The great ecologist Aldo Leopold phrase "thinking like a mountain", was used to link the different concepts, ecosystem services, biophilia, spirit of place, and environmental preferences, will describe later in this chapter, with human well-being (Kellert, 2005) as shown in Figure 1-1.

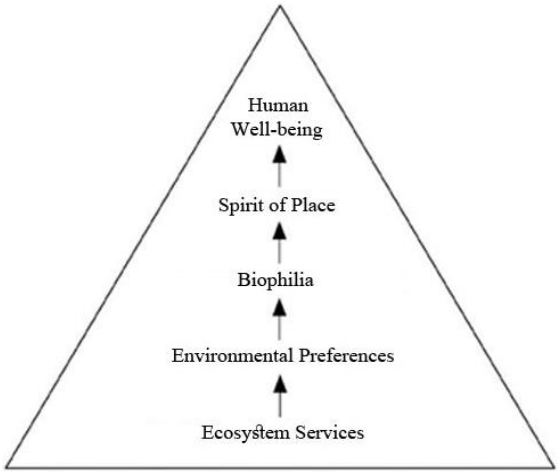

Figure 1-1 "Thinking like a Mountain": Linking Ecosystem Services with Environmental Experience and Human Well-being (Kellert 2005)

1.3 Restorative Environment Theory and Design

The term "restoration" defined by Hartig, a professor of environmental psychology, as "the process of renewing, recovering, or re-establishing physical, psychological, and social resources or capabilities diminished in ongoing efforts to meet adaptive demands" (Hartig *et al.*, 2008).

Restorative environments are the context of restoration activities that allow both permits and promote restoration. According to psychological research, restorative environments has been dominated by one or both of two theories: Attention Restoration Theory (ART), and Psycho-Evolutionary Theory (PET) (Wilkie and Stavridou, 2013), as shown in Figure 1-2.

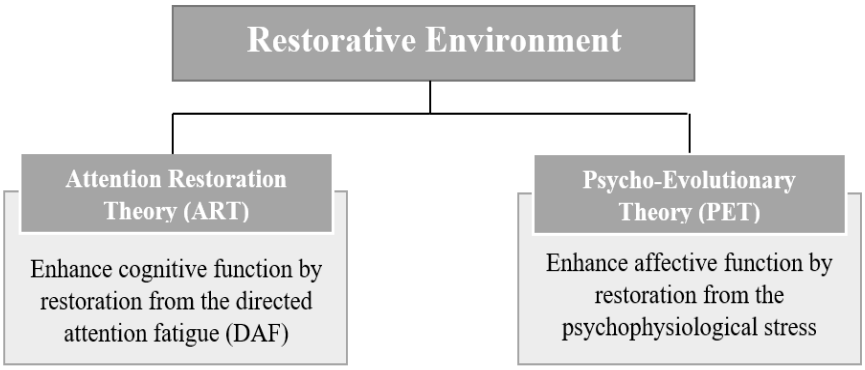

Figure 1-2 Restorative environment theories (Wilkie and Stavridou, 2013)

a) *Attention restoration theory (ART):* assumes that when a person concentrating on a particular task over a time, he will eventually experience attentional fatigue or depletion of a directed attention capacity. Attention fatigue can entail many negative impacts, such as increasing human errors and stress, and decrease problem-solving skills. The central reason for directed attention fatigue is the struggle to pay attention. Consequently, attention restoration theory postulates that being in an environment that does not require the use of directed attention should deplete attention fatigue, this environment determined by four restorative quality:
    - *Being away*: the psychological distance from tasks and daily routine that requires mental activity.
    - *Fascination:* the reliance on objects and processes in exploring the environment that provides effortless, interest-driven attention.
    - *Extent:* a rich and coherent environment for perceptual and conceptual or imaginary experience.
    - *Compatibility:* the match between person's inclination at the time, the demands imposed by the environment, and the environmental supports for intended activity.

    Studies found that nature is superior to urban environments in the recovery from direct attention fatigue because natural environments possess the previous four characteristics.
b) *Psycho-evolutionary theory (PET):* The second theory about the restorative environment, which concerns psychological stress reduction. It emphasizes the beneficial changes in psychological activity and emotions that occur as a person views a scene. This

> initially depends on visual characteristics of the scene that can very rapidly evoke a positive subconscious emotional response, such as interest. The characteristics of the scene that elicit that response include gross structure, gross depth properties, and some general classes of environmental content, such as a scene with moderate and ordered complexity, moderate depth, a focal point, and natural contents such as vegetation and water.

The experimental studies guided by one or both of these theories have rather consistently supported the idea that natural environments have a restorative advantage in comparison to urban settings (Hartig and Staats, 2007).

The restorative environmental design is a new innovative design approach to design the built environment under restoration perspective, aims to reduce the adverse effects of modern design and development on natural systems and human health, and to promote more positive contact between people and nature in the built environment. However, meeting these objectives will require two conditions. First, low-environmental-impact design strategies that minimize and mitigates adverse impacts on the natural environment. Second, positive environmental impact or biophilic design approach that fosters beneficial contact between people and nature in modern buildings and landscapes (Kellert, 2005).

1.3.1 Low-Environmental-Impact design

Modern construction caused a harmful effect to the natural system and human health, this effect can be minimized and mitigated through many strategies (Kellert, 2008), such as:

- Using renewable energy.
- Reducing resource consumption.
- Reusing and recycling products and materials.
- Pursuing energy efficiency.
- Avoiding habitat destruction and loss of biodiversity.
- Lessening waste and pollution.
- Employing nontoxic substances and materials**.**

Moreover, the detailed specification of low-environmental-impact design strategies has been incorporated into certification systems such as the U.S. Green Building Council’s LEED rating approach (Kellert, 2008).

Low-environmental-impact design approach is necessary but insufficient by itself for effective sustainable design and development, and this approach also ignores the important need of positive contact between people and nature in the built environment (Kellert, 2005).

1.3.2 Biophilic design

Biophilic design is the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and process into the design of the built environment, this innate affinity called biophilia as we mentioned above. Consequently, biophilic design determined as the missing link in sustainable design (Kellert, 2008). Stephen Kellert identified two basic dimensions of biophilic design, organic/naturalistic dimension, and place-based/vernacular dimension as shown in Figure 1-3.

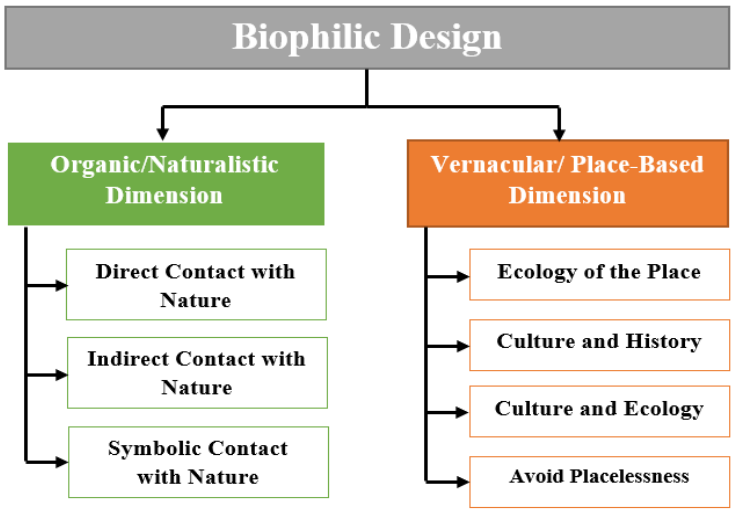

Figure 1-3 The two main dimensions of biophilic design (Kellert, 2005)

a) Organic/Naturalistic dimension

The first basic dimension of biophilic design defined as "shapes and forms in the built environment that directly, indirectly, or symbolically reflect the inherent human affinity for nature" (Kellert, 2008).

Direct attributes of organic design refer to the relatively immediate experience of nature in the built environment, such as natural lighting, natural ventilation, plants, soil, water, geological forms, and even fire or animal life, these features can be the result

of deliberate design decisions, such as large operable windows, or incorporate views of the exterior environment like large rivers and mountains, into the built environment, or buildings orientated to the sun. Consequently, this design decision achieving many physiological, psychological, and cognitive benefits for people (Kellert, 2005).

Indirect attributes refer to experience of nature requiring ongoing human management and intervention, such as water fountain, or a fish aquarium. Designing the indirect experience of nature often involves manipulating such environmental elements as vegetation, animal life, light, air, water, materials (e.g., stone, wood, cotton, hides, wool, leather), and even natural processes, such as aging, weathering, and climate (Kellert, 2005).

The symbolic experience of nature in the built environment occurs through representation, allusion, and metaphorical expression of shapes and patterns and all life forms, including decoration, ornamentation, pictorial expression, and shapes and forms that simulate and mimic nature in a wide diversity of building features such as walls, doors, entryways, columns carpets, fabrics, art, and sometimes even an entire façade. Moreover, these architectural elements evoke sentiments and affect people's responses to and satisfaction derived from the built environment (Kellert, 2005).

b) Vernacular/ place-based dimension

The second basic dimension is a place-based or vernacular dimension, which evokes "spirit of place" theory that explained above, defined as "buildings and landscapes that connect to the culture and ecology of a locality or geographic area". This dimension underscoring how buildings and landscapes of meaning to people become integral to their individual and collective identities, metaphorically transforming inanimate matter into something that feels lifelike and often sustains life (Kellert, 2008).

People are rarely sufficiently motivated to act as responsible stewards of the built environment unless they have a strong attachment to the culture and ecology of the place, this attachment

has proven instrumental in securing resources, attaining safety and security, and avoiding risk and danger (Kellert, 2008).

Effective vernacular design is the fusion of culture and ecology within a particular biogeographical context, and requires the following (Kellert, 2005):

1. Designing in relation to the ecology of place that requires knowledge of the ecological context of constructed building environments, particularly ecosystem functions, structure, and dynamics, to prevent the loss of ecologically important plant and animal species, maintaining critical hydrological and soil features, or sustaining biophysical factors and processes essential to maintaining ecological functions and systems.
2. Designing in relation to culture and history that requires consideration of the cultural and historical character of the places where buildings and other constructions occur. These cultural and historical features foster an emotional and intellectual attachment to the place.
3. Designing in relation to culture and ecology that requires an integration and creative fusion of the culture and ecology of the place. This effective combination produces a distinctive vernacular tradition native to an area, which encourages belonging to the place where the people live.
4. Designing to avoid placelessness, which described as the "weakening of distinct and diverse experiences and identities of places" as mentioned above.

Low environmental impact and organic designs are necessary but not sufficient conditions for achieving restorative environmental design. Without vernacular connections to the culture and ecology of place, design and development are transient and unsustainable. People who are deeply committed to their places and surroundings feeling of stewardship toward the places where the constructions occur and tend to be intolerant of activities that inflict damage on either the natural or built environments and take steps to counteract this harm.

Restorative environmental design seeks to harmonize the natural and human built environments through implementing the three principles of low environmental impact, organic, and vernacular design, these three

design objectives reflect the three previous theories of connecting human well-being and natural systems as shown in Table 1-1 (Kellert, 2005)

Table 1-1 The principles of Restorative Environmental Design (Kellert, 2005)

Theories connecting human and natural systems	Design Strategies – Linking human and Natural Systems	
Ecosystem Services	**Low-Impact Design**	Small ecological footprint in construction and operation of the building
Biophilia	**Organic Design**	Direct, indirect and symbolic experience of nature, using natural materilas and ecological engineering.
Sense of place	**Vernacular Design**	Design in relation of the ecology of place, culture and history. Design to avoid loss of local and regional identities

1.4 Environmental preferences

Preference is defined as choosing among alternatives according to Kaplan, and it implies a rapid interpretation before preferring. In other words, alternatives are compared in terms of some attributes and the one being superior is preferred (Çebi, 2007). People have always relied on their visual sense for understanding the world around them and compare between different alternatives. According to plenty of research people tend to prefer natural over built environments. For example, in samples of European and North American adults, photographs of natural scenes consistently receive higher ratings of liking, scenic beauty, or pleasantness than photographs of urban scenes (van den Berg *et al.*, 2003).

In general, there are two broad environmental preferences paradigms; objective and subjective approaches and both of the paradigms have their own philosophical arguments (Maulan and Miller, 2006). The objective approach lies in the physical characteristics of the scene, and it is judged from its formal quality such as line, masses, color, harmony, and contrast. The subjective approach emphasizes the positive cognitive and affective reactions evoked by various patterns of environment. This approach argues that the human preference for different patterns of the surrounding environment is based on human

knowledge and understanding of the environment. Some of this knowledge and understanding may be innate, something that people is born with, and some may be learned or acquired through culture, experience, and education. (Maulan and Miller, 2006).

The environmental preferences theories that rely on the subjective approach are premised on the notion that people have an innate attraction toward a special characteristics of the natural environment (Alencar, 2013), such as savannah hypothesis, prospect and refuge theory, information perspective on environmental preferences, and fractal theory.

1.4.1 Savannah hypothesis

The Savannah hypothesis is an evolutionary theory introduced by the ecologist Gordon Orians in 1980, this hypothesis postulates that human is psychologically adapted to and prefer landscape features that have characteristics present in African Savannah, the environment which presumably, most of the human evolution occurred in (Alencar, 2013). Although humans now live in many different habitats, Orians argues that the landscape of African Savannah is ingrained in our psych, and consequently in our perception of what constitutes characteristics of preferred environment. The key features of savannah environment including the following (Heerwagen, 2017):

- A high diversity of plant (especially flowers) and animal life for food and resources.
- Clustered trees with spreading canopies for refuge and protection.
- Open grassland that provides easy movement and clear views to the distance.
- Topographic changes for strategic surveillance, such as rock outcropping, to provide early warning of approaching hazards.
- Scattered bodies of water for food, drinking, bathing, and pleasure.
- A "big sky" with a wide, bright field of view to aid visual access in all directions.
- Multiple view corridors and distances.

1.4.2 Prospect and Refuge theory

The prospect and refuge theory is also an evolutionary approach was first proposed by the English geographer Jay Appleton in 1975. The theory postulates that people prefer to be in places where they have good visual access to the surrounding environment (high prospect), while also feeling protected and safe (high refuge) (Heerwagen, 2017). This would have been preferred environmental condition during evolution, while remaining in safety and out of the sight of possible hazards (Alencar, 2013).

1.4.3 Information Perspective on Environmental Preferences

The third theory to understanding environmental preferences was developed by S. Kaplan and R. Kaplan, they argue that humans are "information hungry creatures", they prefer environments that offer the information to help them understanding the around world, from an evolutionary perspective this information is important for their survival (Kaplan, 1987) and (Kaplan *et al.*, 1989). They also argue that this information is critical to enhance people's ability to function in the surrounding environment. Based on numerous research studies, people prefer environments that have spatial qualities of mystery, legibility, coherence and complexity (Heerwagen, 2017):

- *Coherence*: Coherence refers to the features that contribute to the organization, understanding and structuring the environment, such as symmetries or repeating elements.
- *Legibility*: Relates to the legibility of what lies ahead, and the ability to predict and maintain orientation in the landscape as further explores it.
- *Complexity*: Regards the exploration of what lies in front, which is encouraged by the complexity of the information immediately available within the elements of the environment. It refers to how much is 'going on' in a particular scene, how much is there to look at.
- *Mystery*: The further exploration that is stimulated by the promise that new information could be acquired by going deeper into the scene. This also relates to a certain sense of prediction, in a sense that venturing further into the scene could indeed provide more information.

According to this theory the preferred environment needs for enough coherence and legibility to make sense and understand the environment. It also has to be balanced with sufficient complexity and mystery to

create a feeling of enticement in the individual in order to motivate them to explore the environment and gather more information (Kaplan, 1987).

1.4.4 Fractal Theory

The final approach that is used to understand the environmental preferences is related to fractal geometry. Fractal theory is led by the idea that applying the fractal geometries of natural scenes within the built environment can contribute to aesthetic and stress-reducing response. Fractal geometry has been described and explored since the 1970s. The term fractal is derived from the Latin word "fractus", meaning broken or fractured (Joye, 2007). A key property of fractals is their self-similarity, where a similar structure is apparent at increasing (or decreasing) magnifications. Each perfect fractal can be magnified repeatedly by a specific scaling ratio, and will appear the same every time (Salingaros, 2012).

Figure 1-4 Fractal pattern in nature plant (Source, Taylor, 2010)

Fractal patterns can be found in artificial world or natural world, such as trees, plants as shown in Figure 1-4, mountains, lightning, clouds, coastlines, and so on. As a result of evolution, the brain prefer fractal structures and feels relaxed when surrounded by these patterns. Therefore, visual perception studies, which used physiological measures, reveal that people feel more comfortable with fractal images showing nature, over non-fractal images such as non-fractal abstract art (Salingaros, 2012).

Empirical research has found a relationship between preferred environments and restoration, these studies suggest that the tendency to prefer natural over urban environments has some connection to the relative restorative value of natural and urban environments. Thus, certain patterns in environmental preferences, specifically the ubiquitous

preference for natural environments, are linked to the given environments' potential to provide restoration from stress or fatigue (van den Berg *et al.*, 2003) and (Hartig and Staats, 2007).

Environmental preference is related to the aesthetic quality of the natural environment; biophilia implies affection towards animals, plants, and all other living organisms, as well as an innate preference for natural environments because of our evolutionary past. As a result, Biophilia steers our relationship with Nature, including environmental preference (van den Berg *et al.*, 2003).

Summary

Connect the built environment to the natural world can reduce stress and enhance well-being, provide a physical, psychological, and cognitive benefits. This positive connection supported by three theories:

1- *Ecosystem services:* the benefits that people obtain from ecosystems.

2- *Biophilia:* the inherent human inclination to affiliate with natural systems and process.

3- *Spirit of place:* the secure and satisfying connection to the places where the people work and reside.

The world is moving to restorative design movement, to design a restorative environment, three principles need to be met; low environmental impact, organic, and vernacular design, these three design objectives reflect the three previous theories of connecting human well-being and natural systems. Organic and vernacular design is the two basic dimensions of biophilic design approach. The first dimension "Organic Design" is defined as the direct, indirect, and symbolic experience of nature, while the second one "Vernacular Design" is the design in relation of the ecology, culture, and history of place, and avoid loss of local and regional identities. Biophilic design also include the characteristics of preferred environment.

02

Chapter

Biophilic Design

Chapter 2:

Biophilic Design

Introduction

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Summary

Introduction

The human–nature relationship can be understood through the Biophilia concept, which is defined as the humanity's affiliation with nature. Biophilia helps to explain why crashing waves capture us; why a nature scene can grow our creativity; why light and shadows can fascinate us; and why moving through a park have a restorative healing effect. Biophilic design enhancing people's positive relationship to nature in the built environment, it also considered as the missing link in the prevailing approaches to sustainable design.

This chapter will focus on Biophilic design framework and health benefits. It divided into three parts: the first part represents biophilic design concept, principles, and strategies. The second part represents a summary of the important attempts by researchers to determine the conceptual framework of biophilic design. The last part represents biophilic design attributes and the psychological, physiological, and cognitive benefits of each attribute.

2.1 Biophilic Design

Biophilic design is the deliberate attempt to translate the biophilia hypothesis as mentioned above. The successful application of biophilic design result a wide spectrum of physical, mental, and behavioral benefits. Physical outcomes include enhanced physical fitness, lower blood pressure, increased comfort and satisfaction, fewer illness symptoms, and improved health. Mental benefits range from increased satisfaction and motivation, less stress and anxiety, to improved problem solving and creativity. Positive behavioral change includes better coping and mastery skills, enhanced attention, and concentration, improved social interaction, and less hostility and aggression (Kellert and Calabrese, 2015).

2.1.1 Biophilic design principles

The successful application of biophilic design need to certain basic principles. These principles represent fundamental conditions for the effective practice of biophilic design, they include (Kellert and Calabrese, 2015):

- Biophilic design requires repeated and sustained engagement with nature.

- Biophilic design focuses on human adaptations to the natural world that over evolutionary time have advanced people's health, fitness, and wellbeing.
- Biophilic design encourages an emotional attachment to settings and places.
- Biophilic design promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities.
- Biophilic design encourages mutual reinforcing, interconnected, and integrated architectural solutions.

2.1.2 Biophilic Design Strategies

To put people in closer contact with nature can focus on building design, landscape design, interior design, or any combination of the three. A sampling of biophilic design strategies is presented as following (Kellert, 2008):

In General:

- Address biophilia early in the design and planning process by considering biophilic design strategies very early in the design process.
- Seek ways to integrate biophilic design into existing as well as new buildings.
- Conveying the importance of biophilic design to the design community and specific market segments, such as education and healthcare, will take concerted effort by the green building community.
- Visually, ecologically, historically, and culturally connecting a building to the locale helps connect occupants to a place and, in doing so, inspires them to protect that area.

In Landscape and site design:

- Provide open spaces around buildings.
- Maintain existing trees and native landscapes.
- Build pathways through naturalized and landscaped area.
- Replace impervious landscape surfaces with diverse native plantings.

In Building design:

- Provide views to nature through using windows and openings.
- Combine the interior and exterior spaces, such as extend living and working spaces into the surrounding landscapes through terraces, courtyards, and balconies.
- In designing glazing systems, deck railing, and other features that could interfere with views of nature, carefully plan the sightlines, and avoid interference whenever possible.
- Provide high levels of daylighting.
- Incorporate vegetated areas and interior planting beds.
- Provide green roofs.
- Consider incorporating water features in buildings.
- Create a sense of complexity in building design.
- Address both speciousness and refuge in building design.
- Incorporate shapes and forms that mimic nature into buildings.

In Interior design:

- Using potted plants and small gardens as part of the interior design strategy.
- Provide natural materials and nature art in the spaces.
- Use signage and other interpretive features to explain biophilic features and functions so that they will be better appreciated, managed, and understood.
- Workstations should be positioned so that workers can see out windows and benefit from natural lighting, interior gardens.

2.2 Biophilic Design Conceptual Framework (Researchers' Attempts)

There have been many important attempts by researchers to determine the conceptual framework and the elements and attributes of biophilic design:

1. A list of biophilic design features proposed by the environmental psychologist Judith Heerwagen in the article *"Building Biophilia: Connecting People to Nature in Building Design"*, which provides a group of fundamental elements and attributes of biophilic design.

2. The model proposed by Stephen Kellert, one of the most referred *guides* for biophilic design that discussed in the book *"Biophilic Design: The Theory, Science, and Practice of Bringing Building to Life"*, this model contains a wide variety of elements and attributes.

3. The third model was first laid out by Jenifer Cramer and William Dee Browning in the book *"Biophilic Design: The Theory, Science, and Practice of Bringing Building to Life",* and developed after that by Terrapin Bright Green LLC, a multidisciplinary consultant company. This model is mostly proposed by the partner and co-founder William Dee Browning, established three categories meant to help define biophilic buildings each category of them includes different patterns of biophilic design.

4. An updated model proposed by Stephen Kellert and Elizabeth Calabrese in a recently published document "*The Practice of Biophilic Design"*, which details three experiences and 24 attributes of Biophilic design.

2.2.1 Characteristics of Biophilic Design (Heerwagen, 2001)

Heerwagen proposed fundamental features of a biophilic building and identifies specific design attributes associated with each feature as shown in Table 2-1. These features derived from research on habitability, natural processes, and the geometry of nature (Heerwagen and Hase, 2001).

Table 2-1 Elements and attributes of biophilic design (Heerwagen and Hase, 2001)

Elements of Biophilic Design	Attributes and Qualities
Prospect (Ability to see into distance)	• Brightness in the field of view (windows, bright walls). • Ability to get to a distant point for a better view. • Horizon/sky imagery (sun, mountains, clouds). • Strategic viewing conditions. • View corridors.
Refuge (Sense of enclosure or shelter)	• Canopy effect like lowered ceilings.

Water (Indoors or inside views)	• Glimmer or reflective surface (suggests clean water). • Moving water (also suggests clean, aerated water). • Symbolic forms of water.
Biodiversity	• Varied vegetation indoors and out (large trees, plants, flowers) • Windows designed and placed to incorporate nature views • Outdoor natural areas with rich vegetation and animals
Sensory variability	• Changes and variability in environmental color, temperature, air movement, textures, and light over time and spaces. • Natural rhythms and processes (natural ventilation and lighting).
Biomimicry	• Designs derived from nature. • Use of natural patterns, forms, and textures. • Fractal characteristics (self-similarity at different. • levels of scale with random variation in key features rather than exact repetition).
Sense of playfulness	• Incorporation of decor, natural materials, artifacts, objects, and spaces whose primary purpose is to delight, surprise, and amuse.
Enticement	• Discovered complexity. • Information richness that encourages exploration. • Curvilinear surfaces that gradually open information to view.

2.2.2 Biophilic Design Elements and Attributes (Kellert, 2008)

There are two basic dimensions of biophilic design; organic or naturalistic dimension, and place based or vernacular dimension, as we mentioned above, according to Kellert, these two dimensions can be related to six design elements (Kellert, 2008).These elements are related to more than 70 biophilic design attributes, as shown in Table 2-2.

Table 2-2 Elements and attributes of biophilic design (Kellert, 2008)

Environmental features	Natural shapes and forms	Natural patterns and processes
• Color • Water • Air • Sunlight • Plants • Animals • Natural materials • Views and vistas • Façade greening • Geology and landscape • Habitat and ecosystems • Fire	• Botanical motifs • Tree and columnar supports • Animal (mainly vertebrate) motifs • Shells and spirals • Egg, oval, and tubular forms • Arches, vaults, domes • Shapes resisting straight lines and right angles • Simulation of natural features • Biomorphy • Geomorphology • Biomimicry	• Sensory variability • Information richness • Age, change, and the patina of time • Growth and efflorescence • Central focal point • Patterned wholes • Bounded spaces • Transitional spaces • Linked series and chains • Integration of parts to wholes • Complementary contrasts • Dynamic balance and tension • Fractals • Hierarchically organized ratios and scales
Light and space	**Place-based relationships**	**Evolved human-nature relationships**
• Natural light • Filtered and diffused light • Light and shadow • Reflected light • Light pools • Warm light • Light as shape and form • Spaciousness • Spatial variability • Space as shape and form • Spatial harmony • Inside-outside spaces	• Geographic connection to place • Historic connection to place • Ecological connection to place • Cultural connection to place • Indigenous materials • Landscape orientation • Landscape features that define building form • Landscape ecology • Integration of culture and ecology • Spirit of place • Avoiding placelessness	• Prospect and refuge • Order and complexity • Curiosity and enticement • Change and metamorphosis • Security and protection • Mastery and control • Affection and attachment • Attraction and beauty • Exploration and discovery • Information and cognition • Fear and awe • Reverence and spirituality

2.2.3 Design Patterns (Browning 2014)

This model divided into three categories that would help define biophilic design: Nature in the Space, Natural Analogues, and Nature of the Space (Browning *et al.*, 2014).

1. *Nature in The Space:*

   This category addresses the direct, physical, and ephemeral presence of nature in a space or place.

2. *Natural Analogues:*

   Natural Analogues are design features that evoke some aspect of nature.

3. *Nature of The Space:*

The final category exploring human psychologically and physiologically response to spatial patterns as a way of evoking our innate tendency to affiliate with nature.

Every category encompasses many patterns of biophilic design as shown in Table 2-3.

Table 2-3 14 patterns of biophilic design (Browning *et al.*, 2014)

Nature in The Space	Natural Analogues	Nature of The Space
1- Visual Connection with Nature 2- Non-Visual Connection with Nature 3- Non-Rhythmic Sensory Stimuli 4- Thermal and Airflow Variability 5- Presence of Water 6- Dynamic and Diffuse Light 7- Connection with Natural Systems	8- Biomorphic Forms and Patterns 9- Material Connection with Nature 10- Complexity and Order	11- Prospect 12- Refuge 13- Mystery 14- Risk/Peril

2.2.4 Experiences and Attributes of Biophilic Design (Kellert and Calabrese 2015)

According to Kellert there is three kinds of nature experience represent the basic categories of biophilic design framework; the direct experience of nature, the indirect experience of nature, and the experience of space and place (Kellert and Calabrese, 2015).

1. *Direct Experience of Nature*

   The Direct Experience of Nature refers to actual contact with environmental features in the built environment.

2. *Indirect Experience of Nature*

   The Indirect Experience of Nature refers to contact with the representation or image of nature, the transformation of nature from its original condition, or exposure to patterns and processes characteristic of the natural world, such as pictures and artwork, natural materials, ornamentation inspired by natural shapes and forms, environmental processes, and others.

3. *Experience of Place and Space*

   The final category Experience of Space and Place refers to spatial features characteristic of the natural environment that

have advanced human health and wellbeing and create a satisfying indirect experience of nature.

Within these three categories of experience, 24 attributes of biophilic design have been identified as shown in Table 2-4.

Table 2-4 Experiences and Attributes of Biophilic Design (Kellert and Calabrese, 2015)

Direct Experience of Nature	Indirect Experience of Nature	Experience of Place and Space
1. Light **2.** Air **3.** Water **4.** Plants **5.** Animals **6.** Weather **7.** Natural landscapes and ecosystems **8.** Fire	**9.** Images of nature **10.** Natural materials **11.** Natural colors **12.** Simulating natural light and air **13.** Naturalistic shapes and forms **14.** Evoking nature **15.** Information richness **16.** Age, change, and the patina of time **17.** Natural geometries **18.** Biomimicry	**19.** Prospect and refuge **20.** Organized complexity **21.** Integration of parts to wholes **22.** Transitional spaces **23.** Mobility and wayfinding **24.** Cultural and ecological attachment to place

Biophilic design has two basic dimensions organic design; which is defined as the direct, indirect, and symbolic experience of nature, and vernacular design; which is the design in relation to the ecology of place, culture, and history. Biophilic design also include the characteristics of preferred environment as mentioned in chapter one. Figure 2-1 show a summary of Biophilic Design framework of the different attempts.

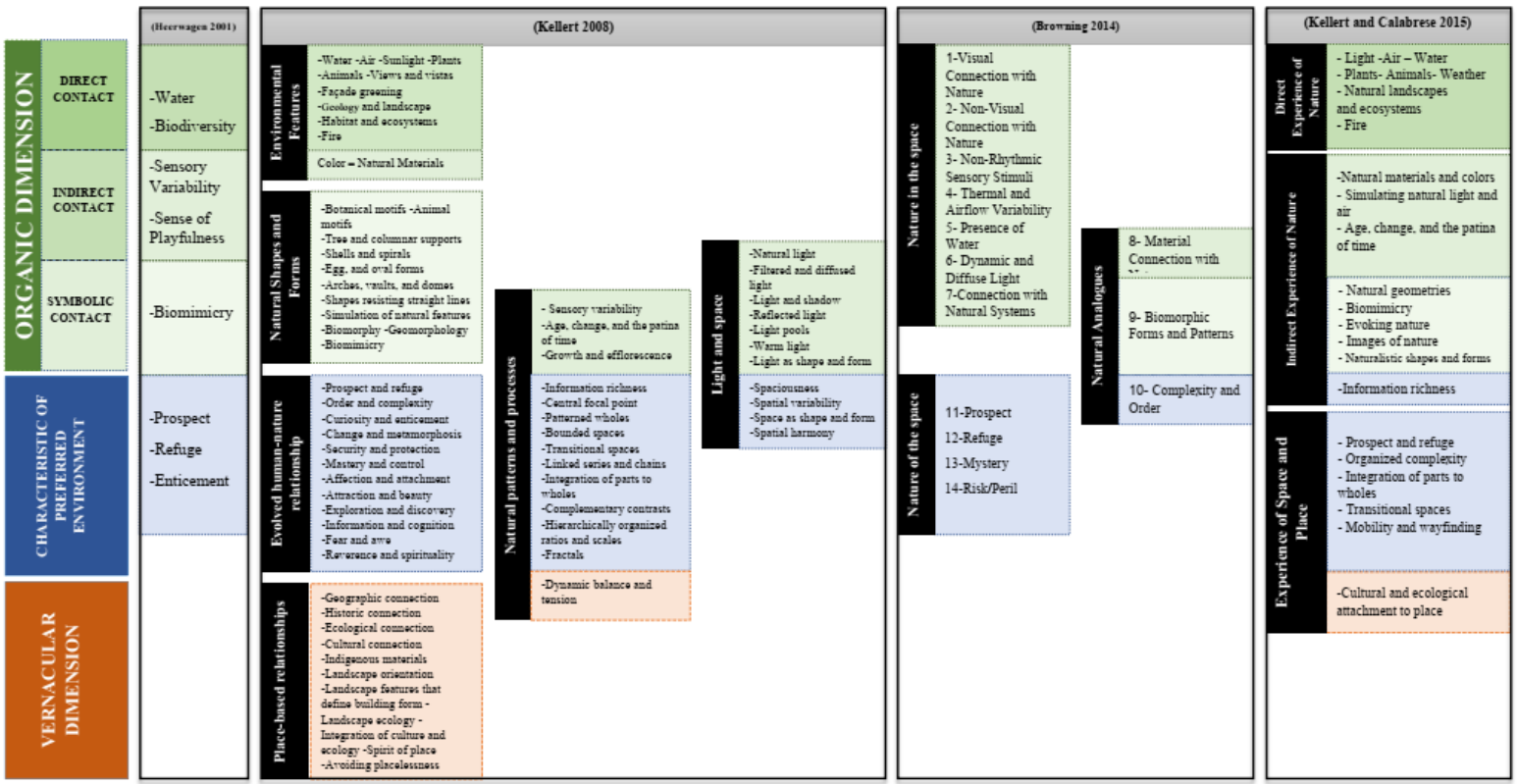


Figure 2-1 A summary of Biophilic Design framework and its relation to nature and humand wellbeing theorie (source, Author)

2.3 Biophilic Design Attributes and Health Benefits

The three basic categories of our biophilic design framework; the direct experience of nature, the indirect experience of nature, and the experience of space and place, includes 24 attributes as mentioned before in Table 2-4.

2.3.1 Direct Experience of Nature

- *Light*

  The experience of natural light is fundamental to human health and wellbeing, enabling an orientation to the day, night, and seasons in response to the sun's location and cycles. An awareness of natural light can also facilitate movement and wayfinding and contribute to comfort and satisfaction. Natural light can assume aesthetically appealing shapes and forms through the creative interplay of light and shadow, diffuse and variable light, and the integration of light with spatial properties (Kellert and Calabrese, 2015).

  Many studies found a relationship between sunshine and enhance mood, productivity, communication, and satisfaction (Denissen *et al.*, 2008; Youssef, 2017). Exposure to natural light improve the production of vitamin D in the body, also balance the body's hormonal levels of serotonin, which linked to mood, and control the production of melatonin that is responsible of regular sleep (AbdelMeguid, 2014). The imbalance of serotonin and melatonin causes many health problems; disturbed sleep-wake pattern, changes body temperature and heartrate, bad mood, alertness, depression, breast cancer (Youssef, 2017).

  Our cognitive functions can be impacted by natural lighting, several studies prove that daylighted workplaces and classrooms enhance concentration, easing the performance of visual tasks, and improve productivity and mental health for users (Youssef, 2017).

  Natural light can be brought deep into interior spaces by such means as glass walls and clerestories, the use of

reflecting colors and materials, and other design strategies. The experience of light in motion can be achieved through the contrast of lighter and darker areas and changes of daylight over time (Kellert and Calabrese, 2015).

- *Air*

  Natural ventilation is important to human comfort, well-being, and productivity (Kellert and Calabrese, 2015). The natural movements such as a light breeze, positively impact concentration and cognitive activity (Youssef, 2017).

  The experience of natural ventilation in the built environment can be enhanced by variations in airflow, temperature, humidity, and barometric pressure. Variability of thermal conditions within a class room can lead to better student performance; and changing in airflow velocity positively impact comfort and enhance concentration (Kellert and Calabrese, 2015).

- *Water*

  Water is essential to life and its positive experience in the built environment can relieve stress, promote satisfaction, and enhance health and performance (Kellert and Calabrese, 2015). The presence of water prompts positive emotional responses and enhance the experience of a place in a manner that is soothing, prompts contemplation, enhances mood, and provides restoration from cognitive fatigue, reduced stress, increased feeling of tranquility, lower heart rate and blood pressure, improved both self-steam and mood (Youssef, 2017).

  The attraction to water can be especially pronounced when associated with the multiple senses of sight, sound, touch, taste, and movement. Varying design strategies can satisfy the desire for contact with water including views of prominent water bodies, fountains, aquaria, constructed wetlands, and others. Water in the built environment is often most pleasing when perceived as clean, in motion, and experienced through multiple senses (although at muted sound levels) (Kellert and Calabrese, 2015).

- *Plants*

Vegetation, especially flowering plants, is one of the most successful strategies for bringing the direct experience of nature into the built environment. The presence of plants in the workplace can reduce stress, promote human creativity, and improve overall mood, contribute to physical health, improve comfort, and enhance performance and productivity (Kellert and Calabrese, 2015; Smith, 2013).

Green areas and gardens offer several benefits to human health; lower heart rate and blood pressure, increase pain tolerance, and faster stress recovery. Plants effectively purify and filter the environment, as they absorb atmospheric gases and release oxygen therefore, they purify the air from the existing pollutants, it also releasing moisture, to prevent dryness (AbdelMeguid, 2014). Forest walking has also revealed that levels of the hormone DHEA tend to increase (Soderlund, 2015). One research study found that presenting flowers to an individual had a positive impact on mood, measured by a significant increase in the Duchenne or 'true' smile and change in social behaviors (Stanke, 2014).

One research study found that presenting flowers to an individual had a positive impact on mood, measured by a significant increase in the Duchenne or 'true' smile and change in social behaviors (Kellert and Calabrese, 2015).

- *Animals*

The presence of animal life has been an essential part of people's experience throughout human history. Positive contact with animal life can be achieved through many design strategies as green roofs, gardens, feeders, aquaria, aviaries, and the creative use of modern technologies such as videos, web cameras, and spotting scopes. Contact with nonhuman animal life should include a diversity of species, and emphasize local rather than non-native species (Kellert and Calabrese, 2015).

- *Weather*

The awareness and response to the weather has been an essential feature of nature experience throughout history, and important to human fitness and survival. The contact with the weather in the built environment can be satisfying and stimulating. This connection can occur through direct exposure to outside conditions, and simulating weather-like qualities through manipulating temperature, airflow, barometric pressure, and humidity. (Kellert and Calabrese, 2015).

- *Natural landscapes and ecosystems*

Interconnected plants, animals, water, soils, rocks, and geological forms are the components of natural landscapes and ecosystems. People prefer landscapes with trees, water, forested edges, and other features that characteristic of the savannah. Thus, the ordinary natural landscape scenery is preferred by most people over the artificial landscapes (Kellert and Calabrese, 2015).

Natural landscape can reduce stress and boost human beings' comfort and physical condition such as heart rate, blood pressure, and salivary cortisol (stress hormone). One study found that walking through forest increase parasympathetic activity, which takes place when we feel relaxed; and decline sympathetic activity, which takes place when we feel stress (Youssef, 2017). As well, another study showed that viewing a forest scene for 20 minutes after a mental stressor returned cerebral blood flow and brain activity to a relaxed state (Ryan *et al.*, 2014). Furthermore, landscape has positive psychological effects on human beings, enhance mood and improve self-steam (AbdelMeguid, 2014).

The self-sustaining ecosystems experience can be satisfying, enjoyable, comfortable, and enhance cognitive performance. Ecosystem environments are rich in biological diversity and support many ecological services. Self-sustaining ecosystems in the built environment can be achieved through many design strategies as constructed wetlands, and grasslands; green roofs; simulated aquatic

environments; and other means. Contact with natural systems can be fostered by views, observational platforms, direct interaction, and even active participation (Kellert and Calabrese, 2015).

- *Fire*

The fire control is one of humanity's greatest achievements that allowed the controlling of energy beyond animal life and facilitated transformation of objects from a state to another. The fire experience can be a source of comfort and anxiety The satisfying presence of fire in the built environment can be achieved through the construction of fireplaces and hearths, but also simulated by the creative use of light, color, movement, and materials of varying heat conductance (Kellert and Calabrese, 2015).

2.3.2 Indirect Experience of Nature

- *Images of nature*

The representation of nature in the built environment as plants, animals, water, landscapes, and geological features, can be emotionally and intellectually satisfying (Kellert and Calabrese, 2015). Also, views of nature have many health benefits, as reduce stress, and improve mental health. Many studies show that viewing videotapes and various pictures of pleasing landscapes to patients increase pain tolerance, reduce stress hormone levels, and result better recovery rates(Youssef, 2017). It was found that painting views of nature with water is the most restorative potential from mental fatigue more than the actual views of an ordinary nature through a window (Youssef, 2017).

The images of nature can occur using photographs, paintings, sculptures, murals, videos, computer simulations, and other representational means. Single or isolated images of nature typically exert little impact. Representational expressions of nature should be repeated, thematic, and abundant (Kellert and Calabrese, 2015).

- *Natural materials*

Prominent natural building and decorative materials include wool, cotton, wood, stone, and leather, used in a

wide range of furnishings, fabrics, products, and other interior and exterior designs (Kellert and Calabrese, 2015). Natural material in the built environment can be decorative or functional, it can be typically treated or extensively reformed, (e.g., wood board, granite countertop) from their natural state (Youssef, 2017).

A research study has found that a difference in wood ratio on the walls of an interior space can led to a various psychological response, they observed that the increase in coverage ratio of the wooden walls can decrease the brain activity and the diastolic blood pressure, which is recommended in many spaces such as spa, and doctors' offices (Browning *et al.*, 2014). Therefore, the amount and type of Biophilic feature, as well as the target users, needs to be considered in design.

- *Natural colors*

Colors is an important means for locating food, water, and other resources, as well as facilitating movement and wayfinding. The modern design given an ability to generate artificial, especially bright colors, so the effective use of color in the built environment is challenging. The natural color can occur through the use of muted "earth" tones characteristic of soil, rock, and plants (Kellert and Calabrese, 2015).

In a series of four experiments examining the effect of the presence of the color green on the psychological functioning of participants, the results concluded that exposure to the color green before conducting a task "facilitates creativity performance, but has no influence on analytical performance (Browning *et al.*, 2014).

- *Simulating natural light and air*

Advances technology in building construction made the indoor lighting and the processed air possible. Artificial light can be designed to mimic the spectral and dynamic qualities of natural light (Kellert and Calabrese, 2015). The interior lighting that holds user's attention and stimulate the

eye, in a manner that create a positive physiological and psychological responses, help users maintaining the circadian system functioning. (Youssef, 2017).

Variable lighting designs trigger different psychological responses; the applied diffuse lighting[1] on ceiling and vertical planes provides a calm visual background to the scene, while manifesting accent lighting[2] and other layering of light sources creates interest and depth. These strategies create a pleasant visual environment, and safe navigation. (Youssef, 2017)

Processed air can also simulate qualities of natural ventilation through variations in airflow, temperature, humidity, and barometric pressure (Kellert and Calabrese, 2015). Important conditions include quality, movement, and flow, stimulation of other senses such as feel and smell, and visual appeal (Youssef, 2017).

- *Naturalistic shapes and forms*

  The naturalistic forms can be diverse from the shapes of plants on building facades, and the leaf-like patterns found on columns, to animal images into fabrics. This occurrence of naturalistic shapes and forms can transform a static space to a dynamic one with qualities of a living system. (Kellert and Calabrese, 2015)

  Researches on view preferences has found that the experience of naturalistic shapes and forms reduced stress due to induced shift in focus, and enhanced concentration (Browning *et al.*, 2014).

- *Evoking nature*

  Evoking nature is the representations that may not literally occur in the nature, but still draw from design principles that encounter the natural world. For example, the wings of Sydney Opera House suggest the qualities of a bird Figure 2-2. Also, Notre Dame's stained-glass windows, a rose-like flower, while the skyline of many

[1] Diffused light is the indirect and soft light.

[2] Accent light is the focused light on an area or object

cities mimic the vertical heterogeneity of a forest. None of these designs occurs in the nature world, but they all draw from design principles and characteristics nature (Kellert and Calabrese, 2015).

Figure 2-2 The "wings" of the Sydney Opera House (Kellert and Calabrese, 2015)

- *Information richness*

The diversity of the nature is obvious, the natural world has been described as the most information-rich environment people will ever know. People tend to respond positively to information-rich and diverse environments that present a wealth of options and opportunities, whether natural or built, so long as the complexity is experienced in a coherent and legible way (Kellert and Calabrese, 2015).

- *Age, change, and the patina of time*

Nature is always changing and respond adaptively to this changing conditions. People respond positively to the dynamic forces of growth and aging. These dynamic tendencies are often most satisfying when balanced by the qualities of unity and stability. Naturally aging materials, weathering, and a sense of the passage of time, are ways to achieve change and a patina of time. (Kellert and Calabrese, 2015)

- *Natural geometries*

Natural geometries refer to mathematical properties commonly encountered in nature. For example, fractals as mentioned before; are a geometric form often encountered in the natural world, where a basic shape occurs in repeated

and predictable ways, which contribute both variety and similarity to a setting. Other prominent natural geometries include hierarchically ordered scales such as the "Golden Ratio" and "Fibonacci Sequence." (Kellert and Calabrese, 2015)

When subjects were shown images of fractal patterns in nature or townscapes of the built environment, electroencephalography (EEG) results reflecting neural and parasympathetic system reactions showed that subjects were more wakefully relaxed when exposed to natural landscapes. The study concluded that in environments with many stimuli and patterns, the patterns that are most likely to hold our attention and induce a relaxed response are fractal patterns commonly found in nature. These results may explain why natural environments are often preferred over built ones. Functional Magnetic Resonance Imaging (FMRI) studies revealed a link between aesthetic response and the brain's pleasure center, people would gravitate toward aesthetic forms that have been reinforced throughout their history. The "nested scaling hierarchy" which are fractals, can be found in many traditional architectural forms, confirming previous generations' greater connection (conscious or not) to the natural environment (Youssef, 2017).

Nature abhors right angles and straight lines; the Golden Angle, which measures approximately 137.5 degrees, is the angle between successive florets in some flowers, while curves and angles of 120 degrees are frequently exhibited in other elements of nature (e.g.,)

The Fibonacci series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34...) is a numeric sequence that occurs in many living things, plants especially the spacing of plant leaves, branches, and flower petals (so that new growth doesn't block the sun or rain from older growth) often follows in the Fibonacci series. Related to the Fibonacci series is the Golden Mean (or Golden Section), a ratio of 1:1.618 that surfaces time and again among living forms that grow and unfold in steps or rotations, such as with the arrangement of seeds in

sunflowers or the spiral of seashells (Browning *et al.*, 2014).

- *Biomimicry*

  Biomimicry refers to forms and functions that found in nature, especially among species, whose properties adopted and suggest solutions to human challenges and problems. For example, the bird's nest structure, the bioclimatic controls of termite mounds, and the structural strength of spider webs. Technologically capturing these characteristics of nonhuman nature can result in direct utilitarian benefits, as well as encourage human interest for the creativity of nature. (Kellert and Calabrese, 2015)

  Biomimicry strategies provide representational design elements within the built environment allow users to connect to the natural world. This connection creates a more visually preferred environment that enhances cognitive performance while helping reduce stress (Browning *et al.*, 2014).

2.3.3 Experience of Place and Space

- *Prospect and refuge*

  Prospect refers to long views of surrounding settings that allow people to perceive both opportunities and dangers, while refuge provides sites of safety and security. The prospect sense can be achieved through such design strategies as internal and external views through windows or view corridors. On the other hand, refuge sense can be achieved through such design strategies as canopy-like features and vertical enclosures (Kellert and Calabrese, 2015). Health benefits are suggested to include reductions in stress, boredom, irritation, fatigue and perceived vulnerability, as well as improved comfort, concentration, attention and perception of safety (Browning *et al.*, 2014).

- *Organized complexity*

  Stephen Kaplan defines complexity as a measure for "how much is 'going on' in particular scene, how much there is to look at" (Salingaros, 2012). People prefer complexity in both natural and human settings that make

places rich in options and opportunities. However, too much complexity is often confusing and messy. The most satisfying settings tend to have qualities of complexity, but in an orderly and organized way (Kellert and Calabrese, 2015).

In architectural design organized complexity is achieved through symmetries and fractal geometries; a key property of fractals is their self-similarity, where a similar structure is apparent at increasing (or decreasing) magnifications configured with a coherent spatial hierarchy, to create a visually nourishing; environment that engenders a positive psychological and cognitive response (Salingaros, 2012).

- *Integration of parts to wholes*

  People prefer in the natural and built environment the settings where disparate parts comprise an integrated whole. The feeling of an emergent whole can be achieved through the successional and sequential linking of spaces, as well as clear and discernible boundaries. In architectural design this satisfying integration of space can be improved by a central focal point. (Kellert and Calabrese, 2015)

- *Transitional spaces*

  Successfully navigating environment depends on clearly understood connections between spaces that facilitated by clear and discernible transitions. Transitional spaces include gateways, hallways, doorways, thresholds, and areas that link the indoors and outdoors, especially courtyards, colonnades, porches, patios, and more. (Kellert and Calabrese, 2015)

- *Mobility and wayfinding*

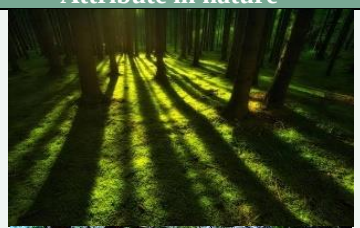
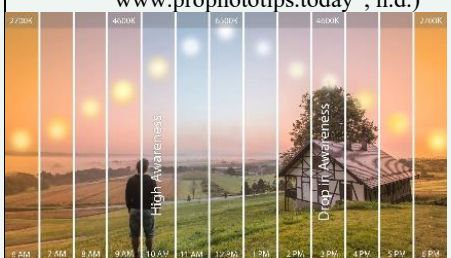
  The freely moving between diverse and complicated spaces enhance people's comfort and wellbeing. Understanding pathways and points of entry are critical to fostering mobility and feelings of security, and the absence of these features may results confusion and anxiety (Kellert and Calabrese, 2015).

- *Cultural and ecological attachment to place*

  Humans evolved as a local creature, it promoted the resources control, enhanced security, and facilitated movement and mobility. The affinity of the familiar places reflects this territorial inclination, which can be enhanced by cultural and ecological means. The designs that are relevant to the culture promote a connection to the place and the sense that a sitting has a distinct human identity. Ecological connections to place can foster an emotional attachment to an area, particularly an awareness of local landscapes, indigenous flora and fauna, and characteristic meteorological conditions. Cultural and ecological attachments to place often motivate people to conserve and sustain both natural and human built environments (Kellert and Calabrese, 2015).

The following Table 2-5 represent a summary of biophilic design attributes and the next one Table 2-6 shows the cognitive function, physical health, and psychological well-being that biophilic design attributes support.

Table 2-5 Biophilic Design attributes summary (Source, Author)

Biophilic Design Attributes		Description	Attribute in nature	Attribute in the built envrironment
Direct Experince of Nature	**Light**	Enabling natural light to enter interior spaces with response to the sun's location and cycles, also interplay of light and shadow, and diffuse and variable light, to creat creative and dynamic shapes and forms.	 Light and shadow in nature (Source, "pixabay.com", 2021& "www.prophototips.today", n.d.)  Circadian lighting in nature (Source, "refurbandrestore.co.uk", n.d.)	  Natural light in the built environment (Source, Seixas *et al.*, 2016 & ("www.dpreview.com", 2013)  Circadian lighting in an office (Source, Knoerzer, n.d.)

	Air	The presence of natural ventilation in the built environment, which can be enhanced by variations in airflow, temperature, humidity, and barometric pressure.		
	Water	The presence of water bodies especially when it associated with the multiple senses of sight, sound, touch, taste, and movement.	 Waterfalls in nature (Source, www.tripadvisor.com.sg", 2021)	 Water fountain (Source, "carvedstonecreations.com", n.d.)
	Plants	The presence of vegetation, especially flowering plants.	 Vegetation in nature (Source, "rare-gallery.com", n.d.)	 Indoor landscape (Amsterdam Offices) (Source, "officesnapshots.com", 2013)

<table>
<tr><td></td><td>Animals</td><td>The contact with nonhuman animal life with a diversity of species and emphasizing local rather than non-native species.</td><td> 
Underwater landscape Bali, Indonesia
(Source, “www.worldatlas.com”, 2019)</td><td> 
Fish tank (Source, “www.centerpointmedicine.com”, n.d.)</td></tr>
<tr><td></td><td>Weather</td><td colspan="2">This connection can occur through direct exposure to outside conditions, and simulating weather-like qualities through manipulating temperature, airflow, barometric pressure, and humidity.</td><td> 

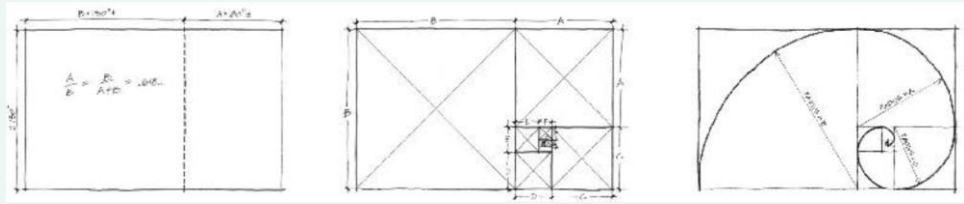
Natural Ventilation in indoor spaces (Source, “www.archdaily.com”, 2021a)</td></tr>
</table>

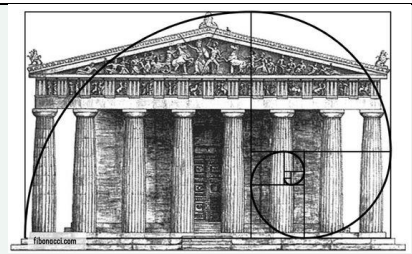
	Natural Landscape and Ecosystem	Interconnected natural landscape and ecosystems components such as plants, animals, water, soils, rocks, and geological forms. The ordinary natural landscape scenery is preferred by most people over the artificial landscapes.	 Forest Landscape (Source, "envirodatagov.org", 2022)	 Indoor waterfall and forest- Jewel Changi Airport, Singapore, 2019 (Source, "www.architonic.com", 2022)
	Fire	The presence of controlled fire sources such as fireplaces and hearths, but also simulated by the creative use of light, color, movement, and materials of varying heat conductance.	 Fire in natre (Source, "stock.adobe.com", n.d.)	 Fireplace in a home (Source, ("pixabay.com", 2016)

<table>
<tr><td rowspan="2">Indirect Experince of Nature</td><td>Natural Materials</td><td>The presence of decorative or functional natural material in the built environment such as wool, cotton, wood, stone, and leather, which can be typically treated or extensively reformed, (e.g., wood board, granite countertop) from their natural state.</td><td> 
Wood in trees (Source, (“pixnio.com”, 2017)</td><td> 
Timber in interior design finishing (Source, (“www.archdaily.com”, 2021b)</td></tr>
<tr><td>Natural Colors</td><td>The presence of natural colors such as muted “earth” tones characteristic of soil, rock, and plants.</td><td colspan="2"> 
Natural colour palette in interior design (Source, “zelmanstyle.com”, 2019)</td></tr>
</table>

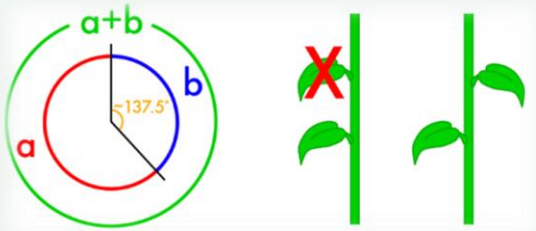
	Stimulating Natural Light and air	Artificial light can be designed to mimic the spectral and dynamic qualities of natural light. Processed air can also simulate qualities of natural ventilation through variations in airflow, temperature, humidity, and barometric pressure.	 Simulating circadian lighting colors in artificial lighting (Source, "www.clantonassociates.com", 2021 & "www.silumen.com", n.d.)	
	Naturalistic Shapes and Forms	The naturalistic forms are the representations of the natural world that can be found in buildings façades and within interiors. Such as animal and botantial motifes, tree and columner support, shells and spirals, egg, oval and tubular forms, arches, vaults, and domes, and	 Forest trees (Source, ("www.chandramauli.org", n.d.)	 Colonnade (Source, ("www.britannica.com", 2008)

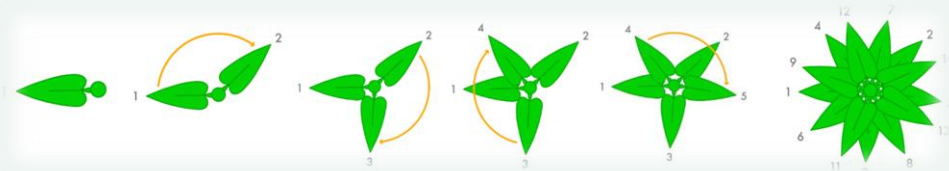
		shapes resisting straight lines and right angles.		
	Evoking Nature	Evoking nature is the representations that may not literally occur in nature, but still draw from design principles that encounter the natural world.	 Oval and egg shape in nature (Source, ("www.mentalfloss.com", 2013)	 London City Hall by Foster use egg-shaped architecture(Source, ("www.archipanic.com", 2019)
	Information Richness	Information richness is the cognitive richness of the natural world, in other words it is present a wealth of options and opportunities, whether natural or built, so long as the complexity is experienced in a coherent and legible way, such as buildings and landscapes that possess variety, textures, and detail that mimic natural patterns when coherently revealed.	 Information richness in nature (Source, ("www.rootedinnature.org", 2006)	 Information richness in design (Source, ("www.rootedinnature.org", 2006)

	Age, Change, and the Patina of Time	The presence of naturally aging materials, weathering, and a sense of the passage of time.	 Naturally aging materials (Source, (“www.lifespan.io”, 2018)
	Natural Geometries	Natural to geometries refer mathematical properties commonly encountered in nature. For example, fractals (self-repeted shapes), hierarchically ordered scales such as the “Golden Ratio” (1:1.618) and “Fibonacci Sequence.” (The series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34...) is a numeric sequence that occurs in many living things), and the “Golden Angle” that measures approximately 137.5 degree.	 The golden ratio (Source, (“slideplayer.com”, 2018)  The examples of ‘golden ratio’ that occurs in nature (Source, (Perera and Coppens, 2019)

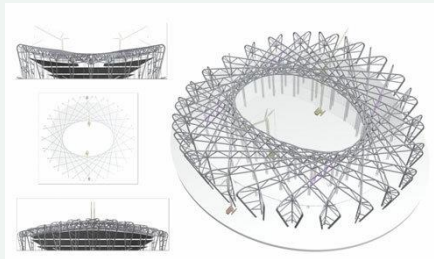


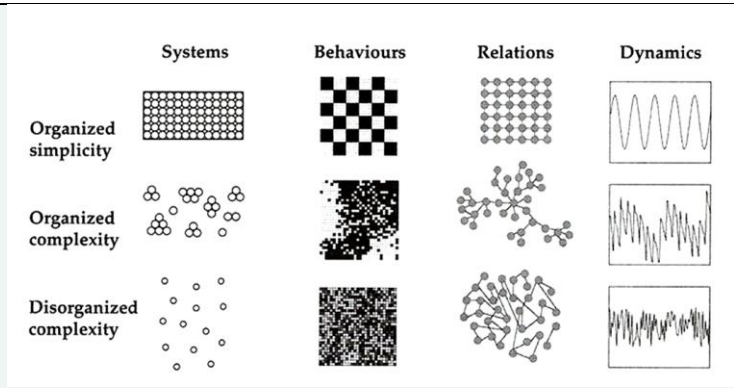
The golden ratio in the Parthenon temple (Source, (“fibonacci.com”, n.d.)





The golden angle in natural plant (Source, (“gofiguremath.org”, 2013)

	Biomimicry	Biomimicry is the designs borrowed from adaptations funcionally found in nature, particularly among other species. For example, the bird's nest structure, the bioclimatic controls of termite mounds, and the structural strength of spider webs.	 The bird nest structure (Source, ("www.michaels.com", n.d.)	 Steel structure of the "Bird's Nest", The Beijing National Stadium, China (Source, (Chan *et al.*, 2006)
Experience of space and place	**Prospect and Refuge**	Prospect and refuge refer to protected and safe places (refuge) with long views of surrounding settings (prospect). The prospect sense can be achieved through such design strategies as external views through windows or view corridors. while refuge sense can be achieved through such design strategies as canopy-like features and vertical enclosures.	 The prospect and refuge in nature (cave) (Source, ("www.west-crete.com", 2008)	 The prospect and refuge in an architectural space (Source, ("www.archdaily.com", 2020)

	Organized Complexity	It is to have qualities of complexity, but in an orderly and organized way.	 Visualization of the simplicity, organized complexity and disorganized complexity (Source, (TÜMTÜRK, 2018)  Organized complixity in nature (Source, ("nature-explorations.com", 2019)

	Integration of Parts to Wholes	Emergent whole can be achieved through the successional and sequential linking of spaces, as well as clear and discernible boundaries, and a central focal point.	 Centeral focal point an symmetry in flower design (Source, (“allyinspirit.tumblr.com”, 2014)	 Centeral focal point an symmetryin architecture design, Saint Peter’s Square, Rome (Source, (“www.turismoroma.it”, n.d.)
	Transitional Spaces	Clearly understood connections between spaces that facilitated by clear and discernible transitions, which include gateways, hallways, doorways, thresholds, and areas that link the indoors and outdoors, especially courtyards, colonnades, porches, patios, and more.	 Transition space from shadowed forest to the lighted river (Source, (“www.hikingphotographer.uk”, 2022)	 Transitional spaces in a traditional Indian house (Source, (“www.re-thinkingthefuture.com”, n.d.)

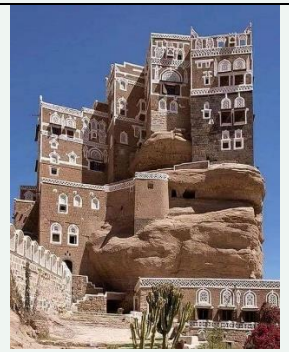
	Mobility and Wayfinding	Understanding pathways and points of entry to fostering mobility and feelings of security.		
	Cultural and Ecological Attachment to Place	Ecological attachment to the place can be done through connection to prominent ecosystems such as watersheds and and dominant biogeographical features (e.g., mountains, deserts, estuaries, rivers, and oceans), also protect the surrounding ecology system and the different species that are living there, therefore, aspire to achieve net ecological productivity. Cultural connection to place integrates the history, geography, and ecology of an area, becoming an integral component of individual and collective identity, this can be done by the architectural heritage of a people, particularly its treasured and distinctive vernacular forms.		 Vernacular Design Sanaa- Yemen (Source, ("www.facebook.com", 2022)

Table 2-6 Biophilic Design attributes impact (Author)

Biophilic Design Attributes	Psychological response	Physiological response	Cognitive response
Direct Experience of nature			
Light	enhance mood psychological restoration	improve the production of vitamin D balance the body's hormonal levels of serotonin responsible of regular sleep	improve productivity and mental health. enhance concentration
Air	positively impact comfort		improve productivity enhance concentration and cognitive productivity
Water	reduce stress promote satisfaction enhance mood and self-steam	enhance health lower heart rate and blood pressure	enhance performance prompts contemplation provides restoration from cognitive fatigue
Plants	reduce stress enhance mood improve comfort	enhance physical health lower heart rate and blood pressure increase pain tolerance purify the air from the existing pollutants increase the hormone DHEA	promote human creativity enhance performance and productivity
Weather	promote satisfaction		
Natural landscapes and ecosystems	reduce stress improve comfort enhance mood and self-steam	lower heart rate, blood pressure, and salivary cortisol (stress hormone) decline sympathetic activity and increase parasympathetic activity	enhance cognitive performance return stressor mind to relaxed state.
Fire		comfort and warmth	

Indirect Experience of nature			
Images of nature	reduce stress	increase pain tolerance lower stress hormone levels	restoration from mental fatigue improve mental health
Natural materials		decreased diastolic blood pressure	positive visual response can decrease the brain activity to relax mood
Natural colors			Improved creative performance
Simulating natural light and air		Maintain circadian system functioning and circadian rhythms (the daily cycle of hormonal activity).	
Naturalistic shapes and forms	reduce stress		enhanced concentration
Evoking nature	reduce stress		enhanced concentration
Natural geometries	relaxed response		
Biomimicry	reduce stress		enhances cognitive performance
Experience of Place and Space			
Prospect and refuge	promote satisfaction reduce stress improved comfort	lower heart rate and blood pressure reduce irritation, fatigue, and perceived vulnerability	improve concentration, attention, and perception of safety

Organized complexity	positive psychological response		positive cognitive response
Cultural and ecological attachment to place	foster an emotional attachment to an area		

Summary

Biophilic design is the deliberated attempt to translate the innate affinity into a building's design, it affords humans a host of psychological, physiological, and cognitive benefits. The fundamental objective of biophilic design is to extract a positive valued experience of the natural and built environment which is one of the principles of restorative environmental design. In (2015) Kellert updated the conceptual framework of biophilia into three experiences; the direct experience of nature, the indirect experience of nature, and the experience of space and place, includes 24 attribute.

03

Chapter

Biophilic Design at Learning Spaces

Chapter 3:

Biophilic Design at Learning Spaces

Introduction

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3.1.2 Learning spaces components

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3.5.8 Vernacular design

Summary

Introduction

Students spend a great deal of time studying, completing homework, working on reports or projects, preparing presentations, taking exams, and many other activities that require effort and sustained directed attention, which may cause a mental fatigue. As a result, design of learning spaces is vital to health and well-being, which affects student's creativity and productivity. The built environment is a multi-sensory experience, stimulated by occupants, the architectural atmosphere of space and light, the quality of indoor environments, and learning and social interactions. Reconnection with nature can enhance the quality of learning spaces, wellbeing, and productivity of students. Recent studies have examined that integrating biophilic design patterns and attributes in university settings has a positive impact on students' physical health, psychological well-being, and social relationships.

This chapter will focus on understanding learning spaces and incorporating biophilic design at the design of these spaces. The chapter divided into five parts; the first part represents learning spaces definition and its components. The second and third parts discuss the importance of incorporating natural elements in learning spaces, and the factors that influence student performance. The fourth part represents the indoor environmental quality in educational buildings, and the last part represents the most essential elements of design a learning space incorporate Biophilic Design attributes.

3.1 Learning Spaces

3.1.1 Definition of learning spaces

The term learning spaces refers to the space allocated for classrooms, science labs, open spaces, and offices. Learning spaces is also defined as the social context, psychological and pedagogical which can affect learning, achievement, and attitudes of the students (Amirul *et al.*, 2013). The OECD[1] defines Learning Spaces as 'a physical space that supports multiple and diverse teaching and learning programmers and pedagogies, including current technologies; one that demonstrates optimal, cost-effective building performance and operation over time; one that respects and is in harmony with the environment; and one that

[1] The Organization for Economic Co-operation and Development (**OECD**) is an international organization that works to build better policies for better lives.

encourages social participation, providing a healthy, comfortable, safe, secure and stimulating setting for its occupants. In its narrowest sense, a physical learning environment is seen as a conventional classroom and, in its widest sense, as a combination of formal and informal education systems where learning takes place both inside and outside of schools (Bannister, 2017).

3.1.2 Learning spaces components

Two major components of the learning environment are physical component and psychosocial component. Physical component includes all physical aspects such as classrooms, teaching materials and learning facilities, both inside and outside the classroom, while psychosocial component is related to the interaction that occurs between students with students, students with teachers and students with the environment. Both of these components complement each other in creating and shaping the learning environment and affect the learning process that occur in it. (Amirul *et al.*, 2013)

3.2 The Importance of Incorporating Natural Elements in Learning Spaces

Studies determined that the reintroduction of nature can enhance the quality of learning environments to benefit health, wellbeing and productivity, and increase the quality of air and humidity which are integral to a learning environment (Bowman, 2019)& . Many studies found a strong evidence for the benefits of visual connection to nature in university settings, such as views of landscapes and green views through windows (Roetzel *et al.*, 2020) (Farley and Veitch, 2001), nature posters and images (Van Den Bogerd *et al.*, 2018), (Van den Berg *et al.*, 2014), indoor plants, the green color (Van Den Bogerd *et al.*, 2020), and nature walks (Windhorst and Williams, 2015). Students who reported higher levels of nature connectedness were also found to be innovative and holistic thinkers (Leong *et al.*, 2014).

Also, several studies found simulated sounds of birds and water are proven to speed up recovery times from Directed Attention after stressors (Alvarsson *et al.*, 2010). Moreover, other studies found the mural images of a nature depicting water were perceived to be the most restorative (Felsten, 2009) and images of a study area with a water feature were found to be preferred. Preference studies found that students prefer

natural colors (Naz and Epps, 2004) and natural materials as wood for furniture in workspaces (Ridoutt *et al.*, 2002), reinforcing preferences for natural materials. When given options of potential lecture classrooms, students preferred posters depicting nature over colorful murals (Van Den Bogerd *et al.*, 2018).

Many researchers looked at campus features, and they determine that "Place Attachment" is an important aspect of the university experience and it correlates to a student's happiness with the campus. "Place Attachment" can be achieved primarily through campus landscapes, and cultural events according to students (Qingjiu and Maliki, 2013). Moreover, a recent study found that university students prefer to study in "refuge" spaces that provide "prospect" views to experience privacy, security, and stimulation (Roetzel *et al.*, 2020).

Furthermore, some studies focus on the comfort and wellbeing of students in university settings. Students who used the campus green spaces more frequently perceived their quality of life as higher when compared with those students who used green spaces less frequently (Mcfarland *et al.*, 2008). Also, students in classrooms with natural daylight (from windows and skylights) perform 20 to 25% better on tests than students without access to daylight (Northeast Energy Efficiency Parterships Inc, 2002). Indoor air quality in classrooms impact perceived comfort and student productivity while learning. Carbon dioxide levels in classrooms can also be improved with natural ventilation (Shi *et al.*, 2017).

Thus, it is recommended to incorporate biophilic design in university settings due to its positive impact in university student quality of life Table 3-1 (Peters and D'Penna, 2020);

- Physical health impact in reduce stress and cortisol levels.
- Psychological well-being by increase feeling of happiness, fostering creativity, and improve cognitive function.
- Social relationships by increasing social involving and belonging to the place.
- Environmental comfort by enhancing lighting and ventilation.

Table 3-1 University student quality of life and Biophilic design patterns (Peters and D'Penna, 2020)

University student quality of life	Biophilic design patterns
Physical Health	- Visual connection with nature (views, photos, and colors as green, yellow, and red). - Non-visual connection with nature (auditory, and olfactory elements with nature). - Presence of water. - Biomorphic forms and patterns.
Psychological well-being	- Visual connection with nature (campus landscape, green views, indoor plants, nature images, and windows view) - Natural materials
Social relationships	- Visual connection with nature (campus landscape, and green views around building). - Non-visual connection with nature (peacefulness of nature) - Local materials.
Environmental comfort	- Prospect and refuge. - Presence of water. - Dynamic and diffuse light. - Connection with natural system. - Thermal and air flow variability.

3.3 Factors Influence Student Performance

There are many factors that influence student's performance, behavior, and social relations.

3.3.1 Environmental factors

Environmental factors such as lighting, temperature, ventilation, and acoustics, directly affect the student's comfort and influence behavior and learning outcomes (Muñoz Cantero *et al.*, 2016).

3.3.2 Physical features

Physical features of learning spaces, such as colors, building configuration, the windows in classrooms, entrance areas, private and public spaces, and furniture, can stimulate emotions, create a sense of security, and prepare the students to learn (Arias-Maldonado, 2015; Earthman, 1998)

3.3.3 Psychological factors

Students can suffer from various psychological problems that severely disrupts their daily performance in various tasks during the academic year, these problems mainly emanate from a multidimensional construct psychological factor. The most important psychological factors that infuluance students' performance is their motivation, stress, and test anxiety for the subject they study (Wondu Teshome Beharu, 2018).

Stress in university learning environment

Reports of universities and colleges worldwide indicate the outbreak of mental health problems among college students (Holt *et al.*, 2019). Furthermore, in recent years reports about students' rates of anxiety and depression have soared, this rise in the rate of university students seeking counselling is five times higher than the average rate of minority students. The most psychiatric disorders show up from ages 14 to 26 years. (Hibbs and Rostain, 2019).

There are many mental health problems that are related to collage, the most common student mental health problem is anxiety, almost one-third of all college students report having felt so depressed. Moreover, mental health issues in the university students, such as depression, anxiety, and eating and sleeping disorders, are associated with lower GPA and higher probability dropping out of college. More than 80 percent of university students felt overwhelmed and exhausted by all they had to do in the past year, while 45 percent of them have felt hopeless. The most important thing is the previous mental health issues can be deadly, suicide is the second leading cause of death among university students.(Hibbs and Rostain, 2019)

In the context of COVID-19, there is increased anxiety around indoor environments and an urgent focus on creating spaces that promote emotional and physical health and immune system. Student and instructor interactions in university learning environments are changing rapidly under stress; for example, many campuses are mandating online

learning, social distancing, and for in person instruction, smaller groups meetings, thus, it is worth noting that as universities reopen, or to integrate hybrid in-person and virtual teaching models for many classes, the design and qualities of the environments where face-to-face interactions take place takes on a special importance. (Peters and D'Penna, 2020)

3.4 Indoor Environmental Quality (IEQ) in Educational Buildings

IEQ refers to the acceptable levels of thermal, visual, and acoustic comfort in addition to Indoor Air Quality (IAQ) (Zuhaib *et al.*, 2018). According to National Institute of Occupational Safety and Health, Indoor Environmental Quality (IEQ) is defined as the buildings environment quality which related to health and wellbeing of those who occupy space in it (The National Institute for Occupational Safety and Health (NIOSH), 2013).

3.4.1 Thermal comfort

Thermal comfort relates to the physical environmental factors in naturally ventilated and conditioned environments. It is expressed as "the condition of mind in which satisfaction is expressed with thermal environment" (ASHRAE 55, 2004).

There is a strong correlation between energy consumption and thermal comfort standards set for buildings. There are physical environmental parameters and personal parameters that affect thermal comfort. Air velocity, air temperature, mean radiant temperature, and relative humidity are considered as four physical environmental parameters, whereas clothing value and metabolic rate are considered as personal parameters (Zuhaib *et al.*, 2018).

3.4.2 Visual comfort

Visual comfort is a subjective measure dependent on certain factors such as illumination, luminance and brightness, luminous spectrum, and risk of glare. The presence of a good visual environment can add to the well-being and productivity of the occupants, whereas, poor lighting can cause discomfort and decrease student productivity.(Zuhaib *et al.*, 2018)

3.4.3 Acoustic comfort

Acoustic comfort is the presence of a comfortable acoustic environment without any uncomfortable noise. Acoustic comfort is considered a crucial for university buildings' IEQ and is generally given high preference in offices and classrooms by occupants (Zuhaib *et al.*, 2018).

3.4.4 Indoor Air Quality (IAQ)

IAQ is directly related to the ventilation rates and concentration of pollutants, which are related to Sick Building Syndrome (SBS). It is related to both chemical and physical causes (carbon oxides, CO and CO2, environmental tobacco smoke, formaldehyde, volatile organic compounds (VOCs), ventilation rate, temperature, dampness, ionizing and non-ionizing radiation. IAQ is known to have acute and chronic effects on the health of the occupants. (Zuhaib *et al.*, 2018)

There are many studies found that IEQ may affects people's performance. Thus, poor indoor environments could affect the student learning process in school, thermal comfort and IAQ were the main contributors to the IEQ of the university buildings (Jamaludin *et al.*, 2016).

3.5 Elements of Design learning spaces incorporate Biophilic Design Attributes

Incorporating biophilic design attributes at learning spaces design are important due to many reasons; It can reduce stress in the space, which is an essential problem that faces students and cause a mental fatigue; reconnection with nature can enhance the quality of learning environments, wellbeing, and productivity of students; It can also increase the quality of air, lighting, and humidity which are essential to the learning environment. Table 3-2 shows the elements of design and the related biophilic design attribute to each element. Every element of design is defined as the following.

Table 3-2 elements of design and the related biophilic design attribute to each element (Author)

Elements of Design	Biophilic Design Attributes
Lighting	**Light**
	Fire
	Stimulating Natural Light
Natural Ventilation	**Air**
Biodiversity and Landscape	**Water**
	Plants
	Animals
	Natural Landscape and Ecosystem
	Weather
Form	**Natural Materials**
	Natural Colors
	Age, Change, and the Patina of Time
	Natural Geometries
	Naturalistic Shapes and Forms
	Information Richness
Opening in Space	**Weather**
	Prospect and Refuge
Ordering	**Organized Complexity**
	Integration of Parts to Wholes
Circulation Elements	**Transitional Spaces**
	Mobility and Wayfinding
Vernacular Design	**Cultural and Ecological Attachment to Place**

3.5.1 Lighting

Lighting is a fundamental element in designing building environment. For centuries, before use of electricity, schools and other learning environment depended completely on natural daylight as the only lighting source. When electricity appeared, classrooms lighting design moved away from natural light to designed with electric lighting sources as their primarily source of light. Learning places illuminance plays a critical role, due to the direct relationship between good lighting and students‟ performance (Samani, 2011) .

Daylight is distinguished as a light source by its unique, changing spectra and distributions (Rea, 2000). The planned use of daylight in non-residential buildings has become an important strategy to improve energy efficiency and improve the quality of light in an indoor environment (Ruck *et al.*, 2000). All daylighting strategies make use of the luminance distribution from the sun, sky, buildings, and ground (Ruck *et al.*, 2000). Daylighting strategies are grouped into two categories: side lighting and top lighting. Side lighting uses natural light transmitted through vertical building surfaces; the light enters a space through windows located in perimeter walls. In top lighting, natural light enters primarily through opening that are part of the roof and are located above the ceiling line (Hampton, 1989).

Illuminance is defined as the luminous flux density at a surface expressed as lumens per square meter (lm/m2) or lux (Rea, 2000). Learning spaces contains different visual tasks; thus, the illuminance can be selected according to the most demanding visual task that occupies a significant part of the time spent in the space (Jamaludin *et al.*, 2016)(Rea, 2000). Recommended horizontal illuminance for the tasks found in educational facilities are illustrated in Table 3-3.

Table 3-3 IES Recommended horizontal illuminance levels in educational spaces (Rea, 2000)

IES Recommended Horizontal Illuminance Levels			
Task	**Horizontal Illuminance ftcandles (Lux)**		**Additional Notes**
Common Applications			
Administrative - Filing	30	(300)	
Mail -sorting	30	(300)	
Conference room	30	(300)	
Reading - electronic ink devices	30	(300)	laser printer, magazines, newspapers
Writing - pencil and black pen	30	(300)	
Writing - red, green and blue pen	40	(400)	
Lunch rooms	10	(100)	
Shipping and receiving	30	(300)	
Passageways	5	(50)	
Education			
Auditorium - exhibition / study	30	(300)	
Classrooms - art	50	(500)	
Classrooms - music room	30	(300)	
Classrooms - home economics	50	(500)	
Classrooms - general	40	(400)	hardcopy and writing
Classrooms - computer labs	15	(150)	
Classrooms - shop	100	(1000)	
Study halls	30	(300)	

3.5.2 Natural ventilation

Ventilation is defined as the process of supplying fresh air into buildings and removing the noxious indoor air by passive, active, or mixed mode techniques. Passive ventilation (cross ventilation, or single-sided ventilation) means the movement of air by wind around the building, temperature differences between the interior and exterior environment, and thermal displacement within the building, through openings such as windows and doors, while active ventilation means the movement of air is supplied by mechanical methods such as air-conditioning and fans. (Norazman *et al.*, 2018).

In educational buildings, indoor air quality (IAQ) influence students' health, attitude, and performance for mental concentration. Efficiently utilization of natural ventilation, not only effects indoor air quality and thermal comfort but also provides energy efficiency (Almeida, Pinto, Pinho, & de Lemos, 2017), dilutes and removes pollutants, odors, and excessive moisture (Toyinbo, 2017).

3.5.3 Biodiversity and landscape

Biodiversity refers to the variety of species whether plants or animals (Kellert, 2005), while landscape is a land with natural sceneries or elements. It has the ability to reduce stress, boost human beings comfort, and improve human physical condition (AbdelMeguid, 2014). Biodiversity and landscape can apply in learning spaces by windows designed and placed to incorporate nature views, and outdoor natural areas with rich vegetation and animals (Kellert, 2005).

3.5.4 Form

Form is the structure of arranging and coordinating the elements and parts of a composition to produce a coherent image (Ching, 2007). According to Francis D.K. Ching in his book Architecture Form, Space, and Order, form is a reference to both internal structure and external outline and the principle that gives unity to the whole. It includes five elements (Ching, 2007):

- **Shape**: It is the characteristic outline or surface configuration of a particular form.
- **Color:** A phenomenon of light and visual perception that may be described in terms of an individual's perception of hue, saturation, and tonal value.

- **Texture**: It is the visual quality that given to a surface by the size, shape, arrangement, and proportions of its parts.
- **Position:** It is the location of a form relative to its surrounding environment or the visual field within it.
- **Orientation:** It is the direction of a form relative to the ground plane, or other forms.

3.5.5 Opening in space

Opening in space is referred to wall fenestration, glazed opening, or break in the surface of a wall. Doors offer entry into a room and influence the patterns of movement, while windows allow natural light to penetrate the space, offer views from the room to the exterior, establish visual connections between the room and adjacent spaces, and provide natural ventilation to the space (Ching, 2007).

3.5.6 Ordering

Order refers not simply to geometric regularity, but rather to a condition in which each part of a whole is properly disposed with reference to other parts and to its purpose to produce a harmonious arrangement (Ching, 2007). According to Francis D.K. Ching in his book Architecture Form, Space, and Order, the following ordering principles are seen as visual devices that allow the varied and diverse forms and spaces of a building to coexist perceptually and conceptually within an ordered, unified, and harmonious whole (Ching, 2007).

- **Axis:** A line established by two points in a space, which forms and spaces can be arranged in a balanced manner.
- **Symmetry:** The balanced distribution or arrangement of equivalent forms or spaces on opposite sides of a dividing line, plane, a center, or axis.
- **Hierarchy:** The articulation of the importance or significance of a form or space by its size, shape, or placement relative to the other forms and spaces of the organization.
- **Rhythm:** A unifying movement characterized by a patterned repetition or alternation of formal elements in the same or a modified form.
- **Datum:** A line, plane, or volume that, by its continuity and regularity, serves to gather, measure, and organize a pattern of forms and spaces.

- **Transformation:** The principle that an architectural concept, structure, or organization can be altered through a series of discrete manipulations and permutations in response to a specific context or set of conditions without a loss of identity or concept.

3.5.7 Circulation elements

Circulation is the path of our movement that can be conceived as the perceptual thread links the spaces of a building, or any series of interior and exterior spaces together (Ching, 2007).

3.5.8 Vernacular design

The term of vernacular is derived from the Latin word "Vernaculus", meaning domestic, native, or indigenous. It can be said that vernacular architecture appears to be a local style of architecture which are not imported or copied from elsewhere (Zolkefli, 2011). Vernacular design refers to buildings and landscapes that foster an attachment to the place by connecting culture, history, and ecology within a geographic context (Kellert, 2005) as mentioned before in Chapter 1. It also defined, according to Stephen R. Kellert in his book "Building for life", as the tailoring of the built environment to the particular physical and cultural places, where people live and work. Effective vernacular design is the fusion of culture and ecology within a particular biogeographical context (Kellert, 2005).

Summary

Biophilic design has been found to reduce human stress and enhance wellbeing in spaces. It could enhance students' physical health, emotional wellbeing, and academic performance success in educational buildings. It can also increase the quality of air, lighting, and humidity which are essential to the learning environment. As a result, incorporating biophilic design attributes and patterns in learning spaces design are essential. There are eight elements of design are important in learning spaces design and can help to incorporate biophilic design attributes: natural and artificial lighting, natural ventilation, interior and exterior landscape, form, opening in space, ordering, circulation elements, and vernacular design.

04

Chapter

Islamic Architecture

Chapter 4:

Islamic Architecture

Introduction

4.1 Introduction to Islamic Architecture

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Summary

Introduction

Biophilic design is an innovative approach that incorporating nature into built environment. As a result of the rapid population growth and the industrial revolution, the modern buildings increasing human separation from natural world. However, the ancient people inspired their designs from natural creatures, thus many hypotheses suggested that these buildings already contained the qualities of biophilic design hundreds of years ago, and this one of the reasons behind the great admiration that most of the people have for historical buildings.

Islamic architecture, which from the seventh century onward, extending from Morocco in the west to Indonesia in the east, from Central Asia in the north to Central Africa in the south, owes its origin to similar structures already existing in Roman, Byzantine, and Persian lands. Therefore, its buildings contain a treasure of the characteristics and features that can respond positively to our natural world.

This chapter will focus on understanding Islamic architecture and Islamic educational buildings “Madrasas”. The chapter contains three parts; the first one represents a brief introduction to Islamic architecture, the second part represents the relationship between nature and Islamic architecture, and the last part represents a brief of Madrasas’ design.

4.1 Introduction to Islamic Architecture

4.1.1 Islamic Architecture concept

There are different definitions on the term “Islamic Architecture”, in general the concept of Islamic architecture refers to the characteristic of building used by Muslims to serve as their identity (Yassin and Utaberta, 2012). The term itself contains two key words: "Islamic" and "Architecture". The first one “Islamic” is defined as; “the religious faith of Muslims, based on the words and religious system founded by the prophet Muhammad and taught by the Quran, the basic principle of which is absolute submission to the only god; Allah” (Mifflin, 2005). Thus “Islamic” taken to refer to both a religious and a cultural entity (Tabbaa and Hillenbrand, 1997). The second one “Architecture” is used to identify cultures, civilizations, and people. It is a unique art through which communities can be identified, shapes their culture, and represent their image to the rest of the world (Ghasemzadeh *et al.*, 2013). ‘Islamic architecture,’ definition was not religious, it instead sought unity in

culturally shared approaches to aesthetics and spatial sensitivities that crossed all denominational, ethnic, and national boundaries within the greater Islamic world and resulted in similar architectural expressions (Rabbat, 2012).

The creation of the Islamic architecture back to the beginning of Islam in areas where Islam arrived as the Arabian Peninsula, the Levant, Egypt, Arab Maghreb, Turkey, Iran, and others; those under long Islamic rule such as India and Andalus (Spain now). Referring to the history of Islamic architecture, different styles and characteristics could be seen in different regions as each region influenced by the interchange of culture features, ideas of authority, administration, and intermarriage. Furthermore, the vernacular techniques, climate and local materials, also influenced the characteristics of Islamic architecture (Nu'Man, 2016).

As a result of regional variations, several distinct styles of architecture developed throughout the Muslim world. Despite the differences between these regional styles, they shared some common features that evolved over thousand years, defining Islamic architecture (Rashid, 2020).

4.1.2 Design strategies of Islamic Architecture

Design strategies and architectural guidelines in Islamic world rooted in the Qur'an (the Word of God) and Sunnah (the behavior and speech of Prophet Mohammad –peace be upon him), they have an immediate and lasting effect on the built environment. These strategies are adaptive and can be applied to any region in the world to help produce Islamic architecture that is appropriate for that regional climate and its culture. The four elements used to help guide the design process for Islamic architecture are therefore (Nu'Man, 2016):

- The heavenly Knowledge from Allah and His Prophet Mohammad (peace be upon him).
- Sustainable strategies and technologies that appropriate for the site.
- The laws of Sacred Geometry[1].

[1] Sacred geometry is the studies of the science of the accurate organizing patterns underlying inside all objects of the universe such as Golden Ratio PHI. (Salama, 2019).

- Cultural sensibility which includes the local environment, materials, aesthetics, and historical influences on the local habitant.

These strategies include the following design functions(Nu'Man, 2016):

- Protecting the inhabitant's privacy through window placement, use of window screen (Mashrabya) and bent entrances.
- Encouraging pedestrian movement through the neighborhood.
- Provide the community building typologies of homes, mosques, educational facilities, and markets, within easy access of each other.
- Conserving energy through building in recycling and wastewater, use local building materials, building orientation and design, using the natural site features.
- Maintain the human scale in buildings design.
- Incorporating cultural norms and perceptions of aesthetics.

4.1.3 Types of buildings in Islamic Architecture

Islamic architecture includes many types of buildings, can be categorized in four main kinds as follows (El-kady, 1998):

- Religious buildings: it considered as the most important buildings type in Islamic architecture and always located at the heart of the city, this category includes many buildings such as the Mosque (both as masjid[1] or jami'[2]), the Madrasa or school, the Khanqah, and the Mausoleum and tombs.
- Residential buildings: it includes the buildings where peoples live such as palaces, and private houses.
- Public buildings (service buildings): such as the Bimaristan or hospital, wakala, Khan, Souq or markets and public bathrooms.

[1] a mosque for a daily prayer by small groups (with *mihrab*, but no *minbar* or pulpit) (ARCHIAM (Architectural and Urban Forms of the Islamic World), 2018)
[2] the congregational or Friday mosque for weekly service, larger than the *masjid*, with a *minbar* (ARCHIAM (Architectural and Urban Forms of the Islamic World), 2018)

- Defensive buildings: It were built due to the wars such as castles.

4.2 Nature in Islamic Architecture

4.2.1 Connecting to nature in Islamic Architecture

Incorporating nature into the built environment is not a not a new phenomenon, ancient architects inspired their designs from natural creatures (Browning *et al.*, 2014). In Islamic architecture the goal of architecture is not restricted to building as shelter, it should provide for human with perfection and evolution with natural environment (Kazemi and Mohebbi, 2014).

Recent studies suggested that historical architecture is a reference book for strategies and settings of biophilic design (Ramzy, 2015a), and these buildings is also a valid reference book that combines the functional aspects of Biomimicry with the psychological qualities of Biophilic design (Ramzy, 2015b). There are many studies evaluate biophilic design qualities in traditional Islamic historical buildings. According to a study in 2018, the Alhambra, a palatine complex in Granada city (Spain now), is successfully fulfills six patterns of biophilic design (Al-Rhodesly *et al.*, 2018). Also a A survey performed by Movahed (2015) examined the impact of the fourteen patterns in the historic Aqa-Bozorg mosque-madrassa (1875 A.D.), most of the visitors had positive experiences in connecting to nature with all the fourteen patterns (Movahed, 2015).

4.2.2 Principles of sustainability and environment protection in Islam

The concept of sustainability is not considered a new term, it is rather a concept embodied by the historical architecture as Islamic architecture in different regions in the world since old ages (Ali *et al.*, 2015). Sustainability and sustainable development stand at the heart of the Islamic faith and values (Omer, 2010). Sustainable development can be defined, from an Islamic point of view, as a multi-dimensional process that seeks to apply a balance between social and economic development on one side, and the environment on the other one. It seeks for use the resources in the best possible way. There are many texts from the Qur'an and the Sunnah that call for the wise utilization of natural resources. All these texts lead to the conviction that all species and the habitats on the planet are part of the perfect universe created by GOD. Thus, respecting

the law of this nature and all its components is an obligation of every Muslim (Nahedh Al-Qemaqchi, 2013). Therefore, Islamic architecture is in total harmony with its natural environment, social patterns and conditions, and, most importantly, the exigencies of its people (Omer, 2010).

Based on previous dissection, Islam embodies many sustainability and environment conservation indicators, the main doctrines of sustainability and environment protection in Islam can be illustrated as follows (Al-Zubaidi, 2007):

- *Resources Conservation:* Islam obliged people; in Quran and Sunnah; to maintain the natural environment when they benefit from it.
- *Environmental Balance:* Everything created by Allah in the environment was created in specific quantities, the intention of rational use of resources is to preserve the harmony that is provided in the natural environment.
- *Common Right Resources:* Islam encourage believers to share the earth's resources such as water, herbage, and fire, and it rejects of any selfishness associated with this utilization.
- *Water Conservation:* Conserving water and maintain its purity were two important issues in Islam because water is a valuable gift from God, and life cannot be continuing without it.
- *Greenery and Plantation:* Islam calls for conserve greenery and plantation as vegetations and plants are bounties from God to humankind helping their living on earth. Thus, Islam forbidden cutting down of trees without a strong and legitimate reasons or putting the garbage under them or in their shadow, also it encourages cultivation and growing plants as a divine work that will be rewarded by God, as shown in Figure 4-1.

Figure 4-1 Plants and greeneryin the Suhaymi house courtyard (Historic Cairo) (Source, cairo.gov.eg, 2018)

- *Air Preservation***:** Islam calls for protecting the air from pollutants that could, directly and indirectly, damage natural elements, such as chemical and biological products. Islam also forbidden polluting air with smokes or distasteful odors that might hurt others. In traditional architecture design natural ventilation was essential to obtain a constant air changing within compact urban fabric.
- *Prevent Noise Pollution:* Islam considered noise as a source of harm that should be prevented as the loud voices in the mosques, even if it is the recited of holy Quran during times other than the obligatory prayer. In Islamic city, the mosque is a public focal point surrounded with markets then the residential sectors. This graduation in siting depends on; the privacy degree; from public to private, and noise levels gradually form the busy city center to quiet residential districts Figure 4-2.

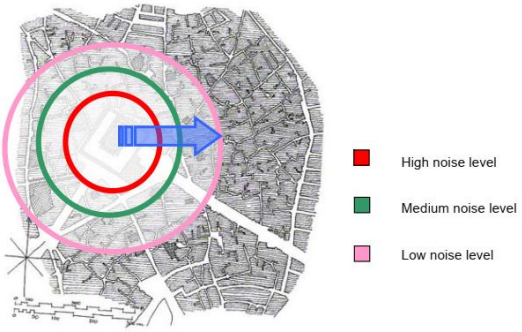

Figure 4-2 Graduation in noise levels in a traditional city in the Arab world (Source: Al-Zubaidi, 2007)

The Islamic architecture has many faces of achieving sustainability ranging in scale from the city, to the house, the garden, and the single architectural element (Feisal *et al.*, 2010). Before the air conditioning, open plans, and curtain walls, building in these regions constructed from local materials that made spaces cool in summer and warm in winter (Feisal *et al.*, 2010).

4.2.3 Islamic architecture features and the passive design

Most of the Islamic city's climate characterized by drought, low rainfall, high intensity of solar radiation, high radiation losses at night, and steadily in relative wind, so they used many architectural features that respond positively to these climate data, (Feisal *et al.*, 2010) such as:

- *The sahn:* An inner courtyard located at the center of the building, surrounded by a "riwaq" or arcade on all sides. It is a common element in religious and residential buildings, contains water element such as a public fountain for ablution in mosques or a pool in the houses. The sahn usually takes a rectangular or square shape, used to gain fresh air into the building in the morning (Feisal *et al.*, 2010) as shown in Figure 4-3.

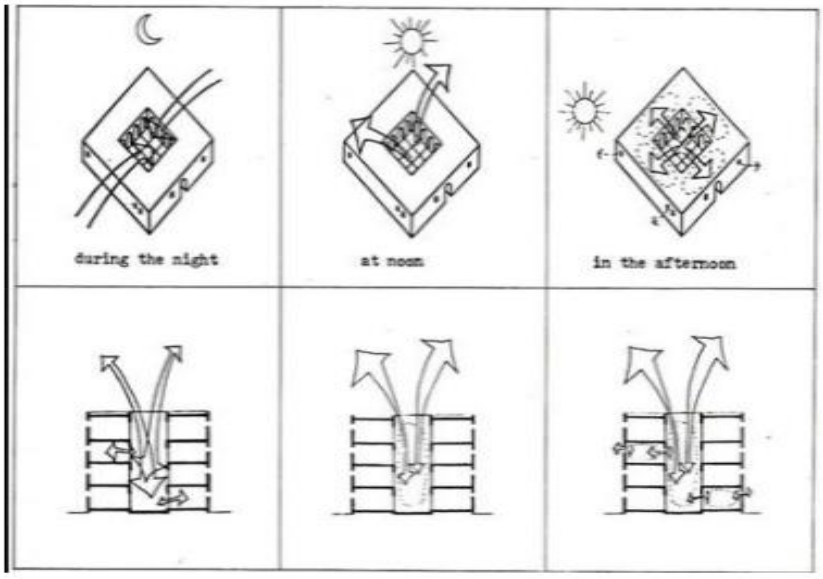

Figure 4-3 The form and function of (Sahn) (Feisal *et al.*, 2010)

- *Iwan:* A vaulted space opens on one side to the courtyard (sahn), usually takes a rectangular shape Figure 4-4. The main function of Iwan is increasing the natural ventilation and gain fresh air into the space (Feisal *et al.*, 2010).
- *Roofing:* Use domed and vaulted ceilings that provide a sun protection surface better than the flat roofing, reduce heat gain, and increase the speed of passing air over the curved surface (Moustafa *et al.*, 2018).

Figure 4-4 Great Mosque of Esfahan, view of the north Iwan from the Sahn (Feisal *et al.*, 2010).

- *Water fountain*: it is usually used in the center of the courtyard (sahn) or interior spaces. These water fountains help in evaporative cooling technique, which allow the hot dry air to pass over cold water to cause evaporation, which absorbs heat and cools air, so promote natural ventilation and increase air moisture.

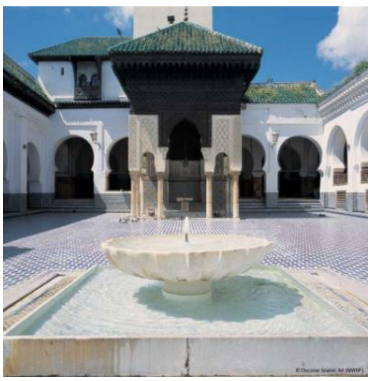

Figure 4-5 Centeral fountain, Qarawiyyin Mosque, Fez, Morocco (Source, Mezzine, 2022)

- *The mashrabiya:* Derived from the Arabic root, "sharab" meaning to drink, so it meant the place reserved for small water pots that needed to stay cool. The mashrabiya is a kind of opening covered with a flat or rounded carved wooden lattice, which composed of small wooden elements assembled in geometrical way to create this grid. It is an effective technique to cool indoor environments and control thermal comfort in buildings due to cooling the inlet passing air on the wet pots through lower tight

lattice of the mashrabiya and expel the hot air from the wide lattice at the upper part. Moreover, the mashrabiya also control natural light and visual privacy Figure 4-6 (Elwan, 2020).

- *The malqaf (wind catcher*): is an architectural feature for cooling and ventilation, it represents a higher shaft than the building, and ends upwards with an opening to catch wind. It is usually raised towards the north side of the building (ElSorady and Rizk, 2020). The malqaf is based on a simple technique as shown in Figure 4-7, the porous water pots convert the dry air into humid air, and the charcoal that putted on a grating increases the flow of air into indoor spaces (Hassan *et al.*, 2016),

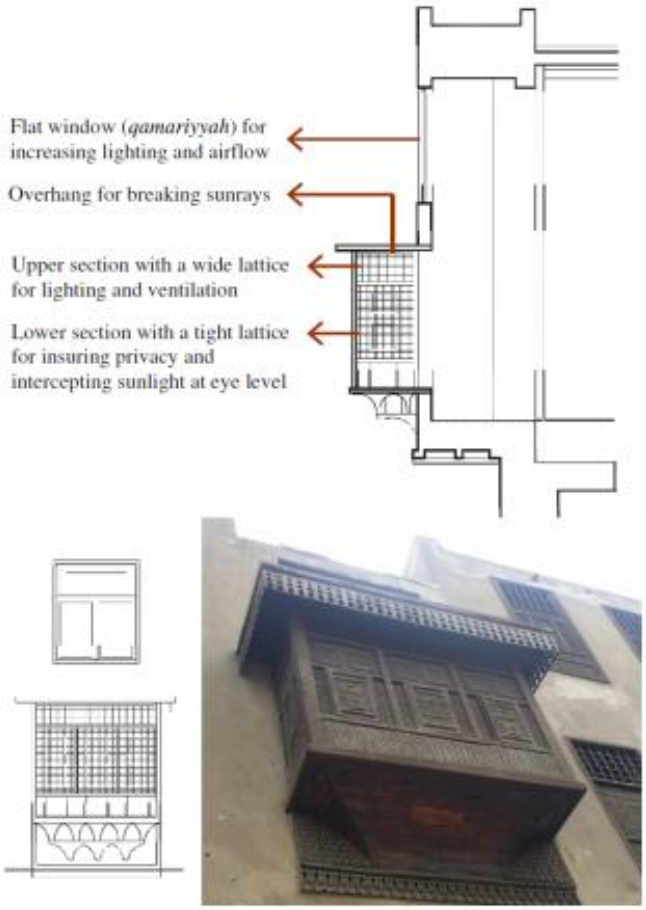

Figure 4-6 The mashrabeya details and main components in Al-Suhaymi house, Cairo, Egypt (Source, Abdelkader and Park, 2018)

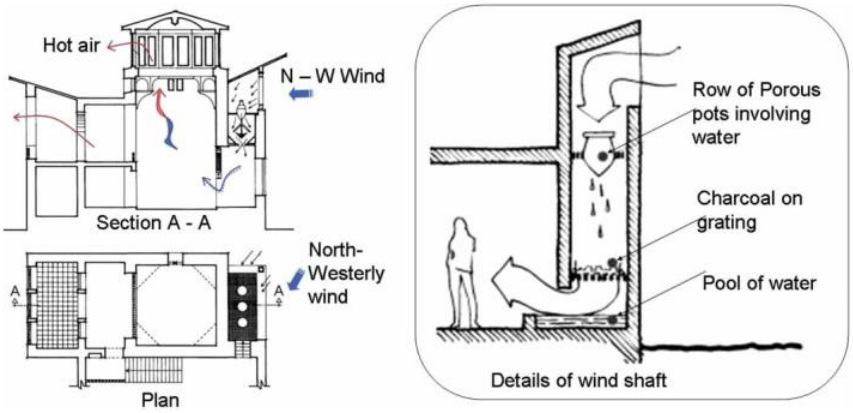

Figure 4-7 The malqaf technique (Hassan *et al.*, 2016)

The shokhshikha: It is usually used to cover main spaces to provide ventilation and spread the indirect daylight better into a space as shown in Figure 4-8. It also works with Al-malkaf (wind catcher) to control thermal comfort through expel the hot air from the top of the space and the malkaf gets the cold air into the space (Feisal *et al.*, 2010).

Figure 4-8 Al-Shokhshikha in Al-Suhaymi house, Cairo (Source, Almrsal.com, 2019)

- *The majaz:* it is usually the main entrance in Islamic Arab houses that designed to lead into a bent corridor, and this bent corridor opens onto the main courtyard, as shown in Figure 4-9. The majaz design protects the interior spaces from weather changes, dust, and noise, and preserves privacy (El-Shorbagy, 2010).

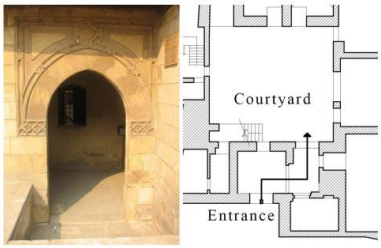

Figure 4-9 The majaz in the Zeinab Khatoun house, Cairo (Source, Abdelkader and Park, 2018)

4.3 Educational Buildings in Islamic Architecture (The Madrasa)

The term ‘madrasa’ in Arabic simply means "school". Madrasa in Islamic Architecture refers to an institution of higher learning to teach a variety of subjects such as mathematics, logics, and religious subjects such as Hadith, Tafsir, Fiqh and so on (Wolper, 2014).

4.3.1 The historical evolution of madrasas

The beginning of madrasas buildings was by The Seljuks Persia in the early 11th century (ARCHIAM (Architectural and Urban Forms of the Islamic World), 2018), they were small buildings include a central domed hall with two side iwans, and the first known madrasa was in Egypt in1005 AD by the Fatimid Khalifas. In 12th century, the madrasa was developed into a multifunctional building that served as: medical school, psychiatric hospital, public dining room, dormitory, and tomb (ARCHIAM (Architectural and Urban Forms of the Islamic World), 2018).

4.3.2 Architectural design of Mamluk Madrasas

Mamluk architecture represents an important period of Islamic architecture because most of the aesthetic principles; that underlie Islamic architecture; were displayed there. Mamluk educational buildings (madrasas) are exhibit most of the aesthetic values of Mamluk architecture (Eilouti and Al-Jokhadar, 2007).

Mamluks spread extensively in Cairo, but they also reached Jerusalem and Aleppo. Mamluk empire can be classified into two periods (Eilouti and Al-Jokhadar, 2007):

1- The “Bahri” period, which ruled from 1250 A.D. to 1382 A.D.
2- The “Burgi” period, which ruled from 1382 A.D. to 1512 A.D.

The exterior layouts of Mamluk’s madrasas respected the site shape where they constructed on. Thus, the ground floor plans were almost irregular shapes. However, the designers were often given the effort to make regular shapes inside, so they use basic shapes (as square and rectangle) as the bases for generating all interior spaces. The major interior spaces were always oriented toward the “Qibla direction” and had perfectly regular shapes, while the Intermediate spaces appeared between them and the irregular outer boundary of the site.

The two main prototypes of Mamluk's madrasas layout shapes are the open courtyard madrasa Figure 4-10, and the closed or domed courtyard (dorqa'a) madrasa Figure 4-11. The dorqa'a prototype is usually smaller building than those with an open courtyard, it is generally larger and have central Iwans surrounded by arcades.

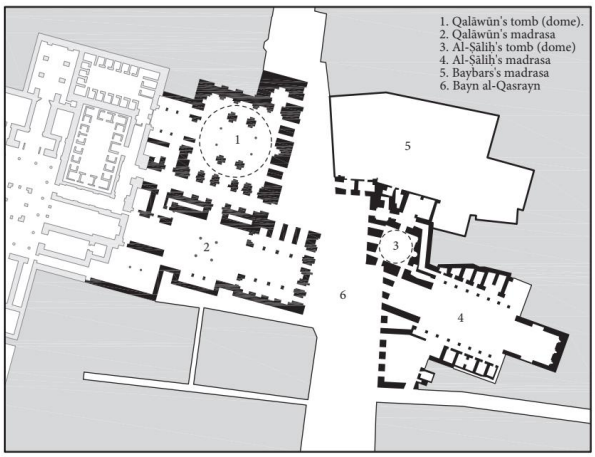

Figure 4-10 The open courtyard madrasa type (al-Sultan Qalawun and al-Salih Madrasas in Cairo) (Source: Ragab, 2015)

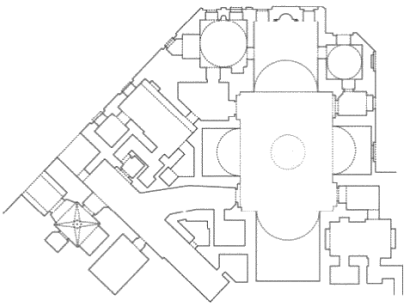

Figure 4-11 The roofed or domed courtyard madrasa dorqa'a type (al-Sultan Inal Madrasa in Cairo). (Source: (Eilouti & Al-Jokhadar, 2007)

The four-Iwan madrasa was the dominant prototype of the mamluk's madrasa. In this prototype, the four Iwans surround the central courtyard (Sahn) and the other spaces were located on the sides. Facilities for many functions have been attached to each Iwan; a residential unit for the Sheikh (teacher), small residential units for students, small court, sabil (free water fountain), minaret (tower), the tomb of the madrasa's patron, corridors and transitional spaces, sadla (secondary Iwan), ablution space, and water closets (Eilouti and Al-Jokhadar, 2007).

Summary

Islamic architecture is the characteristics of the building that designed by Muslims. Islamic rule spread over a vast geographical region, the regional variations result different architectural styles and characteristics, each region influenced by a different culture features, various vernacular techniques, different climate, and local materials. Although these differences, they shared some common features and strategies. Many of these strategies embodies sustainability and environment conservation principles. There are many features in Islamic architecture fulfill environmental design such as the sahn (inner courtyard), The iwan (a vaulted space connected directly to the sahn), central fountain in the courtyard, the mashrabiya (a wooden lattice windows), the malqaf (wind catcher), the shokhshikha, and the majaz. Moreover, recent studies suggested that ancient architecture as Islamic architecture are connected to the nature in a positive manner, and there are many Islamic architecture buildings fulfill biophilic design attributes and patterns. As a result, the built environment in Islamic architecture can be a restorative environment. In Islamic architecture the historical mosque-madrassa, is a symbol of Islamic educational architecture, its design developed from a small building with two side iwans to a large complex with four iwans involve other functions such as student house, mausoleum, and hospital.

05

Chapter

Analytical Study: Biophilic Design in Educational Islamic Buildings

Chapter 5:

Analytical Study: Biophilic Design in Educational Islamic Buildings

5.1 Introduction and Study Scope

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- 5.2.2.5 Opening in space
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- 5.2.2.7 Circulation elements
- 5.2.2.8 Vernacular design

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5.3 Conclusion

5.1 Introduction and Study Scope

Deducing and deriving the research hypothesis that Islamic architecture inspired their designs from natural creatures, and they have been applied biophilic design attributes in learning spaces design. There are many studies evaluate biophilic design qualities in traditional Islamic historical buildings. This chapter will analyze an example of madrasa building to investigate the biophilic design attributes through analyzing the previous eight elements of design of the building, the example is the Sultan Hassan complex in Cairo. This complex is considered as one of the best examples in Egypt representing madrassa-mosque, It built-in 1363 AC during the Mamluk Bahri period. A study in 2018 illustrates that the complex incorporated the following Biophilic Design patterns: order and complexity, change and metaphor of biomorphic forms, prospect and refuge, enticement, and risk and peril (Abdelaal and Soebarto, 2018). In this study we will examine the rest biophilic design attributes in the complex and find out some features in historical Islamic buildings that responds to the criteria of biophilic design used in the example.

5.2 Sultan Hassan complex

5.2.1 General description of the complex

The complex referred by many historians and architects as the best ancient mosque in Cairo and has been praised as one of the major monuments of the Islamic world. The complex built-in 1363 AC during the Mamluk Bahri period as shown in Figure 5-1, it designed by Muhammad ibn Bailick al-Muhseini, the chief architectural designer of his day. He placed his name on the inscription band inside the Hanafi Madrasa (Torky, 2021).

Figure 5-1 Sultan Hassan complex (Source, traveladventures.org,2007)

Location

Sultan Hassan chose a strategic location for his iconic structure away from the Fatimid Cairo and, where most of the emirs erected their buildings. Sultan Hassan selected a site close to the Cairo Citadel. After The sultan death the Mosque was used as a fort. Over time many attempts

have been made to destroy the Mosque, but all have failed due to its robust construction (Mahmoud, 2016).

Description

The complex consists of a school (Madrasa), a huge mosque for Friday prayer, a hospital (Bemaristan) on the western side, and a mausoleum as shown in Figure 5-2. The mosque building is considered as one of the largest in Egypt. It is a massive structure with a150 meters long and thirty-six meters high, its tallest minaret is sixty-eight meters tall. The basic plan of the complex, as shown in Figure 5-3, designed in orthogonal planning oriented to the "Qibla" axis, consists of a central courtyard (Sahn) leading off into four large Iwans. Each of the four iwans represents one school of Sunni Islam; Shafi'i, Maliki, Hanafi and Hanbali, it was meant to house four hundred students.

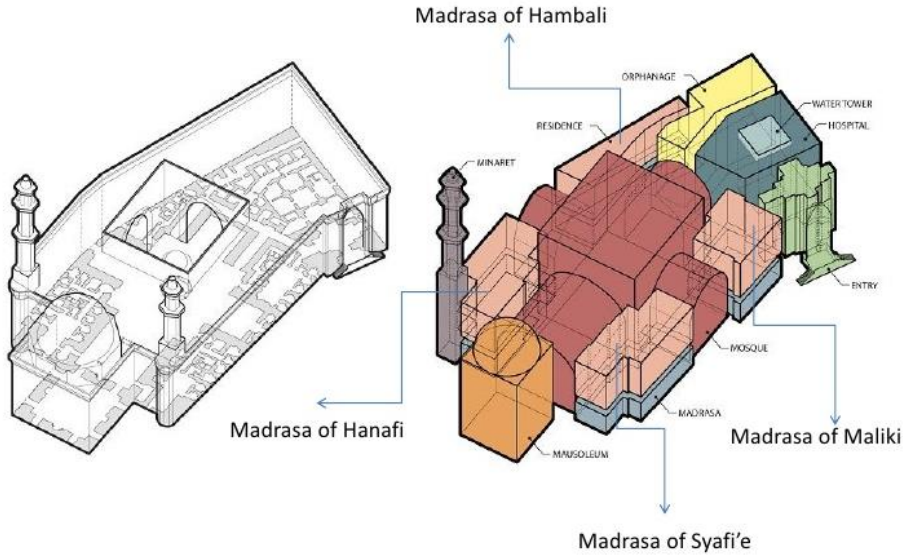


Figure 5-2 Sultan Hassan complex components (Source, slideshare.net, 2016)

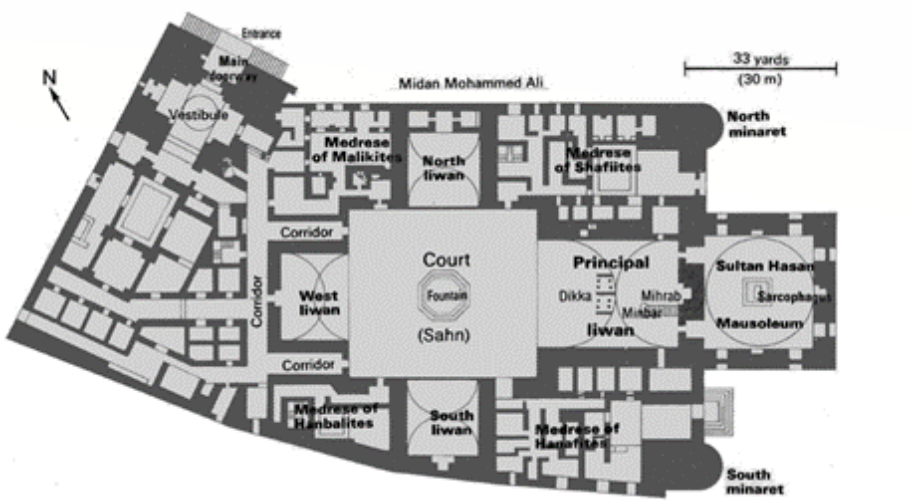


Figure 5-3 The master plan of Sultan Hassan complex (Source, Adel & Kamal, 2010)

The Hanafi madrasa is the largest school, meanwhile the next largest madrasa was that of the Shafi'i as shown in Figure 5-4. In the inside, each madrasa has its own courtyard with an ablution fountain, a qibla oriented iwan, and four or five stories of housing and learning rooms. The mausoleum, which is one of the largest in Cairo with its twenty-one square meter dome, is located behind the quibla-iwan. The hospital part has a complete design with corridors, open spaces, and cells used for doctors and patients. Evidence says it was a highly used hospital by the surrounding community. The shops are also found on the other side of the complex. These shops were used as Waqf to fund the complex maintenance. It was built outside the mosque in order not to disturb the prayers (Adel and Kamal, 2010).

Hanafiyah Madrasa

The Hanafiyah Madrasa, which is the largest, has a courtyard with a fountain, a private teaching (iwan) with an area of 67.5 square meters, and a large room above the (iwan) that may have served as a library as shown in the madrasa master plan in Figure 5-5. The Madrasah has 56 living units with an average area of 10 square meters (Al-Harithy, 2007).

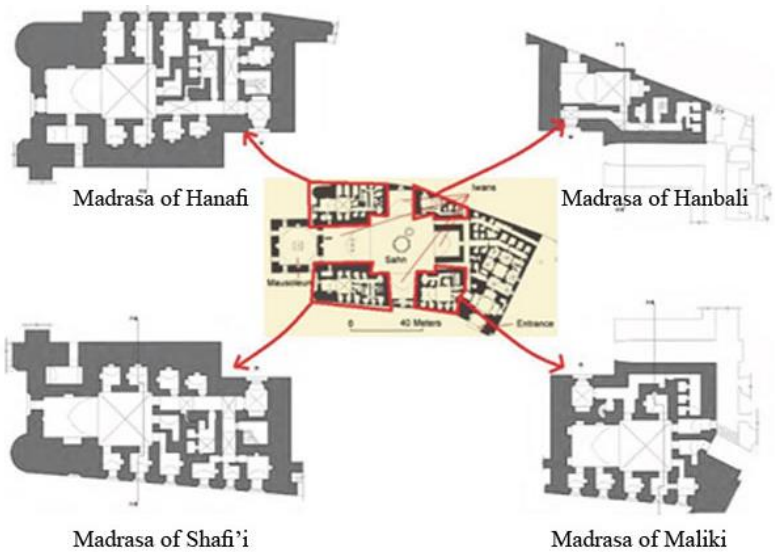


Figure 5-4 The four Madrasas of Sultan Hassan (Source, Mazen, 2016)

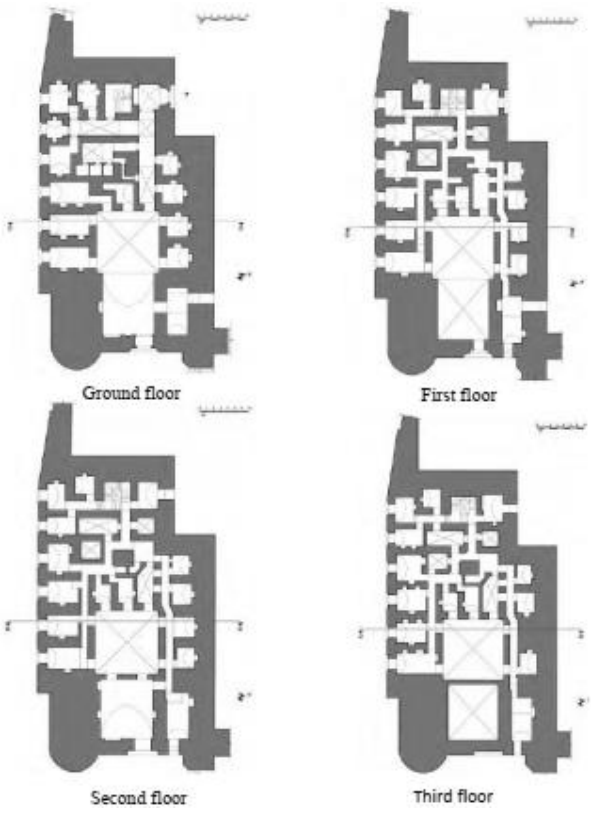


Figure 5-5 Hanafiyah Madrasa, floor plans (Source, Al-Harithy, 2007)

5.2.2 Elements of Design Analysis

5.2.2.1 Lighting

The schools are located at the four façades of the complex to ensure natural lighting for students' dormitory and learning rooms, the rooms use lattice-screen windows that provide an aesthetic integration of light and shadow. Inner court yards were also used to provide natural lighting to the rest of the schools' rooms, it uses to provide daylight, reduce the direct light intensity, and reduce the heat gain impacts. Moreover, the courtyard enables users keep track of sun path; thus, enable them to observe the changes of daylight over time Figure 5-6.

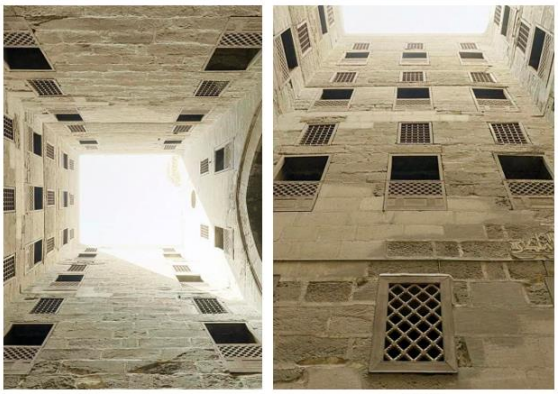
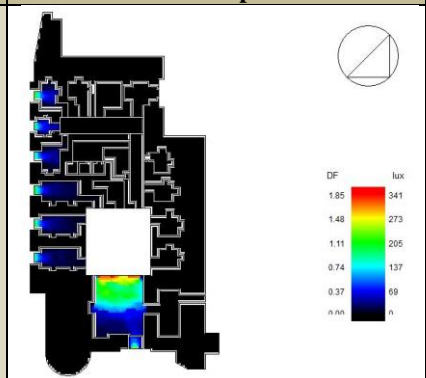
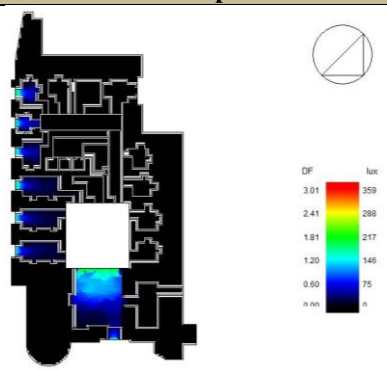
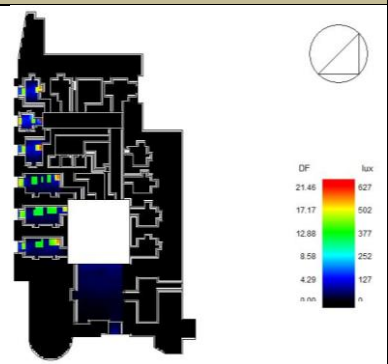
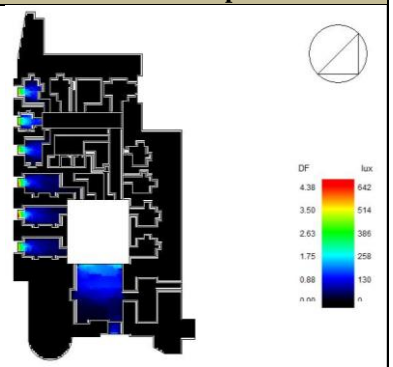
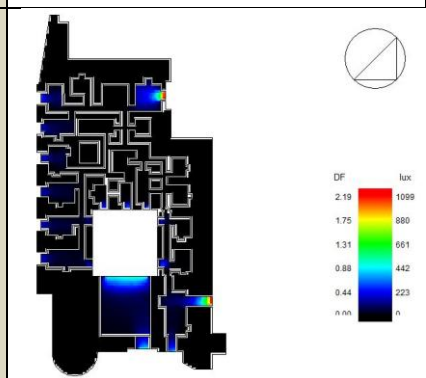
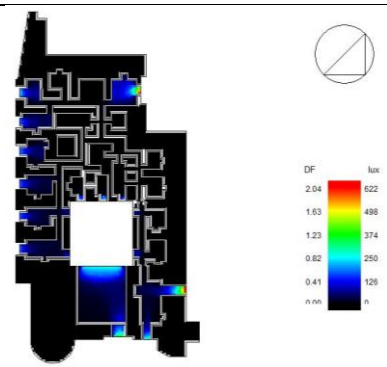
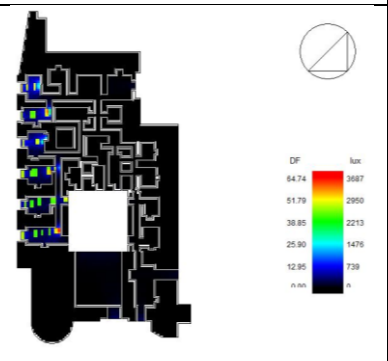
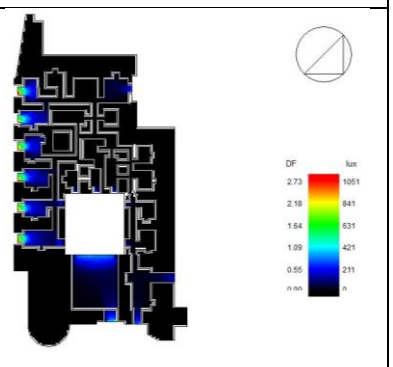


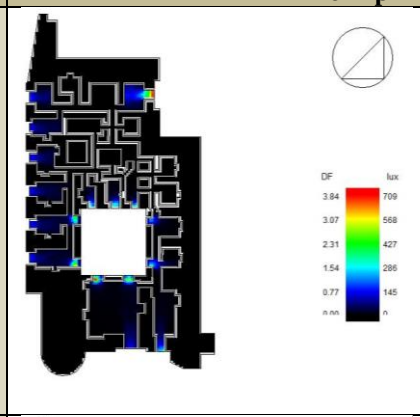
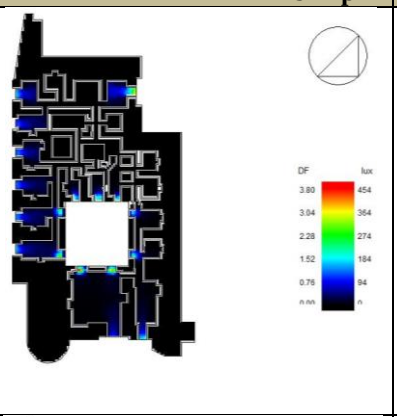
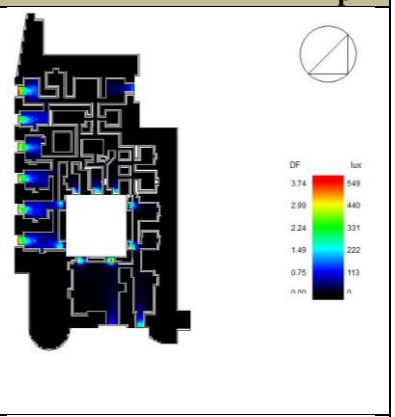
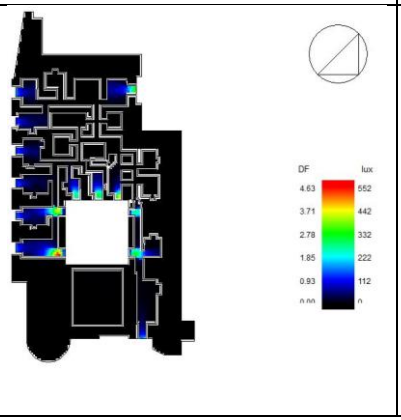
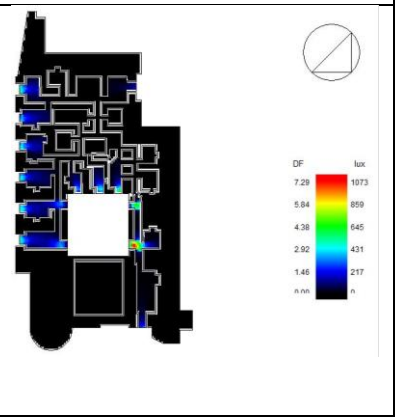
Figure 5-6 Lattice-screen windows and inner court in Hanafiyah madrasa- complex of Sultan Hassan (Source, Sites in VR mobile application, 2018)

The indoor daylighting performance of Hanafiyah madrasa (the largest madrasa) has been simulated using Design Builder software, the following table shows the simulation result of illuminance amount through many times of the day.

According to simulation results in Table 5-1, it is found that the average illuminance through the morning and midday is between 100 and 500 lux, which is accepted according to the IES Recommendation to horizontal illuminance levels in educational spaces (Rea, 2000), while the average illuminance in 4 pm is between 70 and 500 lux in summer and 75 and 200 lux in autumn when the school day ended.

Table 5-1 Simulation result of illuminance amount in the inner rooms of Hanafiyah madrasa through many times of the day

	21-6 4pm	21-9 4pm	21-12 8am	21-12 12pm
Ground floor				
First floor				

	21-6 4pm	21-9 4pm	21-12 8am	21-12 12pm
Second floor				
Third floor				

In the mausoleum the natural lighting were also controlled with the colored imbedded glass “clerestory” windows near the dome, which are defined as vertical windows, located on high walls, extending up from the roofline (El-Darwish and El-Gendy, 2016), that allow occupants keep track of sun path and observe the changes of daylight over time as shown in Figure 5-7. It also used “qamariyyah”; (from ‘qamar’: moon in Arabic language) it is an Inner arched window, has a stucco grille filled with colored glass, which is a source of light device as well as a decorative one that adorned the façade and added color to the interior as shown in Figure 5-8 (Eilouti and Al-Jokhadar, 2007).

Figure 5-7 Natural lighting in Sultan Hassan mausoleum dome (Source,traveladventures.org, 2007)

Figure 5-8 “qamariyyah” and clestories in Sultan Hassan mausoleum dome (Source, Mazen, 2016)

5.2.2.2 Natural ventilation

All the building rooms ventilated naturally by using stack effect technique due to central courtyard in the building and each school. Stack effect is achieved through the difference in air density between inside court and outside. The open courtyards work as container that store or generate cool air through shading, and evaporative cooling by the ablution fountain in each court, thus, the hot air rises to reduce the temperature as shown in Figure 5-9.

The schools' rooms that are located at the external facade have used cross ventilation, while the other rooms that are located at the open courtyards have used single-sided ventilation. Rooms scale and dimensions of cross ventilation and single side ventilation rooms at Hanafiyah madrasa represent in Table 5-2.

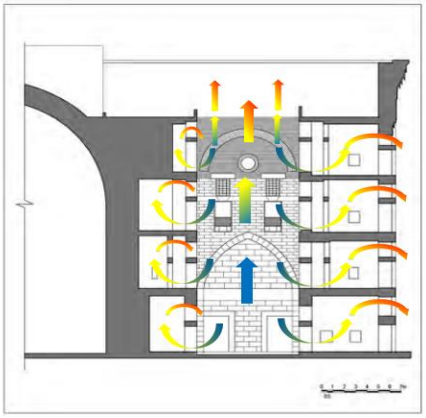


Figure 5-9 Stack effect, single sided and cross ventilation in the Hanafiyah madrasa courtyard (Source, author)

Table 5-2 Rooms scale and dimensions of cross ventilation and single side ventilation rooms at Hanafiyah madrasa

Natural ventilation strategy	**Cross ventilation**	
Room dimensions	each room must have a width less than five times the height (Mossad *et al.*, 2016)	Depth: 4.5 to 5.5 m Hight: 6m Area: average: 15 m2
Opening dimensions		The room has two windows at the outdoor side • Square window: 1.5m*1.5m • Rectangular window: 4m*2m Also, one window on the door side 1.5m*1.5m
Area of window to area of room	the window area should be not less than 15% of the overall room area (AbdelMeguid, 2014)	The window area 60% (the opening area has been treated with lattice screen
Natural ventilation strategy	**Single-sided ventilation**	
Room dimensions	Maximum room depth = 2.5 times the height (AbdelMeguid, 2014)	Depth: 3.0 to 2.5 m Hight: 6m Area: average 8.75 m2
Opening dimensions		The room has two windows at the courtyard side: Rectangular window: 2m*1.5m Rectangular window: 2.5m*1.7m
Area of window to area of room	the window area should be not less than 15% of the overall room area (AbdelMeguid, 2014)	The window area 80% (the opening area has been treated with lattice screen

5.2.2.3 Biodiversity and landscape

The complex has a lack in natural plants and landscape presence inside the building, only a small outdoor garden was designed near the complex as shown in Figure 5-10.

Figure 5-10 An outdoor garden near the sultan Hassan complex (Source, (vetogate.com, 2013)

5.2.2.4 Form

In the sultan Hassan complex, the square is the primary shape of the building layout, and the transformations are applied to this shape, as subdivisions and branching, as shown in Figure 5-11 (Abdelsalam and Ibrahim, 2019). The central square undergoes some stretching in the qibla direction, the area measures 34 meters long and 32 meters wide. It is proportional to the adjacent squares by specific ratio estimated by 1:2 as shown in Figure 5-12. The square is also the principal shape of floor pattern of the main sahn in the complex (Haider and Moussa, 2015) as shown in Figure 5-13.

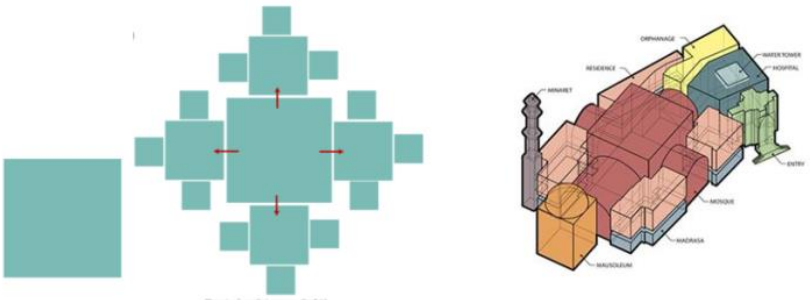
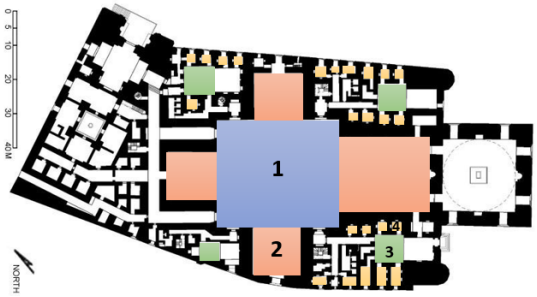


Figure 5-11 The self-similar forms in the Sultan Hassan complex (Source, Abdelsalam and Ibrahim, 2019)



	1 Main Court "Sahn"	2 Iwans	3 Madrasa Main Court
Length (m)	34	16	8
Width (m)	32	16	8
Hight (m)	37	28	27
W/L	1:1.06	1:1	1:1
Area	1088	256	64
Ratio	1:2.1	1:2	

Figure 5-12 Squares portions in Sultan Hassan complex (Source, Author)

Figure 5-13 Main "Sahn" floor pattern in sultan Hassan complex (the square is the principal shape of the pattern) (Source, Haider & Moussa, 2015)

The Sultan Hassan Mausoleum, which is behind the qibla iwan, is covered with a dome considered one of the Islamic world's biggest domes. The original wooden dome was replaced with the current one, it was with an inner diameter 21 m, and covered with lead, and resembled the shape of an egg (Mahmoud, 2016).

The complex façade is made of stone interlaced with marble in some parts, and particularly in the portal. The skyline of the complex was decorated with carved muqarnas cornice. To increase the importance of the mausoleum, the design asserted its uniqueness by carving a different beautiful decoration in the summit of its structure. In addition, the

pyramid like recesses of the windows in the facade were covered by geometric ceramic (Mahmoud, 2016).

In Sultan Hassan complex the designers, started to combine multi type geometric patterns (such as 6, 8, 9, 10, 16, 18 points) in a single decorative pattern as shown in Figure 5-14 (Embi and Abdullahi, 2012).

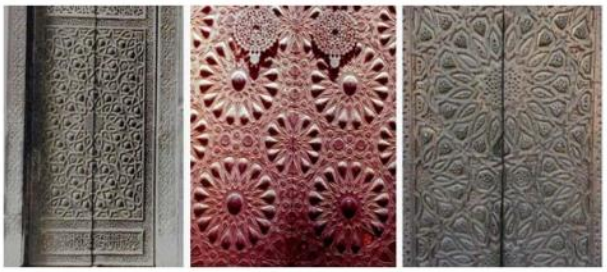


Figure 5-14 Sultan Hassan geometrical pattern (Source, Embi & Abdullahi, 2012)

The complex portal is considered as a masterpiece of Islamic art, the portal contains an arabesque stone carved with geometrical patterns that interlocking with floral bands frame as shown in Figure 5-15 (Mahmoud, 2016).

Figure 5-15 The portal of Sulatn Hassan complex geometrical patterns (Source, Mahmoud, 2016)

The qibla wall in the main iwan is decorated by inlaid marble patterns, and qur'anic stucco carvings banding the upper part as shown in Figure 5-17. In addition, the design uses magnificent floral Chinese motifs, while in the mausoleum chamber the wood was used in inscribed with Quran verses as shown in Figure 5-16 (Mahmoud, 2016).

Figure 5-17 The inscription band in the qibla iwan (Source, en.wikipedia.org, 2005)

Figure 5-16 The mausolum chamber decoration (Source, Mahmoud, 2016)

The floor of sultan Hassan mosque used three common types of marble namely; the white, the red and the black marble (Nazel, 2009).

Natural materials are used for the building: limestone is for the vaults that cover the Iwans, the four centered pointed arches and the external walls; red bricks were used for minerate; marble is used for floors and skirtings, stone is used in the facades, and wood is used for covering the corridor that follows the entrance. These materials are utilized on their natural form especially for the external façade.

5.2.2.5 Opening in space

The complex analysis shows that the design of the plan was based on the direction towards the inside courtyards in most of the rooms. all the rooms have one or more window in one side or two of the space one o, using architectural shading devices as wooden lattice, as mentioned before, to control undesirable solar heat gains and provide the visual continuity between the interior architectural space and the exterior.

5.2.2.6 Ordering

The master plan and 3d form represent the design principles in most of mameluke madrasas, as spaces orientation towards the qibla direction, the simplicity inside the complexity, and the symmetry and balance in the building, as shown in Figure 5-18 and Figure 5-19, and the four quarters of the madrasa (Abdelsalam and Ibrahim, 2019).

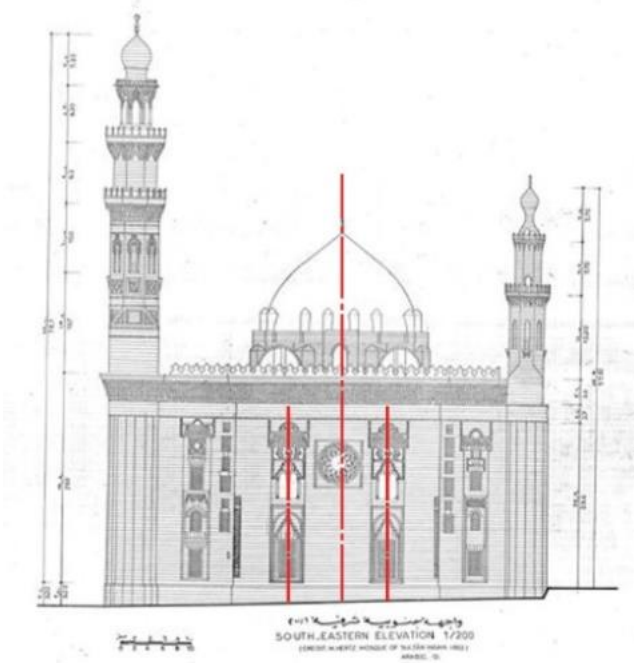


Figure 5-18 The balance and symmetrical design in southeast elevation of Sultan Hassan complex (Source, (aucegypt.edu, 1987), edited by author)

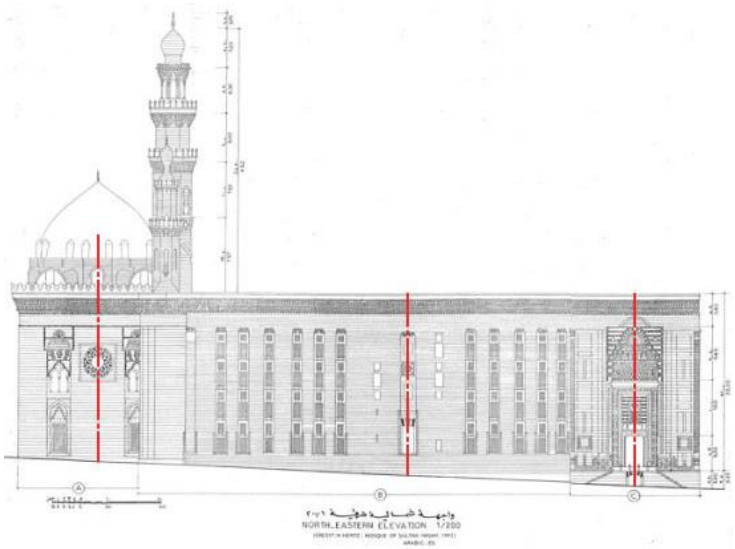


Figure 5-19 The balance and symmetrical design in southeast elevation of Sultan Hassan complex (Source, (aucegypt.edu, 1987), edited by author)

The complex design based on the growth of a main point, which is the center of the main sahn, and where the two main axes cross, for controlling building geometry as shown in Figure 5-20. The central square works as a reference point for all other plan components and visual center (Eilouti and Al-Jokhadar, 2007). The hierarchy is clear between the large central squared courtyard (sahn) compared to the surrounding iwans, the spaces dimensions decrease towards the students' cells gradually as shown in Figure 5-21.

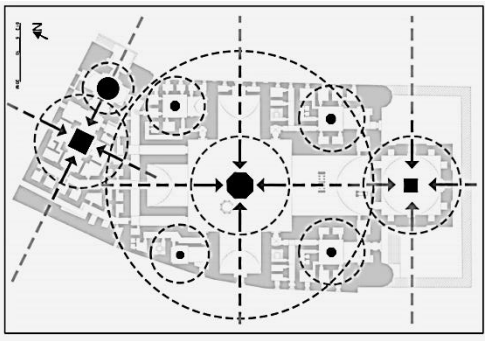


Figure 5-20 The balance and symmetrical design in the Sultan Hassan complex plan (Arjmand *et al.*, 2018)

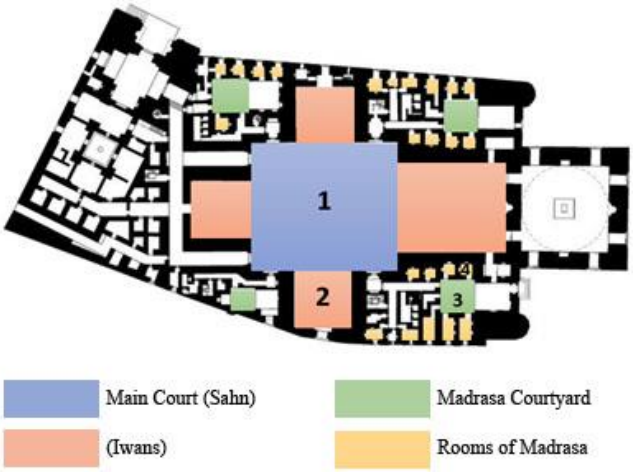


Figure 5-21 Hierarchy of spaces in function, privacy, and dimensions in Sultan Hassan complex (Source, Author)

The spaces of the same function such as student cells and classrooms in each school, are grouped together around the affiliated space, which is the madrasa inner courtyard. The different heights in internal formation changed in the building according to the function of different

spaces. This difference was utilized to emphasize the iwans surrounding the courtyard, which occupied the full height of the building, after the enormous, monumental portal, while the height is decreased in the rooms of madrasas.

The northeastern facade has an extraordinary number of windows in a pattern with six recesses, each one has eight windows as shown in Figure 5-22, this pattern is considered as a magnificent attribute in the Sultan Hassan complex architecture (Mahmoud, 2016).

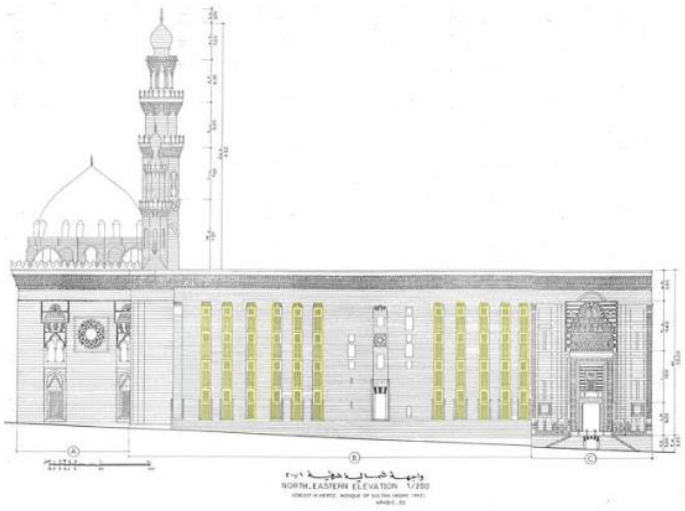


Figure 5-22 The windows pattern in the northeastern elevation of the Sultan Hassan complex (Source,(aucegypt.edu, 1987) , edited by author)

5.2.2.7 Circulation elements

The transitional spaces were used to control the degree of fluidity between the exterior and interior spaces. The spaces follow one another in a gradual manner to prepare the transition from the outside to the inside across the vestibule, the main corridor, and the secondary corridors that lead to the different elements of the Madrasa (Eilouti and Al-Jokhadar, 2007). The main portal controls the sequential transition between the outside street and the main courtyard (sahn) using indirect entrance to ensures privacy. It goes through a 35-meter entrance height, which creates a monumental scale, leading up to a semi-dome or a vault with the curvature of a pointed arch covering this recess as shown in Figure 5-23. Then, the direction of movement changes to going through an inviting, dynamic, intimate, and narrow corridor that is called (majaz) as shown in Figure 5-24, lead to a sudden access to the main courtyard

(sahn) with its natural light as shown in Figure 5-25. Entering the sahn from its corner is a matter of humility, especially when one recognizes how small his body is in comparison to the height of the four Iwans enclosing the massive courtyard. Perceived thickness of walls is a factor of confirming the protection feeling. gigantic courtyard. Perceived thickness of walls is a factor of confirming the protection feeling.

Figure 5-23 Main portal of Sultan Hassan complex (Source, Mazen, 2016)

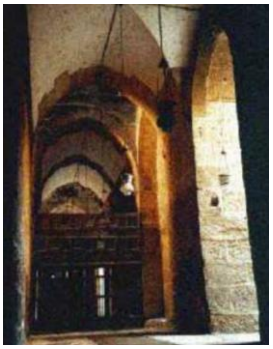


Figure 5-24 The majaz in Sultan Hassan complex (Source, slideserve.com, 2014)

Figure 5-25 The indirect main entrance path to the sahn in Sultan Hassan Complex (Source, Husseiny & Husseiny, 2012)

5.2.2.8 Vernacular design

The complex combines many functions as the schools, the mosque, hospital, and some shops. The existence of such activities in mosques area increase the importance of the mosque and allow it to restore its original importance in the heart of Muslim people. In time, it will allow the increase of awareness of young Muslims about their community problems.

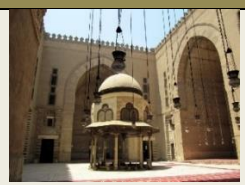
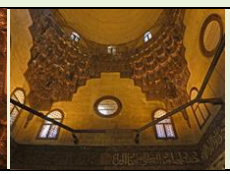
The complex is an environmental-friendly building. With all the shading devices, the open courtyard, and use natural materials, the design of the building is in harmony with the Egyptian hot desert weather. In terms of energy consumption, the building decreases the use of energy by using natural sunlight, and natural ventilation techniques.

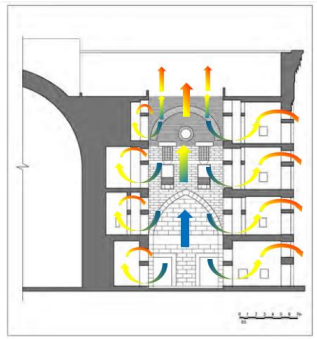
5.2.3 Biophilic design attributes

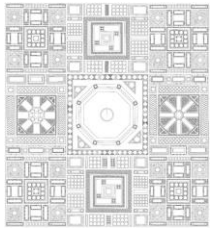
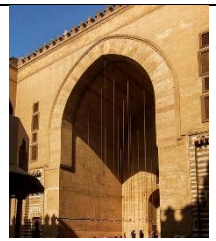
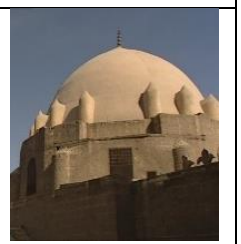
In 2018 a study selected five primary biophilic design patterns that stimulate the human brain for better performance: complex, order, prospect, refuge, enticement and mystery, and risk and peril (Abdelaal and Soebarto, 2018). The study suggested that some case studies of traditional educational buildings or madrasa from the golden age of Islamic civilization as the Sultan Hassan complex incorporated these patterns, and then these biophilic design features in historic buildings can be used as a reference book to evaluate the biophilic design features in today's architecture. Moreover, another study in 2019 proves that the Sultan Hassan complex geometry is acts as a good example of architectural design based on the fractal geometry (Abdelsalam and Ibrahim, 2019).

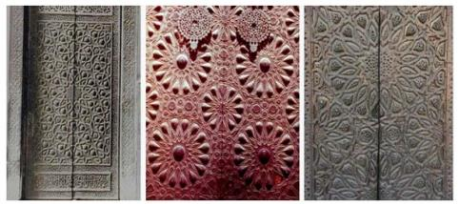
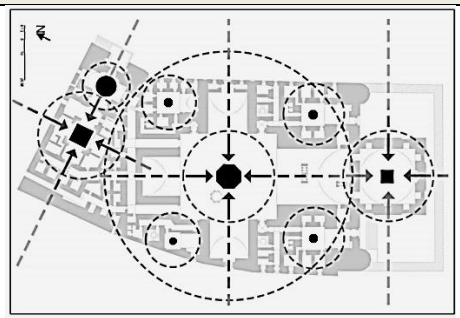
According to the previous analysis the following Table 5-3 represented the design strategies, which used in Sultan Hassan complex, and fulfill biophilic design attributes, and a matrix showing a summary of the design elements that fulfill biophilic attributes is in Table 5-4.

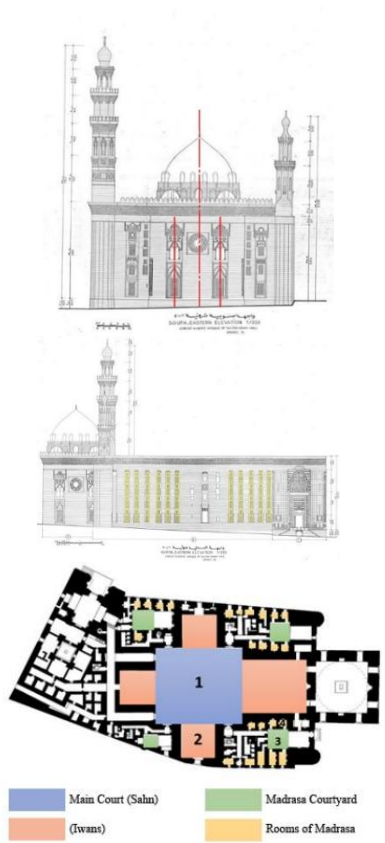
Table 5-3 Design elements and their strategies applied in the Sultan Hassan Complex fulfilling Biophilic design attributes

Element of Design	Design Strategies		Biophilic design attributes	
Lighting	- Inner courtyards.	 	**Light**	- Enabling an orientation to the day, and night and seasons - Response to the sun's location and cycles - Aesthetic shapes and forms through the interplay of light and shadow - Diffuse and variable light
	- Lattice-screen windows.	 		
	- "Clerestories"; vertical windows, located on high walls. - "Qamariyyah"; an Inner arched window, has a stucco grille filled with colored glass.	 		

Natural ventilation	- Use inner courtyards that work as container of cold air - Use evaporative cooling by the fountain in each court. - Use cross ventilation and single-sided ventilation techniques.		**Air**	- variations in airflow, temperature, humidity, and barometric pressure
Biodiversity and Landscape	- All the inner courtyards in every school and the main sahn have an ablation fountain. - Connect all the indoor spaces with the outdoor by windows.		**Water**	- Multiple senses of sight, sound, touch, and movement of water.
			Weather	- Awareness and response to weather
Form	- Use natural materials on their natural form as; stone, lime-brick, wood, and marble.		**Natural Materials**	- Direct experience of decorative or functional, natural material in the built environment.

	- Use square as a primary shape in the design even in the floor-tiles with a geometrical relation between the squares. (1:1.2 portion)	 	**Natural colors**	- Direct experience with muted "earth" tones characteristic of soil, rock, and plants.
			Naturalistic shapes and forms	- Simulation of tree-like shapes (columnar support) - Arches, domes, and vaults. - Botanical and animals' motives. - Egg and oval forms
			Natural geometries	- Self- repeated patterns.
	- Use the domes to cover the mausoleum and the ablution fountain. - Use vaults to cover the four Iwans. - Use floral and geometric motifs.	 	**Information richness**	- Buildings and landscapes that possess information richness, variety, texture, and detail that mimic natural patterns.

			**Age, change, and the patina of time**	- Naturally aging materials, weathering, a sense of the passage of time
Opening in space	- All the rooms have one or more operable window connected to the courtyards or street		**Weather**	- Awareness and response to outside weather
Ordering	- The building oriented towards the qibla direction - The center of the sahn works as a reference point and visual center, where the two main axes cross, for controlling building geometry. - Symmetry and balance design in the facades and orders windows in a pattern.		**Organized complexity**	- Variable and diverse spaces possess attributes of connection and coherence
			Integration of parts to wholes	Disparate parts comprise an integrated whole

	- Hierarchy of spaces in function, privacy, and dimensions.			

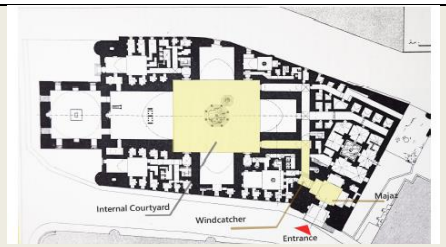
Circulation elements	- Use indirect entrances (majaz). - Use hieratical transitional spaces between the exterior and interior spaces follow one another across the vestibule, the main corridor, and the secondary corridors.		**Transitional spaces**	Clearly understood connections between spaces
			Mobility and wayfinding	Freely moving between diverse and often complicated spaces
			Prospect and refuge	Long views of surrounding settings (Prospect) Provides sites of safety and security (refuge)
Vernacular design	- Use environmental design strategies. - Use local materials. - Combines many functions that important to the community.		**Cultural and ecological attachment to place**	- Historic connection to place - Cultural connection to place - Indigenous materials

Table 5-4 Summary of the design elements that fulfill the biophilic attributes in Sultan Hassan complex

Attributes/ Design Elements		Lighting	Natural Ventilation	Landscape	Form	Openings in Spaces	Ordering	Circulation Elements	Vernacular Design
Light	Direct Experience	●							
Air			●						
Water				●					
Plants									
Animals									
Weather				●		●			
Natural Landscape									
Fire									
Images of Nature	Indirect Experience								
Natural Materials					●				
Natural Colors					●				
Simulating Nature Light									
Naturalistic Shapes					●				
Evoking Nature									
Information Richness					●				
Patina of Time					●				
Natural Geometry					●				
Biomimicry									
Prospect & Refuge	Place and Space							●	
Organized Complexity							●		
Integration of Parts/Whole							●		
Transitional Spaces								●	
Mobility & Wayfinding								●	
Cultural & Ecological									●

According to the previous matrix in Table 5-4 the design elements found in the study complex fulfill sixteen biophilic attributes, eight attributes are missing; plants, animals, natural landscape, and fire, which related to the direct experience of nature, while images of nature, simulating nature light, evoking nature and biomimicry are related to the indirect experience

5.3 Conclusion

Through back to our historical architecture, and the analysis of madrasa sample to investigate the embodied qualities of biophilic design in historic buildings, the findings reveals that these buildings contain many architectural features and characteristics that help in incorporate biophilic design in campus design. Although these features have a lack in applying the direct experience of nature, but it succsuflly fulfil the experience of space and place then the indirect experience of nature, these features includes:

- Inner courtyards that include water bodies to provide natural lighting and ventilation, and the water bodies provide evaporative cooling to the air.
- Natural lighting by using many techniques as; lattice windows, “clerestories” that define as vertical windows, located on high walls, and “qamariyyah” that define as an Inner arched window, has a stucco grille filled with colored glass.
- Passive natural ventilation techniques.
- Natural and local finish materials as stones, lime-bricks, and wood
- Hierarchal spaces with geometrical relation.
- Domes and vaults to cover roof spaces.
- Floral and geometrical decorations and motifs.
- Strong axes and focal point space.
- Use symmetry and balance in the 2d and 3d designs.
- Indirect entrances called “majaz”.
- Hieratical transitional spaces between the exterior and interior.
- Vernacular design strategies

06

Chapter

Case Study

Chapter 6:

Case Study

6.1 Introduction and scope

6.2 General description of AUC campus

6.2.1 Location

6.2.2 Campus design

6.2.3 Campus' three zones description

6.3 Method and Materials

6.4 Results

6.4.1 Elements of design fulfilling biophilic attributes analysis

- 6.4.1.1 Lighting
- 6.4.1.2 Natural ventilation
- 6.4.1.3 Biodiversity and landscape
- 6.4.1.4 Form
- 6.4.1.5 Opening in space
- 6.4.1.6 Ordering
- 6.4.1.7 Circulation elements
- 6.4.1.8 Vernacular design

6.4.2 Users' evaluation of the biophilic design attributes and users' psychological, physical, and cognitive experiences

6.5 Discussion

6.1 Introduction and scope

This study aims to examine biophilic design attributes found in three zones of contemporary learning spaces influenced by various features of Islamic architecture. To achieve the research goal, we have two stages; first, a subjective analysis of the main twenty-four attributes of biophilic design, and the second step is an online questionnaire for users to obtain information about the biophilic design qualities in every zone, and to verify the psychological, cognitive, and physiological performance of these zones.

This chapter is bisected into five parts; the first part shows an introduction to the case study, then the second represents the method and materials. The third one represents the eight design elements analysis in the three zones, and the questionnaire results. The fourth and fifth parts shows the dissection, conclusion, and recommendations.

6.2 General description of AUC campus

6.2.1 Location

The American University in Cairo, which founded in 1919 in the heart of Cairo at Tahrir square as a landmark and cultural oasis Figure 1-2, relocated its campus now to New Cairo. The new campus has located in a 260-acre site in the heart of New Cairo, which is bounded to the west by the Cairo Ring Road, at the north by the Suez Road, and at the south by the Ain El Sokhna Road as shown in Figure 6-2 (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a).

Figure 6-1 The American University of Cairo (Tahrir Campus) (Source, (aucegypt.edu, n.d.)

Figure 6-2 New AUC campus location in the new Cairo (Source, (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a)

6.2.2 Campus design

The master plan of the new campus is like any master plan of a large campus with its complexity of uses and the complexity of the educational entities such as schools, departments, services, and other buildings. In addition to these inherent complexities of the project, there is also another challenge that is the notion of moving an entire campus, which has been standing for almost 100 years, from its current location to an entirely different location, considering that the new campus should express the liberal University's values in an Eastern context with deep traditional roots and high modernism.

AUC selected two firms active in the early planning; Sasaki and Associates (Watertown, Massachusetts, USA), and Abdel-Halim Community Development Collaborative (CDC) (Cairo, Egypt), as the coprime architects to lead the international team of architects in executing the design and construction master plan for the new campus as shown in Figure 6-3 (aucegypt.edu, n.d.).

The design team agreed that there is a closeness between traditional regional urbanism and the desire for a modern liberal campus, this affinity can be found in the complex texture of Islamic city urbanism (Luchetti and Ashraf Salloum, 2004). Its planning and design draw on themes from rich Egyptian heritage and culture, which recognizing the present and anticipating the future.

Sustainability concept was appeared as a core priority in campus' design;

- It is the only campus in Egypt until now which is fully embarking sustainability initiatives, whether in building design or operations, curricula, student activities, orientation… etc. (Khalil *et al.*, 2019).
- The AUC new campus has been recognized as Top green campus in Africa.
- It was one of two African's universities featured as a leading example of low-carbon campuses in the "United Nation's Greening Universities Toolkit".
- It was the top third place of 300 global universities in the University of Indonesia's 2014 Green Metric World University Ranking.
- It is the only higher education institution outside of North America that has been named to The Princeton Review's 2015 Green Colleges Guide (aucegypt.edu, n.d.).

The urban design of campus is comprised of compacted groups of buildings, oriented along a central pedestrian spine as shown in Figure 6-4, linking the academic community to the larger community, this spine interconnected with open spaces, such as courtyards, plazas, garden and the AUC Park, and AUC Square, these open spaces provide a variety of places for; outdoor cultural, and community "gathering" uses and unformal interactive learning. The design also provides a series of secondary paths running parallel and perpendicular to the main spine as entrances into each building group. There are on-site areas that have been reserved for future expansion (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2002).

Figure 6-3 AUC master plan and design architects (Source, Author)

Figure 6-4 Urban analysis of the AUC campus (Source, Author)

The campus is divided into three smaller campuses as shown in Figure 6-5; lower, middle, and upper, each one of them is fulfilling a specific need. The lower campus is open to the public community. The middle campus is the academic core of the campus. With all the schools and research centers in one area to allow for consultation, intellectual exchange, it also includes the library and administration building. The upper campus allows students to collaborate, socialize and multitask by providing an area full of lecture halls, meeting areas, residences, and sports facilities. This area brings recreation and relaxation to a student's daily routine (Jaber and Wieben, 2008).

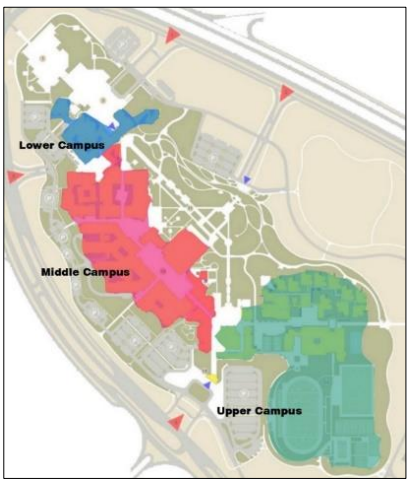


Figure 6-5 AUC three-main functional zones (Source, Author)

6.2.3 Campus' three zones description

The study divides the campus into three different learning-built environment zones as showing in Figure 6-6 according to the amount of Islamic architecture features, the three zones are illustrated as follows.

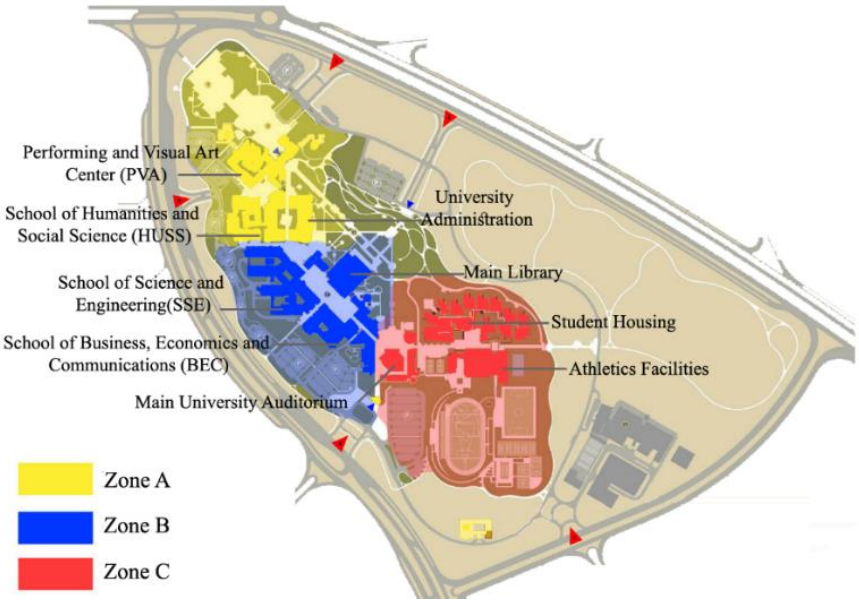


Figure 6-6 AUC Campus Study Zones (Source, Author)

Zone A

The first zone is located at the beginning of the campus. The zone is designed by Abdel-Halim Community Development Collaborative (CDC), and it accommodates two plazas and housed three schools as shown in Figure 6-7, Figure 6-8, and Figure 6-9. The designer influenced by Islamic architecture feature.

Figure 6-7 The School of Humanities and Social Sciences- main elevation

Figure 6-8 Administration Building- Main elevation

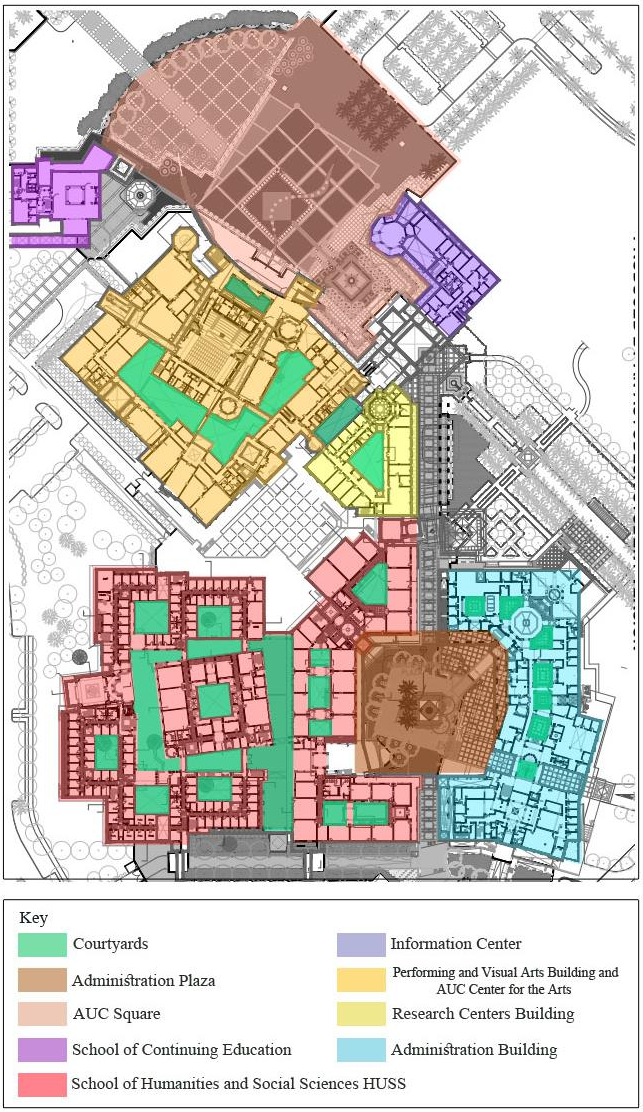


Figure 6-9 Master plan of zone A in AUC campus

Zone B

This zone has been organized around the main public space (AUC Plaza), accommodates the rest of campus' schools, the main library, the campus center, and the core Academic center as shown in Figure 6-10. The buildings in this zone are designed by a group of architects from USA and Mexico as shown in Figure 6-3 with different architectural features some of them influenced by Islamic architecture Figure 6-11, Figure 6-12, Figure 6-13, and Figure 6-14. In this zone the harmony can be seen between traditional Islamic architecture and modern architecture with also a Mexican architecture touch in the southern side of the plaza.

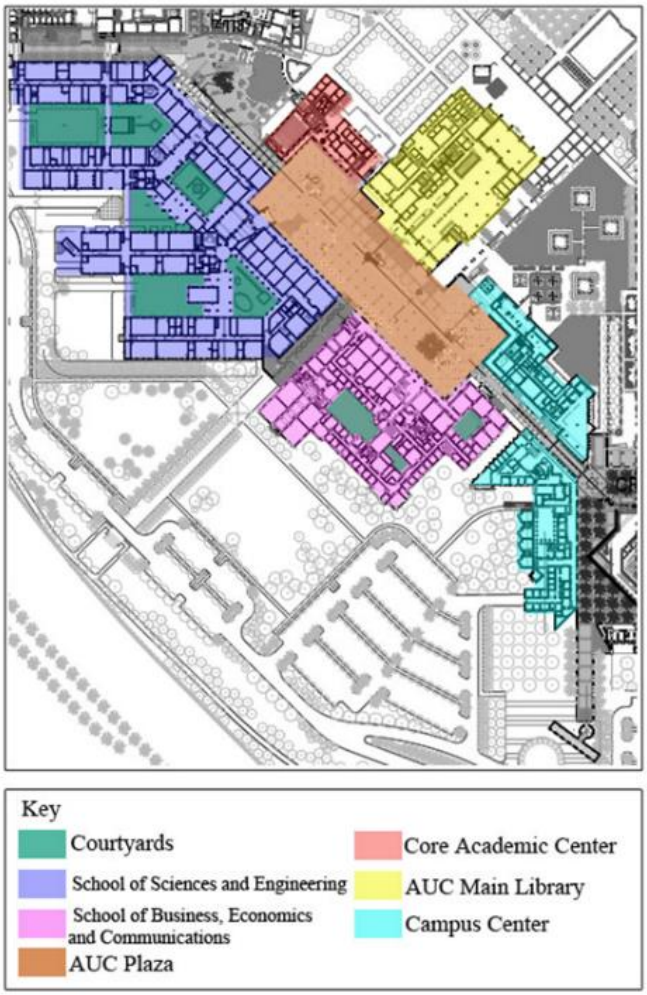


Figure 6-10 Master plan of zone B in AUC campus

Figure 6-11 School of Business, Economics and Communication- Main elevation

Figure 6-12 School of science and engineering-Main elevation

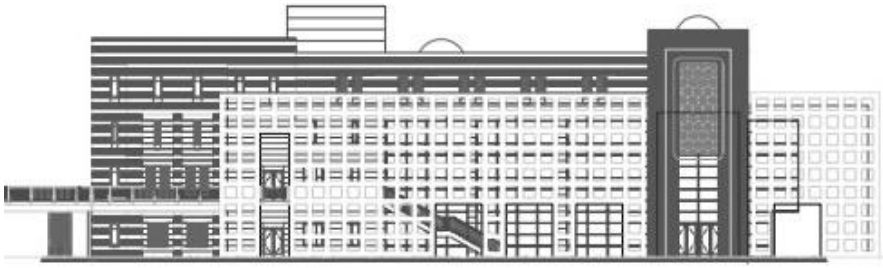


Figure 6-13 Library- Main elevation

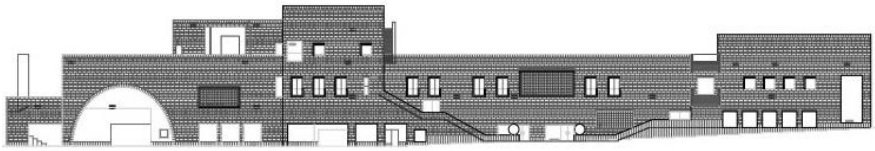


Figure 6-14 Campus center- Main elevation

Zone C

The last zone includes the main auditorium, athletics facilities, and student dorms as shown in Figure 6-15, Figure 6-16, Figure 6-17, and Figure 6-18. This zone is designed by Legorreta (Mexico), which influences his designs from his native Mexico in boldly colors, and Ellerbe Beckett (USA) as shown in Figure 6-3.

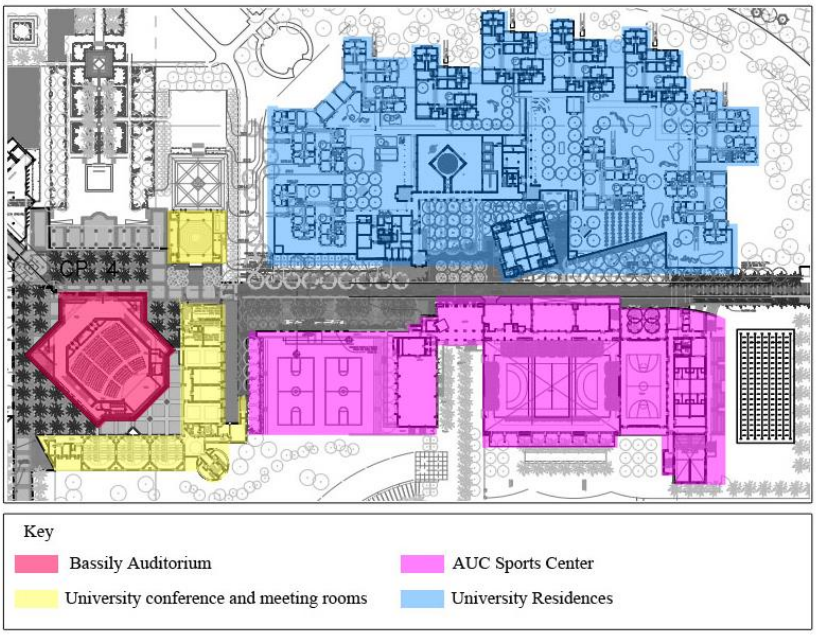


Figure 6-15 Master plan of zone C in AUC campus

Figure 6-16 Student dorms unit- master plan

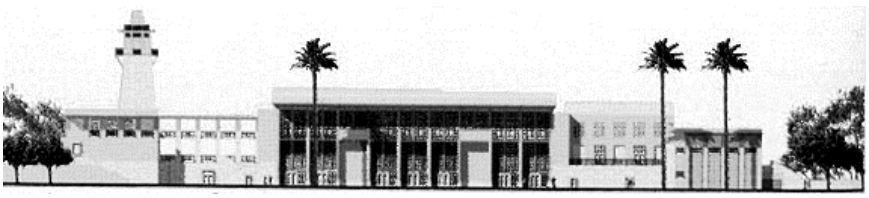


Figure 6-17 Sports center- Main elevation

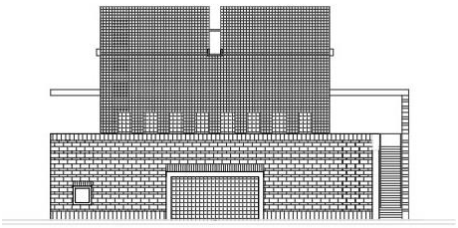


Figure 6-18 Bassily Auditorium- Main elevation

6.3 Method and Materials

This study analyzes the architectural features in the three educational zones in a new educational campus, containing different Islamic architectural features, followed by a designed online questionnaire conducted to users to obtain information about the biophilic design qualities in every zone, and to verify the psychological, cognitive, and physiological performance of these zones.

The online questionnaires divided into three sections. The first section focuses on demographic variables such as age, gender, and educational background. The second section is to examine the biophilic attributes in the three learning-built environment zones and determine in which zone or zones that the users felt more connected to or removed from nature. The final one is to measure the quality of the built environment and determine the psychological and physiological impacts of the biophilic features on the campus students using a 5 bipolar Likert scale to indicate the level of agreement to the statement, and the data are analyzed using the Relative Indices (RI) technique (Ali, 2013). The following formulae are used:

$$RI = \frac{\Sigma\ (5n5 + 4n4 + 3n3 + 2n2 + 1n1)}{5\ (n5 + n4 + n3 + n2 + n1)}$$

where RI is the relative index, and n5, n4, n3, n2, n1 are the number of responding indices The computation of the RI using this formula yields values ranging from 0.2 to 1 as can be shown in Table 6-1.

Table 6-1 Benchmarks for RI Ranges of Evaluation (Source, Ali, 2013)

Categories	RI Range
Very high level of agreement (very good/ strongly agree)	0.20 – 0.35
High level of agreement (good/ agree)	0.36 – 0.51
Neutral in agreement	0.52 – 0.67
Low level in agreement (bad/ disagree)	0.68 – 0.83
Very low level in agreement (very bad/ strongly disagree)	0.84 – 1.00

However, this study is limited to determine the Islamic architecture features in every zone and examine biophilic design attributes in the urban context of the campus, and does not cover all the interior spaces design, due to the large scale of the campus.

6.4 Results

6.4.1 Elements of design fulfilling biophilic attributes analysis

6.4.1.1 Lighting

Campus design integrate daylighting and electric lighting to reduce energy consumption (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a). It brings daylighting into interior spaces by various strategies some of them were inspired from Islamic architecture as inner courtyards, screened windows (The mashrabiya), and clerestories. Indoor learning spaces such as classrooms, reading rooms, and building offices, oriented to exterior spaces such as parks, gardens and courtyards to maximize their potential for natural light. Natural light on interior spaces typically reaches depths of 1.5 to 2.0 times the distance between the upper edge of a window and its sill, this can be increased to (2.0 to 2.5 times) by using light shelves, which was inspired from “the mashrabiya” feature in Islamic buildings (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a).

Zone A

The use of the inner courtyards appears in all buildings as shown in Figure 6-19, and Figure 6-20 to allow much light to enter. In this zone, the buildings use different patterns and shapes of light shelves are inspired from the Islamic mashrabiya as shown in Figure 6-21. These patterns allow a manipulation of natural light and shadow throughout the day to create dynamic and sculptural forms in the rooms. the natural light

manipulation is also uses in many places such as the main portal with its multiple arches as shown in Figure 6-22, inspired by "Star-Ribbed Dome" of the Great Mosque of Cordoba as shown in Figure 6-23 (CDC AbdelHalim-Community Design Collaborative, 2016). Moreover, the outdoor paths use a lattice canopy, which inspired by the ancient Islamic streets, to shade the pedestrian walk, create another dynamic and sculptural forms of natural light as shown in Figure 6-24.

Figure 6-19 Inner courtyards- AUC Administration Building- AUC campus (Source,arch.egy, 2016)

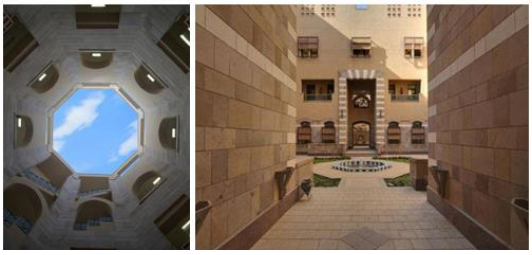


Figure 6-20 Inner courtyard- Research building and School of Humanities and Social Science- AUC campus (Source,arch.egy, 2016)

Figure 6-21 The mashrabiya in Zone -AUC campus (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Figure 6-22 AUC campus main portal (Source, aucegypt.edu, n.d.)

Figure 6-23 (Star-Ribbed Dome) of the Great Mosque of Cordoba (Source, spainthenandnow.com, 2009)

Figure 6-24 Integration of light and shadow in pedestrian walks- zone A- AUC campus (Source, aucegypt.edu, n.d.)

Zone B

The inner courts in this zone are used in the schools' buildings, these courts contain many landscape features as plants and water bodies as shown in Figure 6-25 and Figure 6-28. The mashrabiya and shading devices were used in the windows in the south and west elevations as shown in Figure 6-26 and Figure 6-29. The north and east elevations were used the open glazing windows as shown in Figure 6-27 and Figure

6-30. The outdoor spaces use many architectural features that create a manipulation of daylight light and shadow as shown in Figure 6-31 and Figure 6-32.

Figure 6-25 Louis Greiss courtyard in Abdul Latif Jameel Hall- zone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-28 The courtyard in the School of Sciences and Engineeringzone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-26 The mashrabiya in the south-west elevation of the core academic center- zone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-29 The shading devices in the south-west elevation of the main library- zone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-27 The open glazing windows in the north-east elevation of the school of business- zone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-30 The open glazing windows in the north-east elevation of the main library- zone B- AUC campus (Source, aucegypt.edu, n.d.)

Figure 6-31 The light and shadow in the main library façade- zone B- AUC campus (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Figure 6-32 Light and shadow of a lattice pergola in AUC plaza-zone B (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Zone C

This zone uses many strategies to enhance daylighting. It uses apertures in the ceilings or in the walls to provide daylighting in the interior spaces as shown in Figure 6-33, these roof openings inspired from the shakhshikha and clerestories in Islamic architecture. Inner courts are also used in the student dorms as shown in Figure 6-34. the Outdoors spaces uses lattice exterior shades that providing a beautiful form of the integration between light and shadow as shown in Figure 6-35.

Figure 6-33 Shakhshikha and clerestories in zone C- AUC campus (Source, arch.egy, 2016)

Figure 6-34 Inner courtyards in the student housing (Source, wherekat.blogspot.com, 2010)

Figure 6-35 Light and shadow in the campus center- zone C- AUC campus (Source, (arch.egy, 2016)

6.4.1.2 *Natural* ventilation

The master plan design as shown in Figure 6-37 depends on clusters of compact buildings, oriented toward East and West. The campus design utilizes a planted garden located on the North side of the campus as a cool and low reservoir of natural air. Therefore, the Northwesterly summer wind passes through the garden and brings the cool and moist air into buildings. On the Southwest side of the campus, a shelter belt was planted to prevent winter winds and filter windblown sand (Khalil *et al.*, 2019).

The site was divided into "thermal units", this term used to describe the elements composing a pattern or the assembly of various elements. Every thermal unit consists of the container (the high-pressure element), the field (the low-pressure element), and the tunnel (the connective element) as shown in Figure 6-36. Shaded courtyards and open-air corridors work as containers that store or generate cool air through shading and evaporative cooling. The field element does not need the same degree of enclosure that the container has, so the major public spaces that may

have shaded areas in it as well as sunny areas work as fields that generate warm air and create low-pressure spaces. Circulation elements are worked as tunnels that connect the containers and the fields and allow the cool air to move through it (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a).

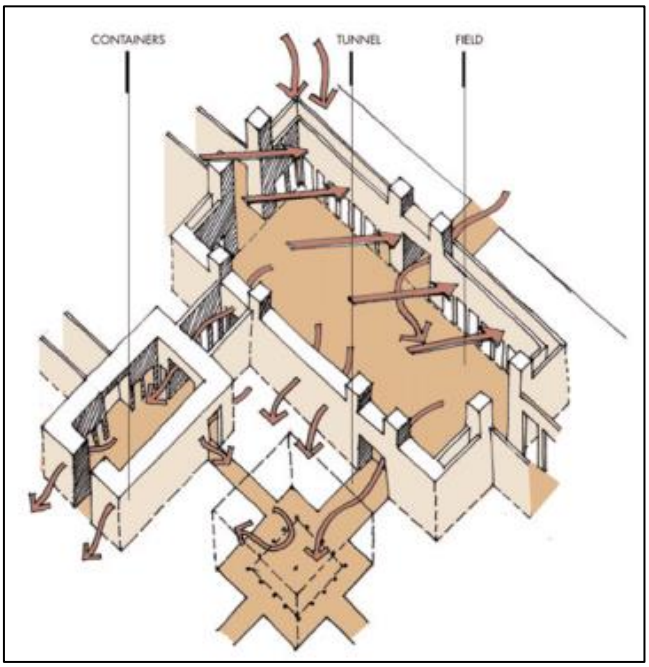


Figure 6-36 Assembly of spaces as a thermal unit diagram (Source, (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000b)

All offices and classrooms have been naturally ventilated, while other spaces such as auditoriums and theaters, computer labs, library, and gymnasiums, have been used mechanical ventilation and cooling.

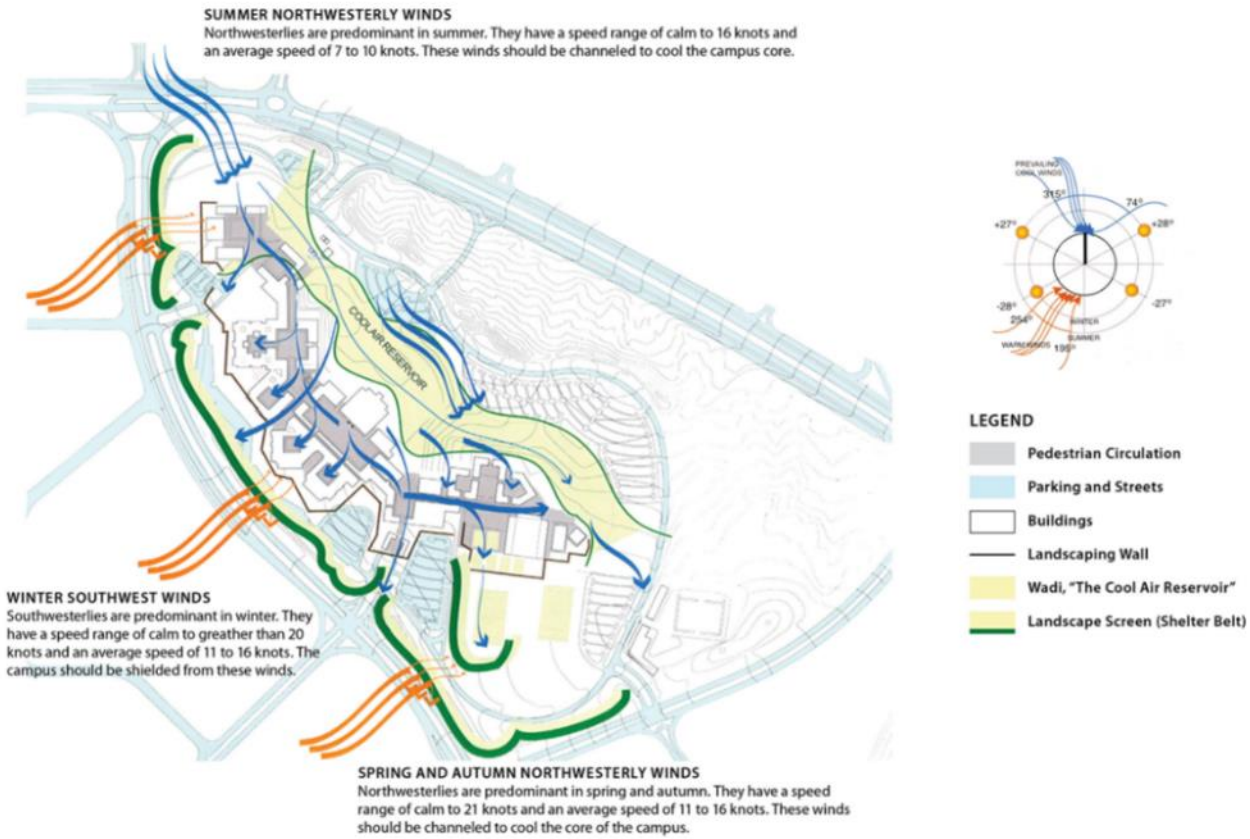


Figure 6-37 Environmental strategy diagram - AUC campus (Source, arch.egy, 2016)

Zone A

In this zone all the buildings used small inner courtyards and shaded passages that utilize as reservoirs of the cool and moist air, while the AUC square and the Administration Plaza work as the solar yards. In the Administration building, wind towers as shown in are used as a rooftop and wall element for passive venting and cooling.

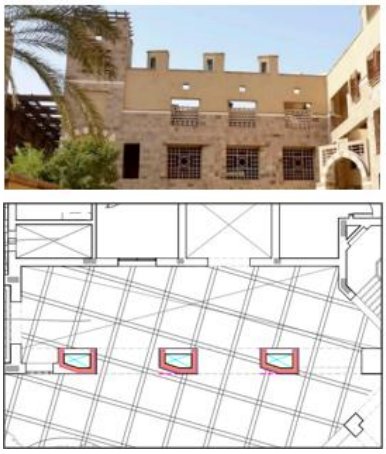


Figure 6-38 Wind towers in Administration building-plan and elevation (Source, Author)

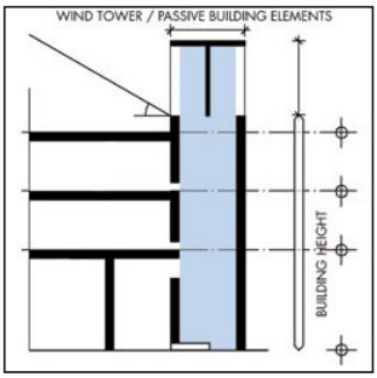


Figure 6-39 Wind tower section (Source, (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a)

Zone B

As well, in this zone the AUC plaza is utilized as the field element, while the inner courtyards in the schools are worked as the containers of the cold air.

Zone C

In zone C the inner courtyards have in the student dorms work as the container element, while the outdoor spaces work as shown in Figure 6-41 as the field. Moreover, a 30-meter-high tower in the sport center as shown in Figure 6-40 was used as a wind catcher that provides naturally and healthy cooling and ventilation for the sports facilities below, it also serves as a navigational reference point for the entire campus, while providing a birds-eye-view of sporting events (Jaber and Wieben, 2008).

Figure 6-40 Mobinil Tower in sport center (Source, wherekat.blogspot.com, 2010)

Figure 6-41 Outdoor spaces in the student housing that work as low-pressure area (Source, wherekat.blogspot.com, 2010)

6.4.1.3 Biodiversity and landscape

The building complex is surrounded by open spaces with a sculpture garden that provides a panoramic view of natural landscape from the schools' windows. The garden was created as the main green space on campus. Some landscape features design follows the geometric type of gardens as shown in , which goes back to Islamic civilizations, especially the Mughal gardens in India and the Islamic gardens in Iran and Spain, were called the paradise gardens or Eden gardens as shown in Figure 6-42 (Hmood, 2018). The garden contains dozens of ornamentals and fruit-bearing tree species, both native and non-native as

shown in Figure 6-43, and Figure 6-44. Also, this design of the garden invites the community and its visitors to explore the difference between these species by using tree labels. This productive vegetation with fruits or flowers provides a good environment to support butterflies, bees, and birds as shown in Figure 6-45.

All the outdoor plazas, passages, and inner courtyards in every zone contain natural elements of landscape whether vegetation elements as shown in Figure 6-48, Figure 6-49, and Figure 6-50, or water bodies as shown in Figure 6-46, and Figure 6-47. These outdoor spaces provide a sense of seasonal variations. Most of the interior spaces in the different zones are connected with the outside by operable windows, porches, and colonnades as shown in Figure 6-51.

Figure 6-42 AUC Garden (Source, earth.google.com, 2015), and Alhambra Garden, Grenada, Spain (Source, alhambra.org/, n.d.)

Figure 6-43 Plants in AUC garden (Source, aucegypt.edu, n.d.)

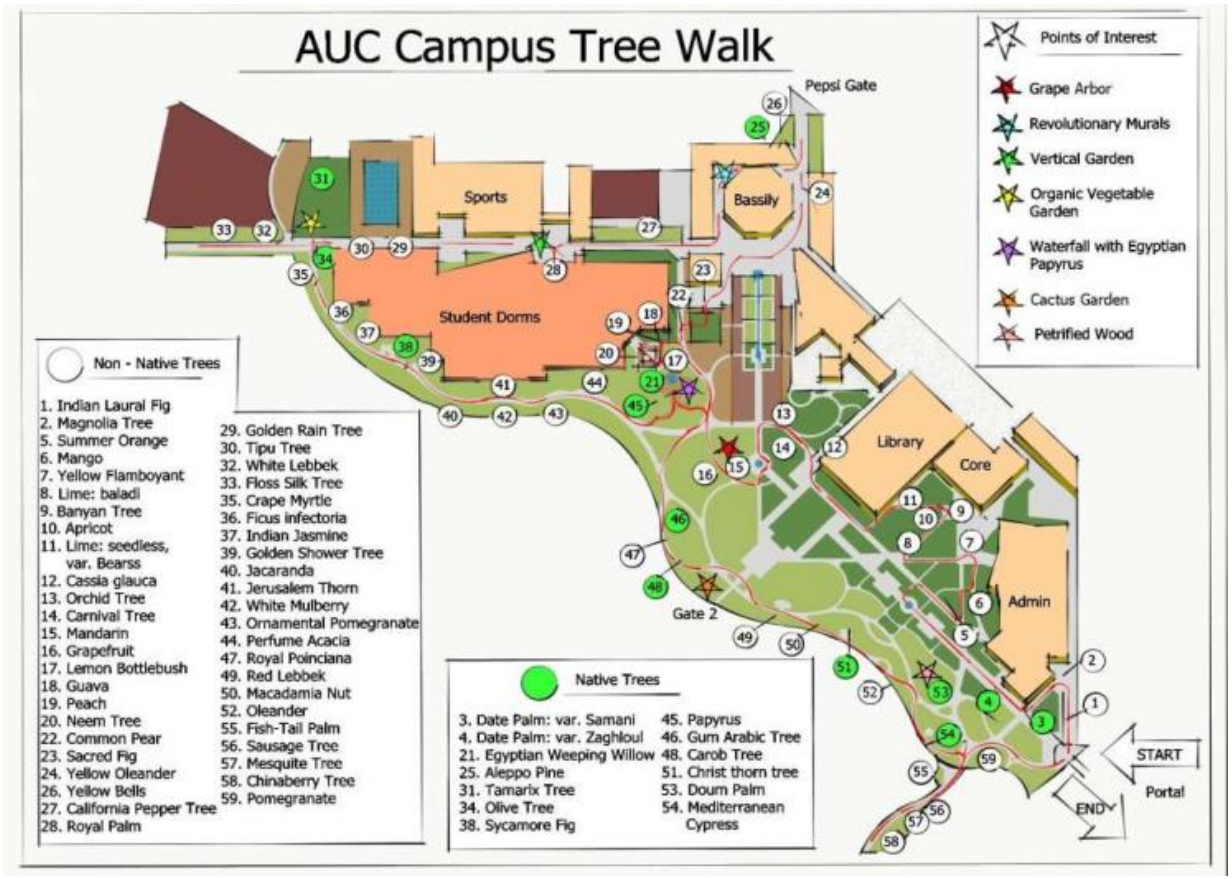


Figure 6-44 AUC garden- Tree walk (Source, aucegypt.edu, n.d.)

Figure 6-45 Birds in AUC garden (Source, (aucegypt.edu, n.d.), (flickr.com, 2015), and (Khalil, 2009))

Figure 6-46 Water bodies in zone A and C - AUC square (Source, aucegypt.edu, n.d.; earth.google.com, 2015)

Figure 6-47 Water bodies in the AUC plaza- zone B- AUC campus (Source, arch.egy, 2016)

Figure 6-48 Natural plants in the Administration plaza- zone A- AUC campus (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Figure 6-49 Natural plants in zone B- AUC campus (Source, earth.google.com, 2015)

Figure 6-50 Natural plants in zone C-AUC campus (Source, arch.egy, 2016)

Figure 6-51 Garden view from the main library (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

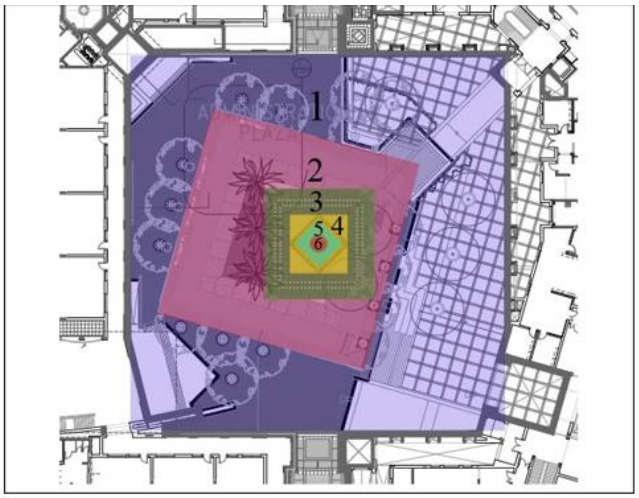
6.4.1.4 *Form*

Architectural diversity is achieved through the articulation of forms and shapes while maintaining continuity of materials, construction techniques, color palette, and repetition of architectural elements such as arcades and colonnades.

Zone A

In this zone, the square is the principal shape of the zone layout, which considered to be one of the stable shapes in Islamic architecture. The square is used in the Administration Plaza and AUC Plaza whether in the plaza outline or in the landscape elements as waterbodies or floor tiles, it also uses in the inner courtyards and the interior spaces as halls, atriums, and offices and classrooms. Some of these interior spaces undergo some transformation to a rectangle shape with an approximate width to length proportion 1:1.3.

In the School of Humanities and Social Science and the Administration building, the master plan consists of groups of offices and classrooms organized around squared courtyards. In the exterior facades the rectangle was the main shape that formed the opening outlines with different proportions. The Administration Plaza with an approximate size 50*50 meters, it is proportional to the inner landscape-floor-tiles squares have a specific ratio estimated by 1:2 as shown in Figure 1-2, the same ratio that used in the Madrasa of Sultan Hassan as mentioned before.



	1 Administration Plaza	2 Floor-tiles	3 Floor-tiles	4 Floor-tiles	5 Floor-tiles	6 Floor-tiles
Length (m)	50	28	14.5	7.6	4	D 2.2
Width (m)	50	28	14.5	7.6	4	
L/W	1:1	1:1	1:1	1:1	1:1	
Ratio		1.8:1	1.9:1	1.9:1	1.9:1	1.8:1

Figure 6-52 Administration Plaza floor-tiles portions analysis (Source, Author)

Most exterior surfaces use local materials such as local granite with gray color finish, and limestone with local colors; white, dark tallow, or sandstone with cream color finish. Also, some walls use Burned mudbrick with terracotta /brown color. The window screens use Local wooden lattice work (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000a), most of exterior wall finish use "ablaq", which is a decorative technique of alternating sequential runs of light and dark stone that inspired from Islamic building. In the plazas' floor they also use natural materials such as Hurghada granite, Basalt pavers with brown color, and sandstone tiles with beige color as shown in Figure 6-53.

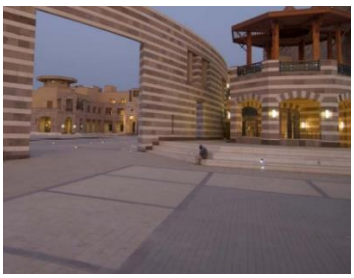


Figure 6-53 wall and floor color and finish -zone A (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Zone B

In this zone, the rectangle shape is the main shape that used in buildings' layout and façade. Islamic architecture uses rectangle in many designs specially with proportional ratios of 3:2 (Tabbaa and Hillenbrand, 1997). However, the layout shapes in this zone vary in width-length proportions, most of them use 1:3 ratio as shown in Figure 6-54. Square shape was appeared in many places such as the façade of the main library and in the floor tiles of AUC plaza, while the inner courtyards use 1:2 ratio.

	1 AUC Plaza	2 Floor-tiles	3 School of Sciences and Engineering
Length (m)	148	37	70
Width (m)	50	12	22
L/W	3:1	3:1	3:1

Figure 6-54 AUC Plaza portions analysis (Source, Author)

This zone uses similar finish materials and colors as zone A in many buildings such as core academic center, the schools. The campus center was designed by Ricardo Legorreta, the design has brought influences from his native Mexico in colors as shown in Figure 6-55.

Figure 6-55 The traditional Mexican architecture colors in the municipalities of Mexico (Source, Alamy.com, 2019) and the campus center color finish, zone B, AUC campus (Source, legorreta.mx, n.d.)

Zone C

The buildings in this zone use stable shapes in the design, as the square in student dorms and the hexagon in the main auditorium, University conference, and meeting rooms, and a rectangle shape in the sports center. The Bassily Auditorium façade uses ceramic or mosaic tiles with blue color as sown in Figure 6-56, and the Architect has

brought influences from his native Mexico to design the boldly colored student residences as shown in Figure 6-57.

Figure 6-56 The Bassily Auditorium in AUC campus (Source, fluor.com, n.d.)

Figure 6-57 The student housing in AUC campus (Source, fluor.com, n.d.)

6.4.1.5 Opening in space

According to the design strategies of the campus, all the wall opening types and sizes meet campus environmental standards (CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates, 2000b). The North-facing walls give the maximum ratio of opening to the solid wall area, so increase the connection between inside and outside, while East-facing walls allow a lesser ratio. West and South-facing walls require the most shading, so West and South elevations use walls screens.

All the rooms have one or more operable window in one side of the space, with single or double glazing, using architectural shading devices such as overhangs, wing walls and louvers, to control undesirable solar heat gains, the window's height ranges from 1.5-3 m, and width ranges from 1.5-3m.

Zone A

Most of the windows in this zone use light shelves and the mashrabiya, oriented toward the inner courtyards or the Administration Plaza with a limited distant view.

Zone B

The North-East schools' windows in this cluster are oriented toward the main plaza, while the rest are oriented toward the inner courtyards. The other buildings such as the library building are oriented their north elevation toward the AUC garden, providing an interesting connection with the nature environment with a distant view as shown in Figure 6-51. Moreover, the openings in the South-West facade of the library are providing a secured and protected shelters to the students with a plaza view as shown in Figure 6-58.

Figure 6-58 Openings in the main library facade work as student shelters, zone B, AUC campus (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

Zone C

The windows in this zone use shading devices, and oriented toward the inner courtyards as the student dorms or oriented toward the inner campus landscape.

6.4.1.6 Ordering

The urban design of campus is comprised of compacted groups of buildings using centralized organization, oriented along a central pedestrian spine in a linear organization as shown in Figure 6-59.

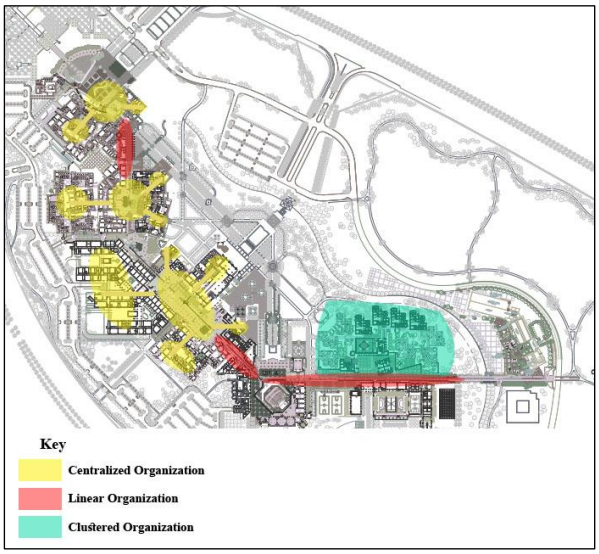


Figure 6-59 Type of urban organization in AUC campus (Source, Author)

The campus layout consists of two main axes as shown in Figure 6-61 and Figure 6-60, the first one starts from the AUC portal and ends by the service gate next to the dorms, having the main plaza of the campus in the middle. The next axis passes through the north garden on the campus starts from the main gate (AUC portal) and ends at Bassily auditorium. The buildings' clusters are organized in a balanced manner on the opposite sides of the central axis, also the main garden landscape is arranged in a symmetrical manner as shown in Figure 6-62.

Figure 6-60 AUC campus' main axes (Source, aucegypt.edu, n.d.)

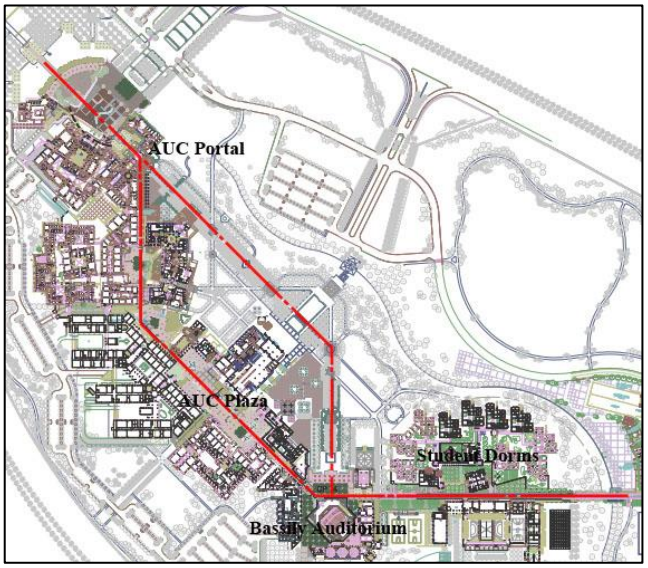


Figure 6-61 AUC campus' main axes diagram (Source, Author)

Figure 6-62 Symmetrical landscape along garden axis in AUC campus (Source, earth.google.com, 2015)

A clear change in the hierarchy of the public spaces along the main axes of the campus, and the secondary buildings' axes that appear in every zone as shown in Figure 6-65, which ranging in scale and privacy from large scale spaces for the entire campus' students, to medium interaction spaces for the whole school, and finally small intimate gathering spaces or class size grouping. This hierarchy of spaces provides a coherent organization and offering a range of environments accommodating mood or season, which transform buildings to human scale.

Repetitive elements, such as arcades and colonnades perceive as an architectural datum that helps to understand the variety of architectural forms in the campus as shown in Figure 6-63. Moreover, the continuous urban structures like a street or connector, can be

understood as the datum against which the formal articulation of various buildings is juxtaposed. Unity is created through the continuous urban structure, and diversity is subject to programmatic need and individual building expression. We can also see the repetition of square and rectangular spaces form in a hierarchical way, as we mentioned above.

Figure 6-63 Arcades in Research Center zone A (Source, fluor.com, n.d.), in Core Academic Center Zone B and Campus Center Zone C (Source, arch.egy, 2016)

The elevations design in every zone follows the ordering principles as symmetry, and hierarchy and rhythm openings as shown in Figure 6-64, Figure 6-66, Figure 6-67, Figure 6-68. Figure 6-69, and Figure 6-70.

Figure 6-64 Symmetrically designed façades give a clear grid of openings lends rhythm and structure in zone A -AUC campus (Source, Edit by Author)

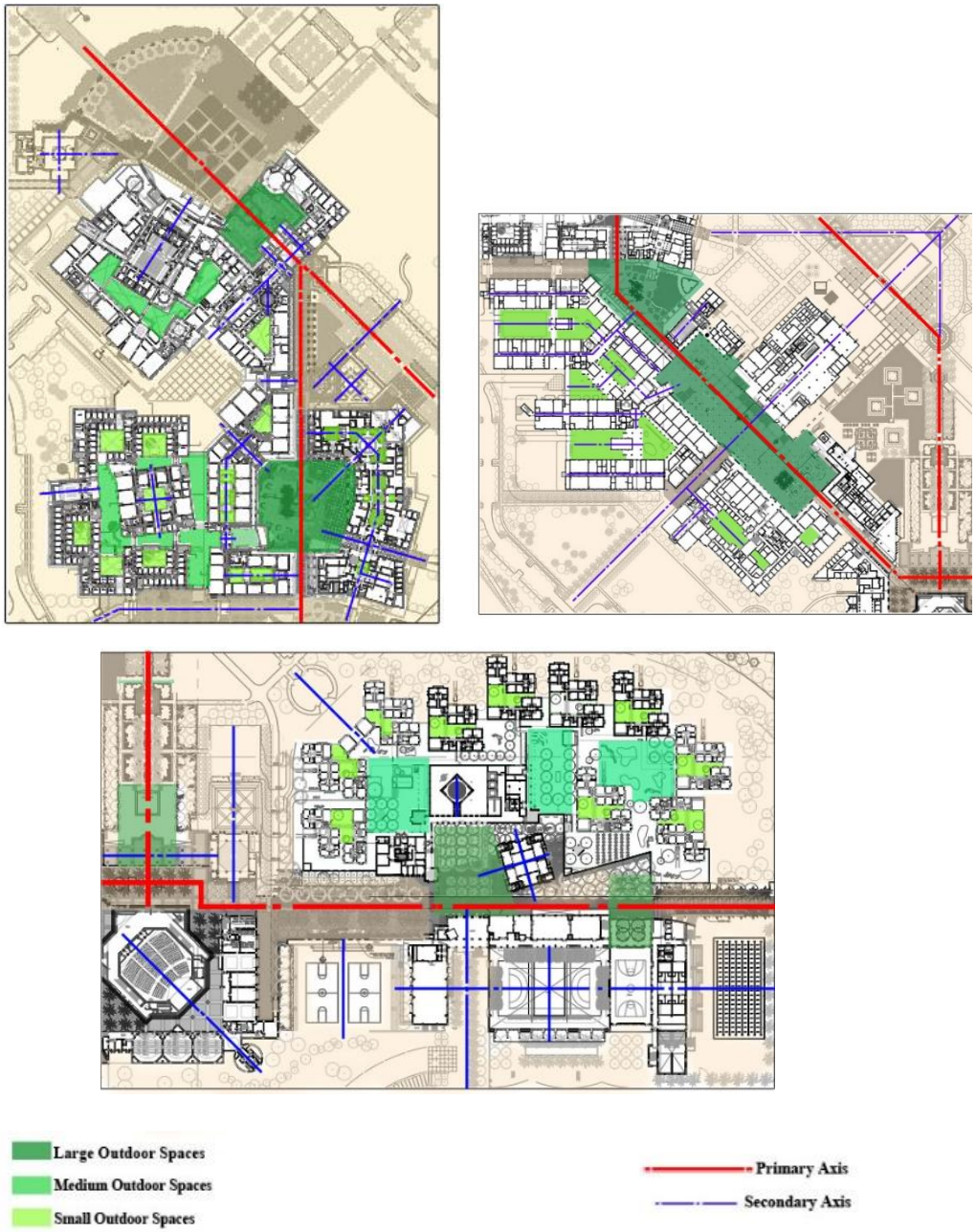


Figure 6-65 The hierarchy of public spaces in zones A, B, C in AUC campus (Source, Author)

Figure 6-66 Symmetrically designed façade- student campus- zone B- AUC campus (Source, Edit by Author)

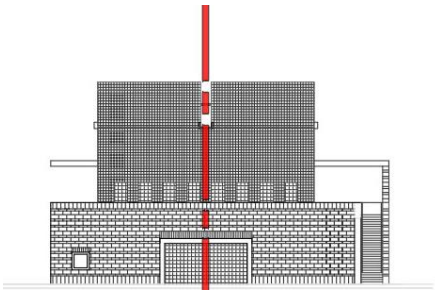


Figure 6-67 Symmetrically designed façade- Bassily Auditorium- zone C- AUC campus (Source, Author)

Figure 6-68 Hierarchical order of openings by size in the schools' elevation in zone A, B and the sports center in zone C – AUC campus (Source, Author)

Figure 6-69 Opening rhythm in the schools' elevation in zone A, B and the sports center in zone C– AUC campus (Source, Author)

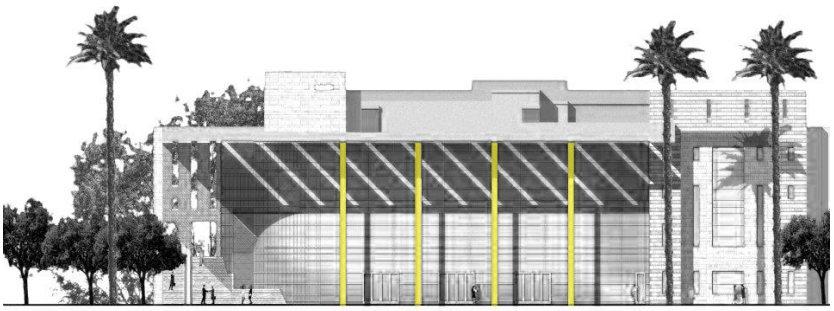


Figure 6-70 Structure rhythm in the main library elevation - zone B- AUC campus (Source, Author)

6.4.1.7 Circulation elements

The vehicular circulation separated completely from the pedestrian path through the campus, thus there is a vehicular loop that surrounds the whole campus, and access is provided at different spots accompanied by parking. The campus urban design provides different alternatives of pedestrian paths as shown in Figure 6-71. The first one is the primary circulation pattern of continuous walking surfaces that are unobstructed

by landscape or fixed furniture along all "major lines" of the major public spaces, passages, and courtyards. Major lines are understood as those circulation paths that connect entrances to departmental buildings, and entries or gateways to major public spaces. Also, walking surfaces at the periphery of major public spaces (the area of the colonnades) are provided. The second path is a connected system of passageways between courtyards of academic schools that provide a sequence of outdoor spaces with seasonal variations. Most pathways are attached to activities, main entrances of different buildings, or classrooms with outdoor surveillance creating connectivity between the indoor and the outdoor which revive the spaces.

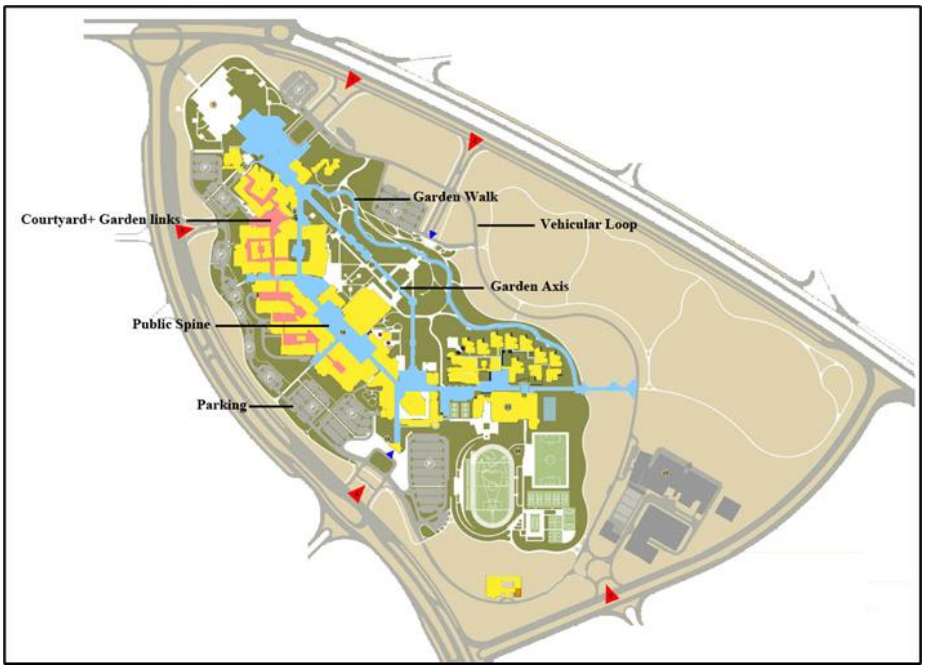


Figure 6-71 Circulation elements and transitional spaces in AUC campus (Source, Author)

Entrances, lobbies, vestibules, lounges, multi-use spaces, corridors, and overlooks are the elements of interior circulation. Lounges and overlooks, which are designed adjacent to major public spaces, courtyards, or gardens, are for break-out from activities, gathering and repose. The multi-story lounges and multi-use spaces (such as atriums) work as major public spaces or interior plazas within buildings and located central to most surrounding building programs and easily accessible from building entrances and exterior public spaces such as

courtyards and gardens, they also integrated with the main paths of circulation through the building. Entrances to classrooms, labs and study areas are connected to internal corridors or internal colonnades than the direct connection to exterior public spaces. The design also uses the bridge connectors between building as shown in Figure 6-72 rooftops as a circulation element.

Figure 6-72 Bridge connectors between buildings in AUC campus (Source, (CDC AbdelHalim-Community Design Collaborative, 2016)

6.4.1.8 Vernacular design

Plan organization and buildings' fabric is related to the historic patterns and environmental conditions of the region like wind direction, solar orientation, etc. Some of these organizational principles are translated into the compactness of the campus plans, the organization of buildings around courtyards and the use of sheltered paths.

Most of the used plants are native and adapted plants such as palm trees, and most of the used species are grown from seeds locally produced. This productive vegetation with fruits or flowers, made a good environment that supports many native animal species as mentioned before.

Zone A

The buildings' design in this zone uses Islamic architecture features that follows passive design strategies as wind catchers, the mashrabiya, and inner courts. The finishing materials are derived from the natural site as we mentioned before. These features create a strong identity to this zone.

Zone B

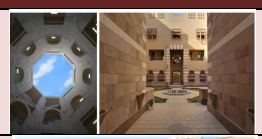
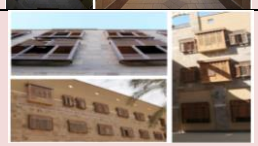
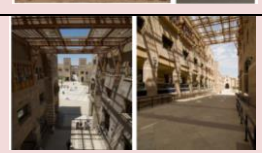
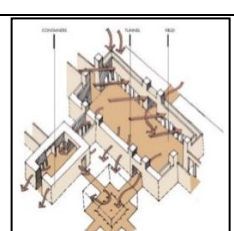
Many buildings in this zone use similar features to those used in zone A but in a more modern manner, such as the main library and the campus center. Although these features create a different identity or personality to the built environment, but the design integrated in harmony with the other zones.

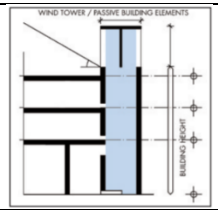
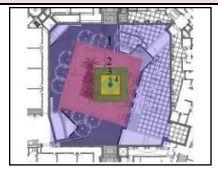
Zone C

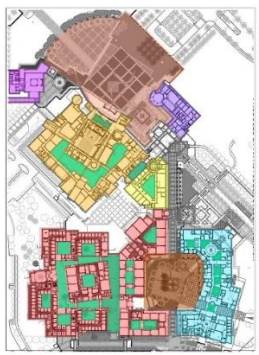
The buildings in this zone use many features from the previous zones such inner-courtyards, lattice windows. The finishing materials in this zone are more artificial materials than other zones. The zone has its unique identity that harmonizes in a satisfactory manner with the rest of the campus.

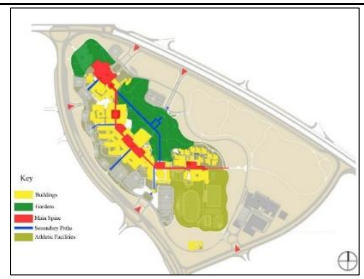
According to the previous analysis the following tables: Table 6-2, Table 6-3, and Table 6-4 represented the design strategies, which used in the three zones, and fulfill biophilic design attributes.

Table 6-2 Design elements and their strategies applied in the zone A in AUC campus fulfilling Biophilic design attributes

Architectural design elements	Design Strategies		Biophilic design attributes	
Lighting	- Inner courtyards in all buildings		**Light**	- Enabling an orientation to the day, night and seasons - Response to the sun's location and cycles - Aesthetic shapes and forms through the interplay of light and shadow - Diffuse and variable light
	- Different patterns of screened windows and "mashrabiya"			
	- Lattice canopies to shade pedestrian walks			
Natural ventilation	- Oriented clusters as East/West - Heavily planted north garden		**Air**	- variations in airflow, temperature, humidity, and barometric pressure
	- Use "thermal unit"; consist of the container (the high-pressure element), the field (the low-pressure element), and the tunnel (the connective element).			

	- Use wall elements for passive venting and cooling as wind towers			
Biodiversity and Landscape	- AUC garden use native and non-native vegetation, which support animals' life, and water bodies		**Water**	- Multiple senses of sight, sound, touch, and movement of water
			Plants	- Direct experience of natural plants and green areas into the built environment
	- Inner courtyards and plazas use natural elements as trees and water bodies		**Animals**	- Presence of nonhuman animal life
			Natural landscape and ecosystem	- Presence of ordinary natural scenery
	- Connect all the indoor spaces with the outdoor by windows, porches, and colonnades.			
			Weather	- Awareness and response to weather
Form	Use square as a primary shape in the buildings design and the main plaza and its floor-tiles with a geometrical relation between the squares. (1:1.9 portion)		**Natural Materials**	- Direct experience of decorative or functional, natural material in the built environment

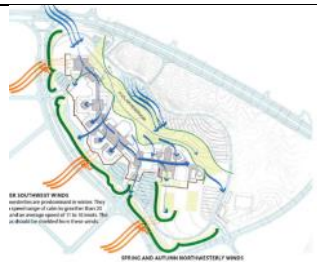
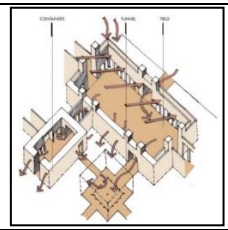
	- Repetition of architectural elements such as colonnades.		**Natural colors**	- Direct experience with muted "earth" tones characteristic of soil, rock, and plants.
			Natural geometries	- Self- repeated patterns.
	- The master plan consists of groups of offices and classrooms organized around squared courtyards.		**Naturalistic shapes and forms**	- Simulation of tree-like shapes (columnar support) - Arches that resemble or copy forms found in nature (shell forms)
			Information richness	- Buildings and landscapes that possess information richness, variety, texture, and detail that mimic natural patterns
	- Use local materials with earth tone colors - Use "ablaq", a technique of alternating courses of light and dark stone.			
Opening in space	- All the rooms have one or more operable window connected to the courtyards or plazas		**Weather**	- Awareness and response to outside weather

<table>
<tr><td rowspan="4">Ordering</td><td>- The urban design of campus is comprised of compacted groups of buildings using centralized organization</td><td>  </td><td>Organized complexity</td><td>- Variable and diverse spaces possess attributes of connection and coherence</td></tr>
<tr><td>- The campus buildings and garden oriented along central axes in a symmetrical manner.
- The public spaces work as focal points.</td><td>  </td><td rowspan="3">Integration of parts to wholes</td><td rowspan="3">- Disparate parts comprise an integrated whole</td></tr>
<tr><td>- Hierarchical order of openings by size in school’s elevations</td><td>  </td></tr>
<tr><td>- Opening rhythm in school's elevations</td><td>  </td></tr>
</table>

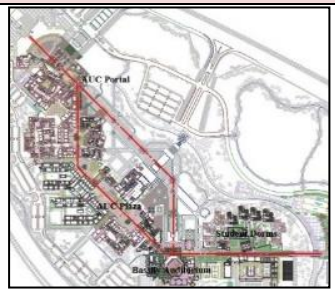
	- Hierarchy of public spaces in scale and privacy along the axes			
Circulation elements	- Different alternatives of pedestrian circulation in the outdoor - Entrances, lobbies, vestibules, lounges, multi-use spaces, galleries, corridors, and overlooks are the elements of the interior circulation.		**Transitional spaces**	- Clearly understood connections between spaces
			Mobility and wayfinding	- Freely moving between diverse and often complicated spaces
	- Use bridge connectors between building rooftops as a circulation element		**Prospect and refuge**	- Provide secure and safe spaces with long view to the surrounding settings as bridges
Vernacular design	- Use environmental design strategies depend on vernacular architecture - Use native and adapted plants - Use local materials - Plan organization and massing of the building fabric relative to historic patterns		**Cultural and ecological attachment to place**	- Historic connection to place - Cultural connection to place - Indigenous materials

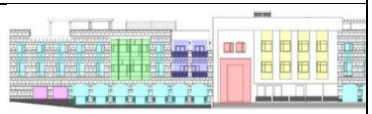
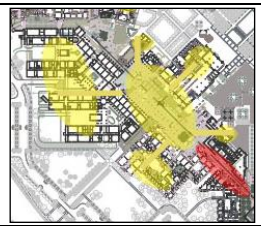
Table 6-3 Design elements and their strategies applied in the zone B in AUC campus fulfilling Biophilic design attributes

Architectural design elements	Design Strategies (zone B)		Biophilic design attributes	
Lighting	- Inner courtyards in schools' buildings		**Light**	- Enabling an orientation to the day, night and seasons - Response to the sun's location and cycles - Aesthetic shapes and forms through the interplay of light and shadow - Diffuse and variable light
	- Light shelves and other shaded devices as mashrabiya in south and west elevations			
	- Open glazing windows in north elevations			
	- Use a lattice pergola in the plaza			

Natural ventilation	- Oriented clusters as East/West - Heavily planted north garden		**Air**	- variations in airflow, temperature, humidity, and barometric pressure
	- Use "thermal unit" in school buildings.			
Biodiversity and Landscape	- AUC garden use native and non-native vegetation, which support animals' life, and water bodies	 	**Water**	- Multiple senses of sight, sound, touch, and movement of water
			Plants	- Direct experience of natural plants and green areas into the built environment
	- Inner courtyards and plazas use natural elements as trees and water bodies	 	**Animals**	- Presence of nonhuman animal life
			Natural landscape and ecosystem	- Presence of ordinary natural scenery

	- Connect all the indoor spaces with the outdoor by windows, porches, and colonnades.		**Weather**	- Awareness and response to weather
Form	- Use earth tone colors finish in some buildings and bright colors in the others		**Natural colors**	- Direct experience with bright colors and muted "earth" tones characteristic of soil, rock, and plants.
	- The schools consist of groups of offices and classrooms organized around courtyards - The other buildings organized around the main plaza		**Naturalistic shapes and forms**	- Simulation of tree-like shapes (columnar support) - Arches that resemble or copy forms found in nature (shell forms)
	- Repetition of architectural elements such as arcades and colonnades.		**Information richness**	Buildings and landscapes that possess information richness, variety, texture, and detail that mimic natural patterns

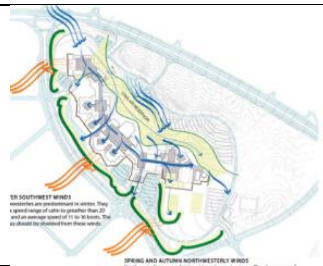
Opening in space	- All the rooms have one or more operable window connected to the courtyards, plaza, or garden.		**Weather**	- Awareness and response to outside weather
			Prospect and refuge	- Provides sites of safety and security with long view to the surrounding settings
	- The openings in the library facade provide a secured and protected shelters to the students with a plaza view	 		
Ordering	- The campus buildings and garden oriented along central axes in a symmetrical manner.		**Organized complexity**	- Variable and diverse spaces possess attributes of connection and coherence
			Integration of parts to wholes	- Disparate parts comprise an integrated whole
	- Symmetrically designed façades give a clear grid of openings lends rhythm and structure			

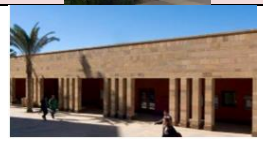
	- Hierarchy of public spaces in scale and privacy along the axes			
	- Hierarchical order of openings by size in school's elevations			
	- Opening rhythm in school's elevations			
	- The compacted groups of buildings using centralized and linear organization			
Circulation elements	- Different alternatives of pedestrian circulation in the outdoor - Entrances, lobbies, lounges, multi-use spaces, corridors and		**Transitional spaces**	- Clearly understood connections between spaces

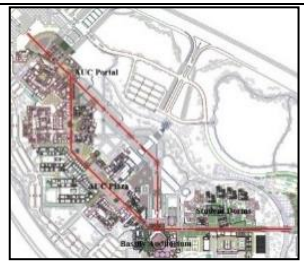
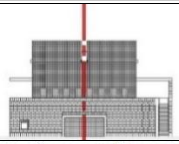
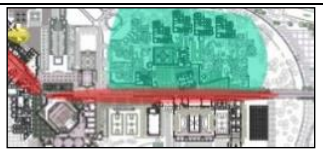
	overlooks are interior circulation elements		**Mobility and wayfinding**	- Freely moving between diverse and often complicated spaces
	- Use bridge connectors between building rooftops as a circulation element		**Prospect and refuge**	- Provide secure and safe spaces with long view to the surrounding settings as bridges
Vernacular design	- vernacular architecture features - Use native and adapted plants - Use local materials		**Cultural and ecological attachment to place**	- Historic connection to place - Cultural connection to place - Indigenous materials

Table 6-4 Design elements and their strategies applied in the zone C in AUC campus fulfilling Biophilic design attributes

Architectural design elements	Design Strategies (zone C)		Biophilic design attributes	
Lighting	- Inner courtyards in student housing		**Light**	- Enabling an orientation to the day, night and seasons - Response to the sun's location and cycles - Aesthetic shapes and forms through the interplay of light and shadow - Diffuse and variable light
	- Roof openings (Shakhshikha) and "Clerestories" (vertical windows, located on high walls)			
	- Open glazing windows in north elevations of sport center			
	- Shading devices in student housing and campus center			
	- lattice exterior shades			

<table>
<tr><td rowspan="3">Natural ventilation</td><td>- Oriented clusters as East/West
- Heavily planted north garden</td><td>  </td><td rowspan="3">Air</td><td rowspan="3">- variations in airflow, temperature, humidity, and barometric pressure</td></tr>
<tr><td>- Use inner courts in the student housing</td><td>  </td></tr>
<tr><td>- Use a tower of sport center as wind catcher</td><td>  </td></tr>
<tr><td rowspan="2">Biodiversity and Landscape</td><td rowspan="2">- Inner courtyards use natural elements as trees and water bodies</td><td rowspan="2">  </td><td>Water</td><td>- Multiple senses of sight, sound, touch, and movement of water</td></tr>
<tr><td>Plants</td><td>- Direct experience of natural plants and green areas into the built environment</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

	- AUC garden use native and non-native vegetation, which support animals' life, and water bodies		**Animals**	- Presence of nonhuman animal life
	- Connect all the indoor spaces with the outdoor by windows or terraces.		**Natural landscape and ecosystem**	- Presence of ordinary natural scenery
			Weather	- Awareness and response to weather
Form	- Repetition of architectural elements such as colonnades.		**Naturalistic shapes and forms**	- Simulation of tree-like shapes (columnar support)
	- Use earth tone colors finish in some buildings and bright colors in the others		**Natural colors**	- Direct experience with bright flowering colors
Opening in space	- All the rooms have one or more operable window connected to the courtyards or garden.		**Weather**	Awareness and response to outside weather

Ordering	- The campus buildings and garden oriented along central axes in a symmetrical manner.		**Organized complexity**	- Variable and diverse spaces possess attributes of connection and coherence
			Integration of parts to wholes	Disparate parts comprise an integrated whole
	- Symmetrically designed façades			
	- Hierarchy of public spaces in scale and privacy along the axes			
	- Hierarchical order of openings by size in the facade			
	- Opening rhythm in elevation			
	- The compacted groups of buildings using clustered and linear organization			

Circulation elements	- Different alternatives of pedestrian circulation in the outdoor		**Mobility and wayfinding**	- Freely moving between diverse and often complicated spaces
			Prospect and refuge	- Provide secure and safe spaces with long view to the surrounding settings as bridges
	- Entrances, lobbies, vestibules, lounges, multi-use spaces, galleries, corridors and overlooks are the elements of the interior circulation.		**Transitional spaces**	- Clearly understood connections between spaces
Vernacular design	- vernacular architecture features in sport center - Use native and adapted plants		**Cultural and ecological attachment to place**	- Historic connection to place - Cultural connection to place

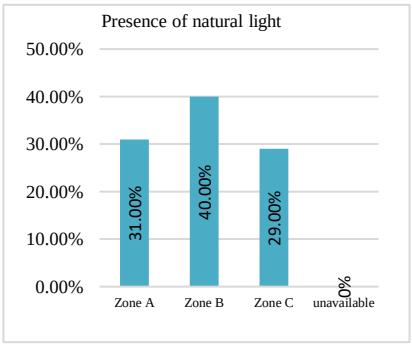
6.4.2 Users' evaluation of the biophilic design attributes and users' psychological, physiological, and cognitive experiences

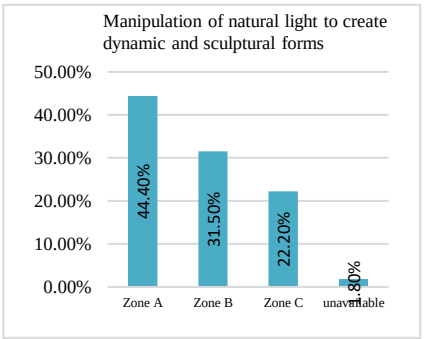
The respondents in this questionnaire surveys 55% of them were academic architects that visited the campus many times before, were the rest of the respondents, which is 45%, were students in the campus. The respondents ages ranging between 20 to 40 years.

Direct Experience of Nature

Light

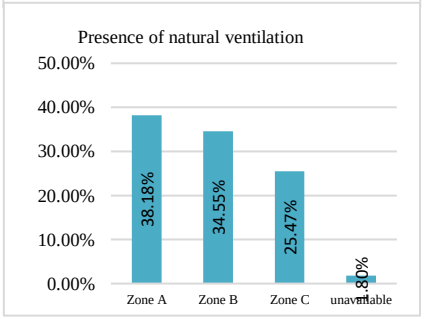
The graph shows that zone B has the most amount of daylighting with 40% of the votes, and this might refer to the wide openings and outdoor spaces in this zone. However, according to the survey 44% of the votes indicate that the manipulation of natural light, which create dynamic and sculptural forms, is more obvious in zone A, and this might refer to the different shapes of the mashrabiya in this zone.





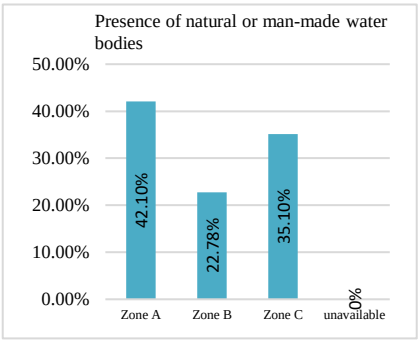
Air

According to questionnaires the presence of natural ventilation is allowed in all the zones in the following order of votes: zone A 38%, zone B 35%, and zone C 25%.



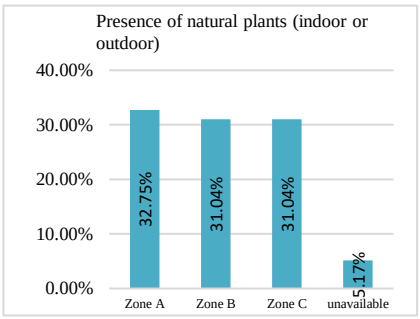
Water

The graph shows that 42% of the votes indicated that the water features in zone A is more obvious than other zones, and this is might because some water sprinklers are not used in AUC plaza in zone B.



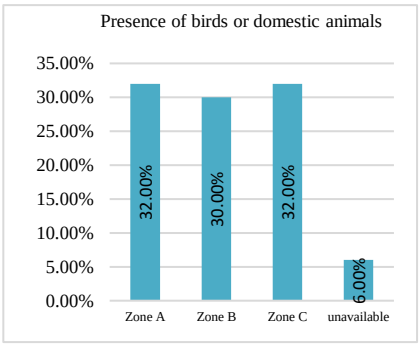
Plants

According to the survey the natural plants distributed along the campus as the following order of votes: zone A 33%, zone B and C 31%.



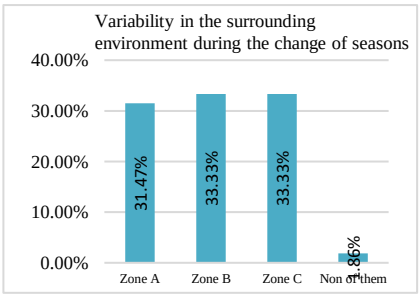
Animals

The graph shows that the birds and domestic animals were seen by users in all zones according to the following order of votes: zone A and C 32%, and zone B 30%.

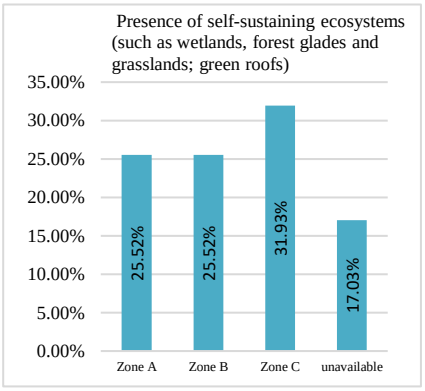


Weather

According to the survey result, the users feel the weather attribute in all zones, this is because using operable window connected to the courtyards, plazas, or gardens.

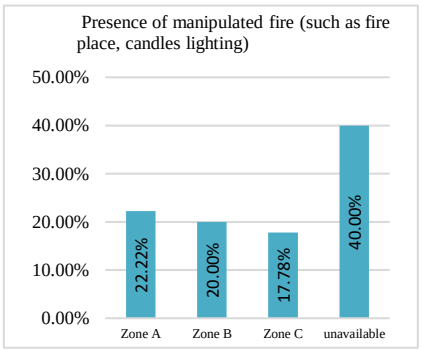


Natural landscapes and ecosystems



According to the survey, 32% thought that the natural landscape and ecosystem is more presence in zone C, and this is might refer to use some native natural plants with random distribution in this zone. 25.5% thought that it is more presence in zone A, 25.5% thought that it is more presence in zone B, and the rest 17% thought that the self-sustaining landscape and ecosystem is not found.

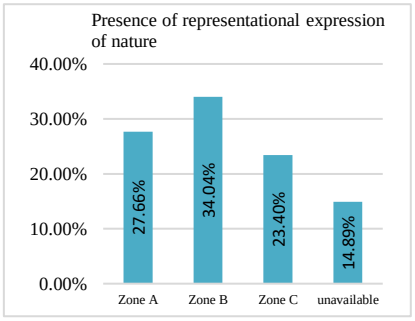
Fire



The graph shows that 40% of users thought that fire attribute is absent in the campus.

Indirect Experience of Nature

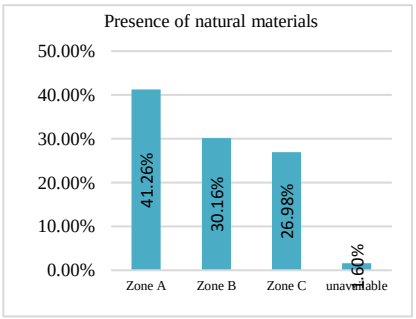
Images of nature

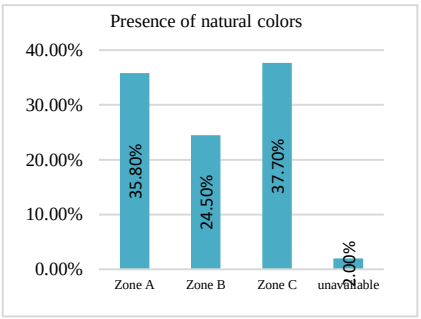


According to survey results, 34% of users thought that the presence of representational expression of nature such as photographs, paintings, and murals is more obvious in zone B, and 28% thought that it is more obvious in zone A.

Natural colors and materials

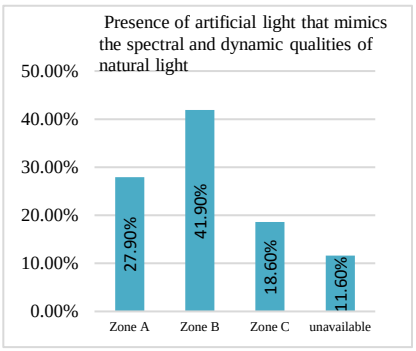
The results of the survey show that the presence of natural materials is more obvious in zone A with 41%, while the presence of natural colors as bright colors and earth tones is obvious in zone c with 38% votes, and zone A with 36% votes, and this is because the use of bright colors in zone C and the earth tone colors in zone A, and C.

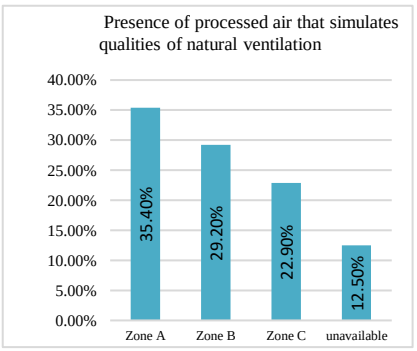




Simulating natural light and air

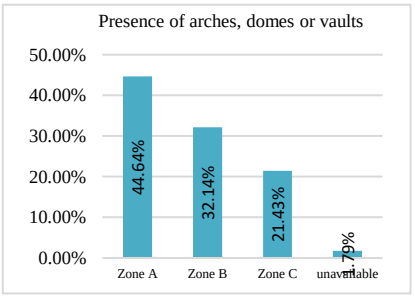
The graph shows that 42% of votes indicate that the artificial light that mimics the spectral and dynamic qualities of natural light is clear in zone B, while 35% of votes indicate that the processed air that simulates qualities of natural ventilation is obvious in zone A.

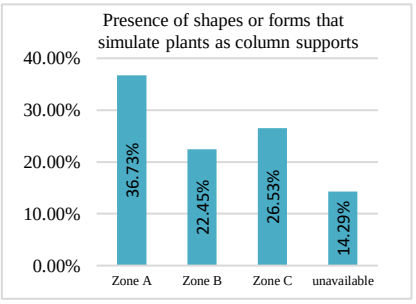


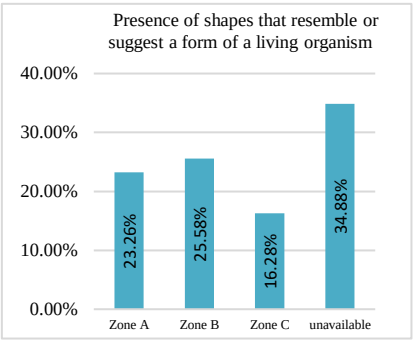


Naturalistic shapes and forms

The following graphs show that the presence of naturalistic shapes and forms is clear in zone A, and this might refer to the use of archades in this zone.







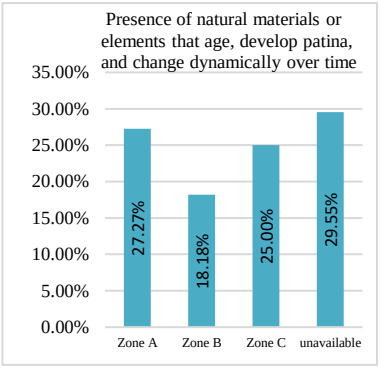
Evoking nature

35% of votes indicate that evoking nature is absent in the campus.

Information richness

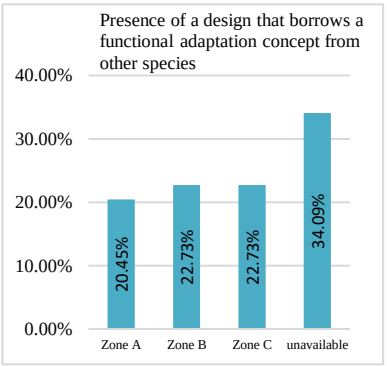
According to survey results, the presence of a set of details contained in an element of the building or a piece of texture, graphic or artis apparent in zone A with 42% of votes. This refers to the use of some Islamic architecture features as the mashrabiya, and the self-repeated shapes.

Age, change, and the patina of time



The natural materials that age or change dynamically over time is not clear in the campus. Therefore, 30% votes it as unavailable, while 27% votes that it is apparent in zone A, might because the use of natural materials, and 25% vote for zone C.

Biomimicry

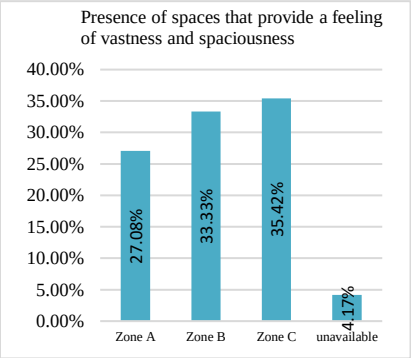


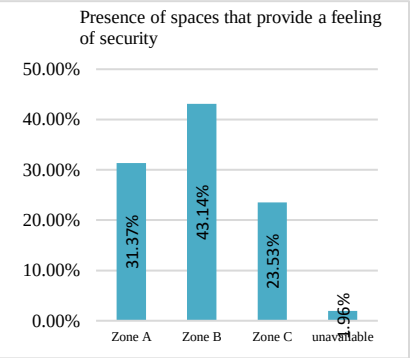
Moreover, the presence of a design that borrows a functional adaptation concept from other species such as solar panel system (solar panel system mimics the way leaves harvest energy) is not available in the campus. Therefore, 34% voted it as unavailable.

Experience of Place and Space

Prospect and refuge

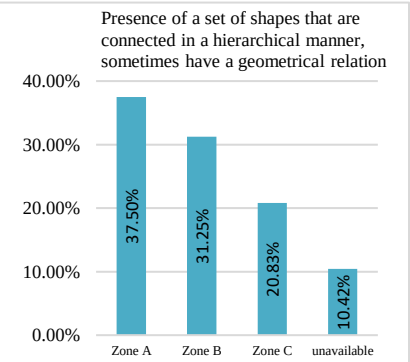
According to survey result, the refuge spaces is more available in zone B with 43% of votes, this might refer to using some private spaces as the openings in the library facade that provide a secured and protected shelters to the students with a plaza view, while the prospect spaces is available in the three zones as the following order, zone C 35% of votes, zone B 33%, and zone A 27%.





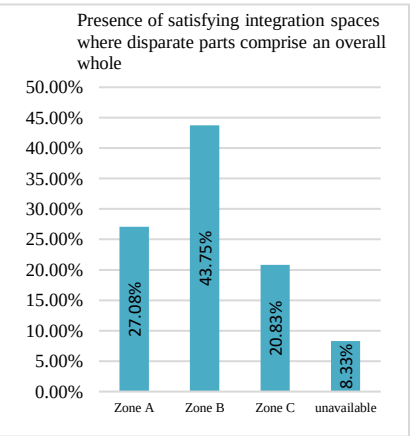
Organized complexity/ Natural geometry

The graph shows that the presence of a set of shapes that are connected in a hierarchal manner, and sometimes have a geometrical relation as golden ratio and Fibonacci Sequence, is clear in zone A with 38% of votes, and this because using a self-repeated square shape in the Administration Plaza.



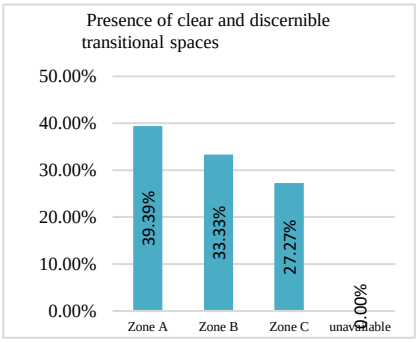
Integration of parts to wholes

According to survey result, the satisfying integration of parts to wholes is clear in zone B with 44% of votes, and this might refer to the clear and the understanding distribution of buildings design with the outdoor arears.



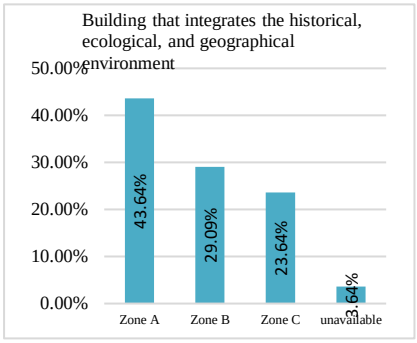
Transitional spaces/ Mobility and wayfinding

The clear transitional spaces are understandable in the three zones according to the following order of votes, zone A 39%, zone B 33%, and zone C 27%.



Cultural and ecological attachment to place

According to survey results, the cultural and ecological attachment to place is more obvious in zone A with 44% of votes, because of the using of a traditional Islamic city urbanism texture in design is clear in this zone more the rest.



According to the previous analysis and the survey results, the following Table 6-5 shows a matrix of a summary of the biophilic attributes in the three zones.

Table 6-5 A summary of the biophilic attributes in the three zones

	Attributes/ Zones		Zone A	Zone B	Zone C
1	Light	Direct Experience	●	●	●
2	Air		●	●	●
3	Water		●	●	●
4	Plants		●	●	●
5	Animals		●	●	●
6	Weather		●	●	●
7	Natural Landscape		●	●	●
8	Fire				
9	Images of Nature	Indirect Experience	●	●	
10	Natural Materials		●	●	●
11	Natural Colors		●		●
12	Simulating Nature Light and Air		●	●	
13	Naturalistic Shapes		●	●	●
14	Evoking Nature				
15	Information Richness		●	●	
16	Patina of Time				
17	Natural Geometry		●		
18	Biomimicry				
19	Prospect & Refuge	Place and Space	●	●	●
20	Organized Complexity		●	●	●
21	Integration of Parts/Whole		●	●	●
22	Transitional Spaces		●	●	●
23	Mobility & Wayfinding		●	●	●
24	Cultural & Ecological		●	●	●

The following chart in Figure 6-73 shows a summary of the survey results of the three experiences in the three zones/spaces A, B, and C. Based on the previous online questionnaire results, it is found that almost 33% of users feel the presence of the direct and the indirect experience of nature in zone A, and almost 36% of them feel the experience of place and space in zone A. For Zone B almost 29% of the direct experience of nature, 29% of the indirect experience of nature, and almost 35% of the experience of place and space. As for Zone C almost 29% of the direct experience of nature, 24% of the indirect experience of nature, and almost 25% of the experience of place and space.

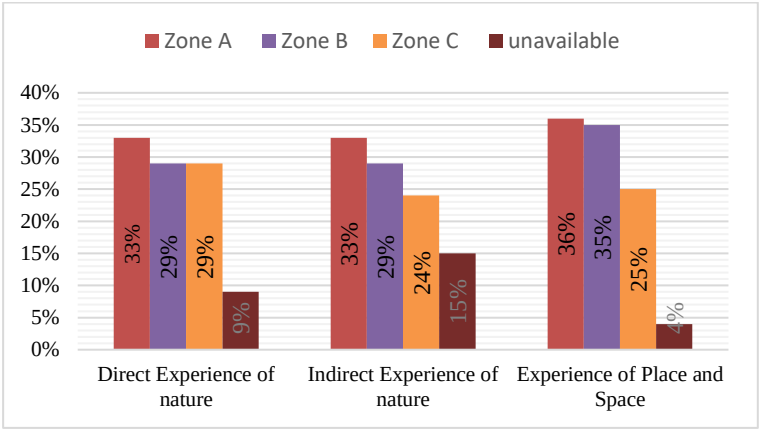


Figure 6-73 Schematic percentages of biophilic design experiences according to questionnaire results for zone A, B, & C (Source, Author)

The users' satisfaction and evaluation of spaces based on psychological, cognitive, and physiological performance is done and can be shown in Table 6-6, the table shows the RI value of some of the evaluation variables collected from various research (Youssef, 2017) and (Chen, 2017) focusing on the psychological, cognitive, and physiological performance of the campus based on the 5 bipolar Likert scale evaluation of users.

Table 6-6 RI Average results based on users' evaluation of the campus (Source, Author)

Performance Variables	Psychological Performance	Cognitive Performance	Physiological Performance	RI Value	
Mood and self-esteem	√			**0.41**	Good
Relationships	√			**0.39**	Good
Health			√	**0.44**	Good
Sleep quality			√	**0.54**	Neutral
Comfortable	√			**0.43**	Agree
Stressful	√	√	√	**0.65**	Disagree
Satisfying	√			**0.40**	Agree
Interesting		√		**0.33**	Strongly Agree
Safe		√		**0.30**	Strongly Agree
Relaxing	√	√		**0.44**	Agree
Increasing productivity		√		**0.42**	Agree
Increasing creativity		√		**0.43**	Agree
Increasing concentration		√		**0.41**	Good
Odors	√	√		**0.45**	Good
Air quality		√	√	**0.42**	Good
Thermal comfort		√	√	**0.55**	Neutral
View		√	√	**0.45**	Good
Natural and artificial lighting		√	√	**0.41**	Good
General Evaluation	√	√	√	**0.36**	Good

6.5 Discussion

In general, according to the design elements analysis and their strategies that applied in each zone in Table 6-2, Table 6-3, and Table 6-4; the first zone A has the following features that inspired from Islamic architecture: inner courtyards in all buildings with natural landscape elements, the mashrabiya in windows with different designs, lattice canopies in the narrow outdoor paths, wind towers in the Administration building, self-repeated square shapes in the Administration plaza, the archades and the ablaq in most of the elevations. The second zone B has the following features: inner courtyards in all school buildings with natural landscape elements, the mashrabiya in east and west windows, the archades and the ablaq in elevations. The last zone C has the following features: inner courtyards with natural landscape elements in

the student dorms, the shakhshikha in some interior spaces in the campus center, and the mashrabiya in some windows of the dorms, and a single wind catcher in sports center.

According to the previous matrix in Table 6-5, which based on the design analysis and guided with the survey results, it found that the design elements found in the study zone A almost fulfill all the biophilic design attributes, only four attributes are missing; fire, which related to the direct experience of nature, while evoking nature, patina of time, and biomimicry are related to the indirect experience. In zone B, the results found that it fulfills eighteen biophilic design attributes, seven attributes are missing; fire, which related to the direct experience of nature, while natural colors, evoking nature, patina of time, natural geometry, and biomimicry are related to the indirect experience. In zone C it fulfills sixteen biophilic design attributes, eight attributes are missing; fire, which related to the direct experience of nature, while images of nature, simulating nature light and air, evoking nature, information richness, patina of time, natural geometry, and biomimicry are related to the indirect experience.

Zone A, which design by CDC Abdelhalim Ibrahim (Community Design Collaborative), has the most various Islamic features in the campus, then zone B and C. and these findings match the user's evaluation of the attributes in the three zones in Figure 6-73. The psychological, physiological, and cognitive performance as can be shown in Table 6-6 showing the RI that indicate "good" based on the referenced Table 6-1.

These results when reviewed it was found that although Islamic features were found yet they were not all functioning properly, for instance the mashrabiya in windows are covered with glass and water sprinklers are not used in some outdoor spaces. For these reasons, the results rated only "good". The biophilic design attributes are found and can be felt to some extent by users in influenced Islamic architecture buildings although these biophilic features are not functioning as supposed to be. These biophilic features, if effectively used, can be applied to our modern built environment with greater intensity, because of their significant effect in reducing stress and enhance human well-being.

07

Chapter

Conclusion and Recommendation

7. Conclusion and Recommendations

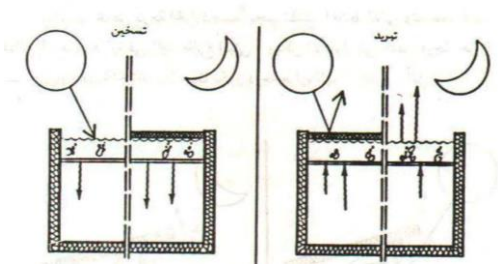
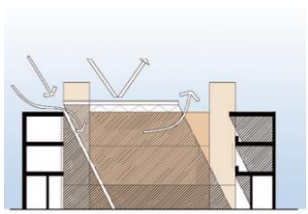
Restorative environment is essential in campuses learning spaces design due to the stress and mental fatigue that university students suffer from. Biophilic design and environmental design are important approaches for achieving a restorative learning space. Incorporating Biophilic design attributes in university settings have a positive cognitive response such as: improve productivity and mental health, enhance concentration and cognitive performance, and help to promote creativity. These features also improve the students' psychological response such as: reduce stress, enhance mood and self-steam, improve comfort, and promote satisfaction and relaxation; it also has a positive physiological response as; lower heart rate and cortisol (stress hormone), and balance the body's hormonal levels.

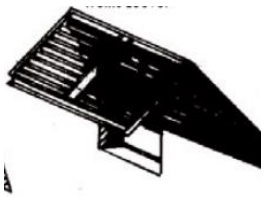
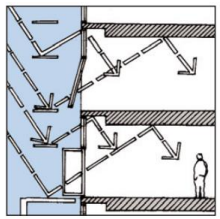
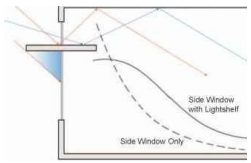
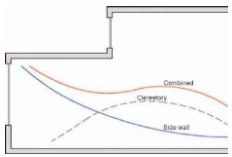
This research brings to light the importance of reviewing the history of architecture by using different lenses, and how the historical buildings can serve as an excellent example for applying biophilic design or mapping the architectural features of biophilia to assist designers today. In this thesis, the biophilic design attributes have been examined in Sultan Hassan complex as an example of madrasa building in Islamic architecture, and the findings reveals that the complex fulfill biophilic attributes. The architectural features in this complex respond positively to some indirect contact to nature attributes as natural colors and materials, and the information richness, while it successfully fulfills almost all the experience of space and place attributes. Although these features can not fulfill all the direct nature contact attributes, but it responds effectively to some attributes as light and air.

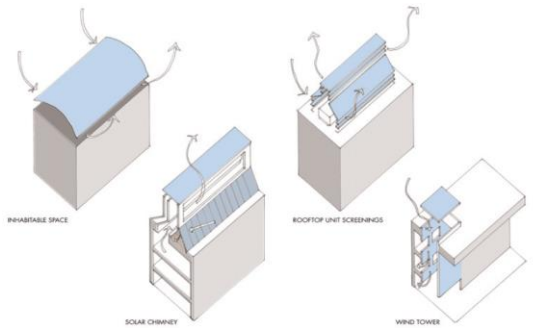
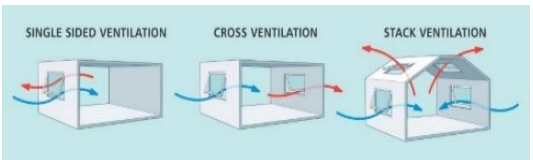
The purpose of this study has been to examine biophilic design attributes in learning spaces that use Islamic architecture characteristics and features. To address this, three modern learning spaces zones influenced by Islamic architecture using varying amounts of Islamic architecture features have been studied. It is suggested that to achieve biophilic qualities, more features and strategies influenced by Islamic architecture are to be added properly in new buildings, because from this study's results of schematic percentages showed only moderate values in terms of biophilic features and findings from the psychological, cognitive, and physiological performances rated only "good" evaluation.

The Table 7-1 shows some of the architectural features and its related biophilic design attributes that can be added in educational buildings design to improve biophilic design quality.

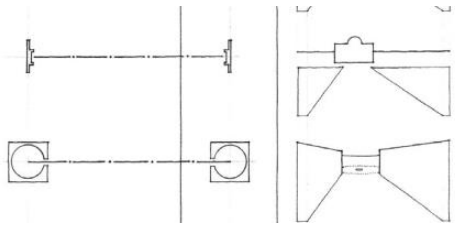
Table 7-1 Architectural features influenced by Islamic architecture help to fulfill biophilic design qualities in learning spaces (Source, Author)

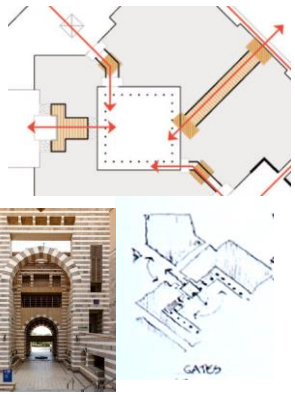
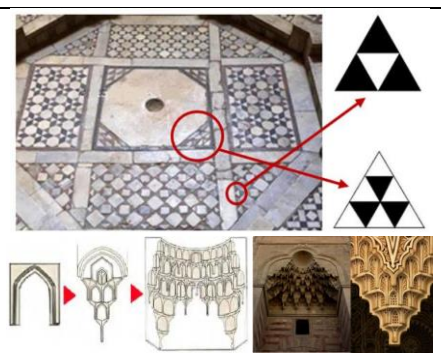
Architecture feature		Describe	Biophilic design attributes
Inner courtyards	  	Use inner courtyards with water elements and vegetation improve natural lighting and enhance natural ventilation and thermal comfort.	✓ Light ✓ Air ✓ Water ✓ Plants ✓ Weather ✓ Integration of parts to wholes ✓ Transitional spaces ✓ Mobility and wayfinding ✓ Cultural and ecological attachment to place

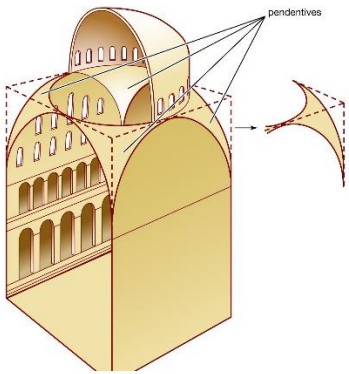
Lattice windows (the mashrabiya)	  	Use windows covered with a wooden lattice that inspired from the mashrabiya helps to cool indoor environment, create dynamic and sculptural forms of natural light, and provide privacy.	✓ Light ✓ Air ✓ Weather ✓ Organized complexity ✓ Refuge ✓ Cultural and ecological attachment to the place
The shakhshikha and clerestories	  	Roof openings or vertical windows located on high walls provide ventilation and spread the indirect daylight better into a space.	✓ Light ✓ Air ✓ Weather

Passive natural ventilation techniques	 	Use Passive natural ventilation techniques as cross ventilation, evaporative cooling, wind catchers, and solar chimneys to improve the thermal comfort in the spaces.	✓ Air ✓ Weather
Water elements		Use water elements as fountain or water sprinkles in the interior and exterior landscape.	✓ Water

Outdoor gardens	 	Use outdoor gardens and landscape specially geometric gardens with clear and strong axies and pathes.	✓ Light ✓ Air ✓ Water ✓ Plants ✓ Weather ✓ Animals ✓ Natural landscapes and ecosystems ✓ Natural colors ✓ Information richness ✓ Organized complexity ✓ Cultural and ecological attachment to place ✓
Natural and vernacular materials	Use natural and local materials as wood and stones in the indoor and outdoor spaces.		✓ Natural materials ✓ Natural colors ✓ Age change and the patina of time ✓ Cultural and ecological attachment to the place

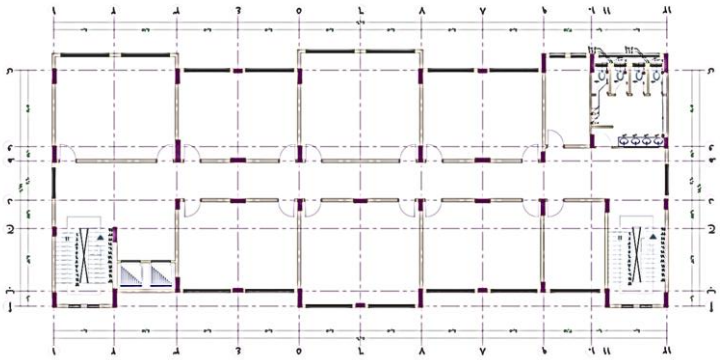
Symmetry and clear axes	 	Use central axes, symmetry and balance design, and focal points.	✓ Information richness ✓ Organized complexity ✓ Mobility and wayfinding ✓ Integration of parts to wholes

Clear transitional spaces		Use direct and indirect transitional spaces between the exterior and interior space follow one another, as courtyards, colonnades, porches, gates, and more.	✓ Information richness ✓ Organized complexity ✓ Mobility and wayfinding ✓ Integration of parts to wholes
Fractals		Use self-repeated shapes in interior or exterior design with a constant ratio between the repeated shapes.	✓ Natural geometries

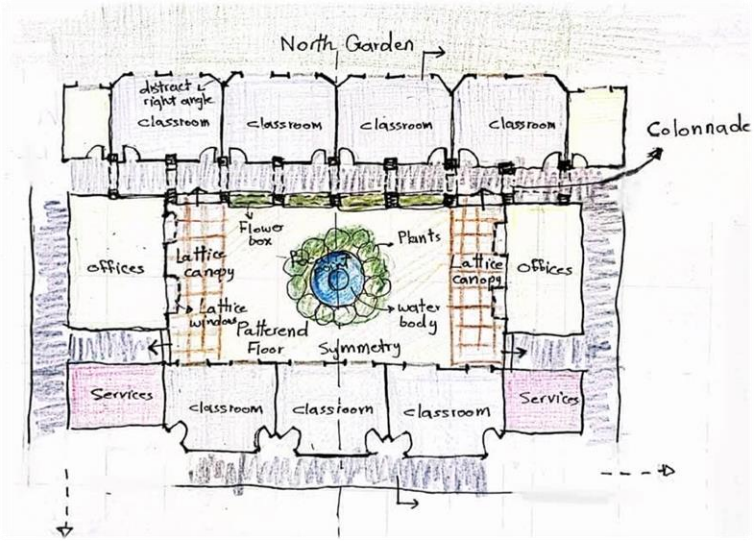
Domes and vaults		Use domes, arches, and vaults to cover the roof in some spaces.	✓ Naturalistic shapes and forms ✓ Cultural and ecological attachment to the place
Colonnade and arches		Use colonnade in pathes and around courtyards.	✓ Naturalistic shapes and forms

Lattice canopies		Use wooden lattice canopy for pergolas and pathes.	✓ Light ✓ Air ✓ Weather ✓ Information richness ✓ Organized complexity ✓ Transitional spaces ✓ Cultural and ecological attachment to place

The following architectural plan represent a ballot sample of an educational building floor in an Egyptian campus contains seven classrooms and many offices.



The following sketch represent a design proposal with the same spaces after appllying the previous architectural features to enhance biophilic experience. The prototype able to horizontal and verticale extension and repetition (taking into consideratio the environmental factors as lighting).



Plan

Section

From a broad perspective, biophilic design reducing stress, and enhancing both human comfort and well-being is vital in the built-environment design. Thus, this new approach in design needs to be examined thoroughly on several types of buildings as residential buildings. It is important to understand biophilic attributes, strategies, and elements well to apply them in architectural design. Future studies can be done to test the impact of biophilic design attributes on each of the users' psychological, physiological, and cognitive experiences. Moreover, further studies and analysis are needed to investigate the embodied qualities of biophilic design in historic buildings, which can be used as a reference to apply the biophilic design features in today’s architecture.

References

References

Abdelaal, M.S. and Soebarto, V. (2018), "History matters: The origins of biophilic design of innovative learning spaces in traditional architecture", *Archnet-IJAR*, Vol. 12 No. 3, pp. 108–127.

Abdelkader, R. and Park, J. (2018), "Spatial Principles of Traditional Cairene Courtyard Houses in Cairo", *Journal of Asian Architecture and Building Engineering*, Vol. 17 No. 2, pp. 245–252.

AbdelMeguid, S.M. (2014), *Biophilic Design (Strategies for Hospitals Retrofit)*, Master thesis, Ain Shams University and University of Stuttgart.

Abdelsalam, M. and Ibrahim, M. (2019), "Fractal dimension of islamic architecture: The case of the mameluke madrasas: Al-Sultan Hassan Madrasa", *Gazi University Journal of Science*, Vol. 32 No. 1, pp. 27–37.

Adel, K. and Kamal, M. (2010), "Sultan Hassan Mosque : an Islamic Architectural Wonder", *Journal of Islamic Architecture*, Vol. 1 No. 2, pp. 94–105.

Al-Harithy, H. (2007), "The Four Madrasahs in the Complex of Sultan Ḥasan (1356–61): The Complete Survey", *The Middle East Documentation Center (MEDOC). The University of Chicago*, Vol. 11 No. 2, pp. 49–76.

Al-Rhodesly, A., Al-Hagla, K.S., Farghaly, T. and El-Gamal, M. (2018), "Revisiting the Alhambra architecture: Biophilic Design approach", *Proceedings of the 6th International Conference on Heritage and Sustainable Development Volume 1*, eug green lines instituite, Granada, Spain, pp. 373–386.

Al-Zubaidi, M.S.S. (2007), *The Sustainability Potential of Traditional Architecture in the Arab World- With Reference to Domestic Buildings in the UAE*, Doctoral thesis, University of Huddersfield.

Alamy.com. (2019), "Traditional Mexican architecture in the municipalities of Mexico.", available at: https://www.alamy.com/traditional-mexican-architecture-in-the-municipalities-of-mexico-image246919558.html (accessed 20 May 2020).

Alencar, T.A. (2013), *Biophilic Design Framework (Structuring the Relationship between Exposure to Nature and Health Benefits)*, Master thesis, The University of British Columbia.

alhambra.org/. (n.d.). "ALHAMBRA GRANADA GUIDED TOURS", available at: https://www.alhambra.org/en/alhambra-tours.html (accessed 21 May 2020).

Ali, A., Utaberta, N., Surat, M. and Qays Oleiwi, M. (2015), "Green Architecture and Islamic Architecture: The Islamic Arabic City and the Traditional Islamic House", *Applied Mechanics and Materials*, Vol. 747, pp. 24–27.

Ali, M. (2013), *Methodologies in Architectural Research*, First Edit., IIUM Press (International Islamic University Malaysia).

"allyinspirit.tumblr.com". (2014), , available at:

https://allyinspirit.tumblr.com/post/106353148054/gazania-or-treasure-flower-symbol-of-good (accessed 5 November 2022).

Almrsal.com. (2019), "الشخشيخة في العمارة الإسلامية", available at: https://www.almrsal.com/post/838885 (accessed 11 March 2022).

Alvarsson, J.J., Wiens, S. and Nilsson, M.E. (2010), "Stress Recovery During Exposure to Nature Sound and Environmental Noise", *International Journal of Environmental Research and Public Health*, Vol. 7 No. 3, pp. 1036–1046.

Amirul, N.J., Nidzam, C., Ahmad, C., Yahya, A., Faizal, M., Abdullah, N.L., Adnan, M., *et al.* (2013), "The Physical Classroom Learning Environment", *2nd International Higher Education Teaching and Learning Conference 2013*, Sultan Idris Education University, Tanjong Malim, Malaysia.

arch.egy. (2016), "الجامعة الأمريكية بالقاهرة", available at: https://www.facebook.com/arch.egy/posts/3100986163494372 (accessed 15 February 2020).

ARCHIAM (Architectural and Urban Forms of the Islamic World). (2018), "Lecture 4: Mosques and Madrasas in the Islamic World.", Part four of 10 presentations developed for the Aga Khan Trust for Culture Education Programme, University of Liverpool, UK.

Arias-Maldonado, M. (2015), *Environment and Society (Socionatural Relations in the Anthropocene)*, Springer, Switzerland.

Arjmand, R., Mirsafa, M. and Talebi, Z. (2018), "Islamic Educational Spaces: Architecture of Madrasah and Muslim Educational Institutions", *International Handbooks of Religion and Education 7*, Springer, pp. 469–510.

ASHRAE 55. (2004), "Thermal Environmental Conditions for Human Occupancy (Supersedes ANSI/ASHRAE Standard 55 (1992))", American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, Atlanta, GA.

aucegypt.edu. (1987), "Madrasa of Sultan Hasan", *Saleh Lamei Collection; Regional Architecture Center; Rare Books and Special Collections Library; the American University in Cairo*, available at: https://digitalcollections.aucegypt.edu/digital/collection/p15795coll35/id/105/rec/69 (accessed 12 May 2020).

aucegypt.edu. (n.d.). "New Cairo Campus", *The American University in Cairo*, available at: https://www.aucegypt.edu/about/visitor-information/new-cairo-campus (accessed 15 February 2020a).

aucegypt.edu. (n.d.). "Architects", *The American University in Cairo*, available at: https://www.aucegypt.edu/about/visitor-information/new-cairo-campus/architects (accessed 15 May 2020b).

aucegypt.edu. (n.d.). "AUC New Cairo Campus Facts and Figures", *The American University in Cairo*, available at: https://www.aucegypt.edu/about/visitor-information/new-cairo-campus/facts-and-figures (accessed 20 May 2020c).

aucegypt.edu. (n.d.). "AUC Campus Tree Walk", *The American University in Cairo*,

available at: https://documents.aucegypt.edu/docs/Sustainability_Rise/Tree Walk Guide_Final_19.11.2012.pdf (accessed 25 May 2020d).

Bannister, D. (2017), "Guidelines on exploring and adapting (Learning Spaces in Schools)", European Schoolnet (EUN Partnership AISBL), UK.

Van den Berg, A.E., Jorgensen, A. and Wilson, E.R. (2014), "Evaluating restoration in urban green spaces (Does setting type make a difference?)", *Landscape and Urban Planning*, Elsevier B.V., Vol. 127, pp. 173–181.

van den Berg, A.E., Koole, S.L. and van der Wulp, N.Y. (2003), "Environmental preference and restoration: (How) are they related?", *Journal of Environmental Psychology*, Vol. 23, pp. 135–146.

Van Den Bogerd, N., Coosje Dijkstra, S., Seidell, J.C. and Maas, J. (2018), "Greenery in the university environment (Students' preferences and perceived restoration likelihood)", *PLoS ONE*, Vol. 13 No. 2, pp. 1–19.

Van Den Bogerd, N., Dijkstra, S.C., Tanja-Dijkstra, K., de Boer, M.R., Seidell, J.C., Koole, S.L. and Maas, J. (2020), "Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality", *Building and Environment*, Elsevier Ltd, Vol. 171, available at:https://doi.org/10.1016/j.buildenv.2020.106675.

Bowman, C.L. (2019), *The Biophilic Classroom (The Benefits of Nature in a Learning Environment)*, *CIBSE Carbon Conssultants Low IES*, England.

Browning, W., Ryan, C. and Clancy, J. (2014), *14 Patterns of Biophilic Design*, *Terrapin Bright Green,LLC*, New York.

cairo.gov.eg. (2018), "Al-Suhaimi House", *The Ministry of Planning*, available at: http://www.cairo.gov.eg/ar/Bank of Ideas/Pages/houses_palaces_of_culture.aspx?ID=6 (accessed 17 May 2022).

"carvedstonecreations.com". (n.d.). , available at: https://carvedstonecreations.com/large-water-fountains-to-make-your-commercial-office-or-brand-stand-out/ (accessed 2 November 2022).

CDC AbdelHalim-Community Design Collaborative. (2016), *Narratives of The Built and Unbuilt of AUC New Campus (Photography Competition of AUC New Campus)*, Cairo, Egypt.

CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates. (2000a), *Executive Summary (The American University in Cairo)*, Watertown, Massachusetts, USA and Cairo, Egypt.

CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates. (2000b), *The American University in Cairo Design Principles*, Watertown, Massachusetts, USA and Cairo, Egypt.

CDC AbdelHalim-Community Design Collaborative and INC Sasaki-Associates. (2002), *Schematic Design Report-Update to the Basis of Design (The American University in Cairo)*, Watertown, Massachusetts, USA and Cairo, Egypt.

Çebi, A.İ. (2007), *Preference for Environmental Attributes for Different Setting Types*, Master thesis, Blkent University.

Chan, W.H., Lu, M. and Zhang, J.P. (2006), "Attaining cost efficiency in constructing sports facilities for Beijing 2008 Olympic Games by use of operations simulation", *Proceedings - Winter Simulation Conference*, IEEE, pp. 2063–2070.

Chen, Y. (2017), *The Impact of Biophilic Design on Health and Wellbeing of Residents Through Raising Environmtal Awarness and Nature Connectedness*, Master thesis, The University of Georgia.

Ching, F.D.K. (2007), *Architecture Form, Space, and Order*, Third Edit., John Wiley & Sons, Inc.

Denissen, J.J.A., Butalid, L., Penke, L. and van Aken, M.A.G. (2008), "The Effects of Weather on Daily Mood: A Multilevel Approach", *Emotion*, American Psychological Association, Vol. 8 No. 5, pp. 662–667.

earth.google.com. (2015), "The American University in Cairo", *Google Earth Online*, available at: https://earth.google.com/web/search/AUC,+Road‹+New+Cairo+1/@30.0192905,31.50140394,323.33390762a,761.98800814d,35y,133.3639235h,0.11341319t,-0r/data=CigiJgokCcS5EpajwjRAEcW5EpajwjTAGUwPEm0PjzVAIfhnyHmRPlTA (accessed 21 May 2020).

Earthman, G.I. (1998), "The Impact of School Building Condition and student Achievement, and Behavior", *The European Investment Bank/Organization for Economic Coordination and Development International Conference*, Luxembourg.

Eilouti, B.H. and Al-Jokhadar, A.M. (2007), "A Generative System for Mamluk Madrasa Form-Making", *Nexus Network Journal*, Vol. 9 No. 1, pp. 7–30.

El-Darwish, I.I. and El-Gendy, R.A. (2016), "The Role of Fenestration in Promoting Daylight Performance (The mosques of Alexandria since the 19th century)", *Alexandria Engineering Journal*, Faculty of Engineering, Alexandria University, Vol. 55 No. 4, pp. 3185–3193.

El-kady, S.M. lotfy A.E. (1998), *Islamic Architecture in Egypt (Theory and Practice)*, Doctoral thesis, Assiut University.

El-Shorbagy, A. (2010), "Traditional Islamic-Arab House: Vocabulary And Syntax.", *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, Vol. 10 No. 4, pp. 15–20.

ElSorady, D.A. and Rizk, S.M. (2020), "LEED v4.1 Operations and Maintenance for Existing Buildings and Compliance Assessment (Bayt Al-Suhaymi, Historic Cairo)", *Alexandria Engineering Journal*, Faculty of Engineering, Alexandria University, Vol. 59 No. 1, pp. 519–531.

Elwan, M.M. (2020), "The Role of Traditional Lattice Window 'Mashrabiya' in Delivering Single-sided Ventilation-A CFD Study", *International Journal of*

Engineering Trends and Technology (IJETT), Vol. 68 No. 9, pp. 154–161.

Embi, M.R. and Abdullahi, Y. (2012), "Evolution of Islamic Geometrical Patterns", *Global Journal Al-Thaqafah (GJAT)*, Vol. 2 No. 2, pp. 27–39.

en.wikipedia.org. (2005), "Mosque-Madrasa of Sultan Hassan", available at: https://en.wikipedia.org/wiki/Mosque-Madrasa_of_Sultan_Hassan#/media/File:Sultan_Hasan_Bismillah.JPG (accessed 13 May 2020).

"envirodatagov.org". (2022), , available at: https://envirodatagov.org/the-environmental-historians-action-collaborative-co-organizes-conference-on-the-climate-crisis/ (accessed 2 November 2022).

Farley, K. and Veitch, J.A. (2001), *A Room with a View : A Review of the Effects of Windows on Work and Well- Being*, Institute for Research in Construction, National Research Council, Canada, available at:https://doi.org/10.4224/20378971.

Feisal, Z., El, A. and Momtaz, R.I. (2010), "Sustainability in Architecture Between The Past and The Future", *International Conference on Urban and Green Architecture*, The Indian Institute of Architecture.

Felsten, G. (2009), "Where to Take a Study Break on The College Campus (An Attention Restoration Theory Perspective)", *Journal of Environmental Psychology*, Elsevier Ltd, Vol. 29 No. 1, pp. 160–167.

"fibonacci.com". (n.d.). , available at: https://fibonacci.com/art-architecture/ (accessed 5 November 2022).

flickr.com. (2015), "AUC garden", available at: https://www.flickr.com/photos/varghad/16644556162/in/photolist-rmPGEf-rWLC2A-rWLA8A-nHUBx7-kU54KZ-rnkfgD-qY2qne-tDT7nb-rAmsrk-rttkP1-rstxQf-eELX9x-rFyymX-tEi1MV-rDnnN1-qKQ53r-rR2BDr-rFyFGi-wAheWA-5iketF-tkPbEP-rew8Jg-ow8SST-x6xZLg-tDoixD-xnzCna-tAv8Ks-xHb (accessed 21 May 2020).

fluor.com. (n.d.). "American University In Cairo Project and Construction Management", *Fluor Corporation (NYSE:FLR)*, available at: https://www.fluor.com/projects/cairo-egypt-university-project-management (accessed 25 May 2020).

Fromm, E. (1974), *The Anatomy of Human Destructiveness.*, *Library of Congress Cataloging*, Holt, Rinehart and Winston, New York, available at:https://doi.org/10.2307/2063568.

Ghasemzadeh, B., Fathebaghalli, A. and Tarvirdinassab, A. (2013), "Symbols and Signs in Islamic Architecture", *European Review of Artistic Studies (ERAS)*, Vol. 4 No. 3, pp. 62–78.

"gofiguremath.org". (2013), , available at: https://gofiguremath.org/natures-favorite-math/the-golden-ratio/the-golden-angle/ (accessed 5 November 2022).

Haider, G. and Moussa, M. (2015), "Explicit and Implicit Geometric Orders in Mamluk

Floors (Secrets of the Sultan Hassan Floor in Cairo)", in Ostwald, M.J. and Williams, K. (Eds.), *Architecture and Mathematics from Antiquity to the Future: Volume I: Antiquity to the 1500s*, Birkhäuser, pp. 483–496.

Hampton, W.R. (1989), "Daylighting Strategies: Skylighting in Hot Dry Climates", *The Arid Lands Newsletter*, Vol. 28.

Hartig, T., Bringslimark, T. and Patil, G. (2008), "Restorative Environmental Design: What, When, Where, and for Whome?", in Kellert, S.R., Heerwagen, J. and L.Mador, M. (Eds.), *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*, John Wiley & Sons, Inc, United States of America, pp. 133–149.

Hartig, T., Mitchell, R., De Vries, S. and Frumkin, H. (2014), "Nature and Health", *Annual Review of Public Health*, Vol. 35, pp. 207–228.

Hartig, T. and Staats, H. (2007), "Linking Preference For Environments With Their Restorative Quality", *From Landscape Research to Landscape Planning*, Springer International Publishing, Netherlands, pp. 279–292.

Hassan, A.M., Lee, H. and Yoo, U.S. (2016), "From Medieval Cairo to Modern Masdar City (Lessons Learned Through a Comparative Study)", *Architectural Science Review*, Vol. 59 No. 1, pp. 39–52.

Heerwagen, J. (2017), "Psychosocial Value of Space", *WBDG (Whole Building Design Guide)*, available at: https://www.wbdg.org/resources/psychosocial-value-space (accessed 4 April 2022).

Heerwagen, J. and Hase, B. (2001), "Building Biophilia: Connecting People to Nature in Building Design", available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.454.4959&rep=rep1&type=pdf.

Hibbs, B.J. and Rostain, A.L. (2019), *The Stressed Years of Their Lives : Helping Your Kids Survive and Thrive During Their Collage Years*, St. Martin's Press, New York, USA.

Hmood, K.F. (2018), "Unity and Diversity in Geometric Gardens", in Almusaed, A. (Ed.), *Landscape Architecture (The Sense of Places, Models and Applications)*, Intechopen, pp. 25–44.

Holt, E.W., Lombard, Q.K., Best, N., Smiley-Smith, S. and Quinn, J.E. (2019), "Active and Passive Use of Green Space, Health, and Well-Being Amongst University Students", *International Journal of Environmental Research and Public Health*, Vol. 16 No. 3, available at:https://doi.org/10.3390/ijerph16030424.

Jaber, L. and Wieben, P. (2008), *AUC Today Fall 2008*, *The American University in Cairo*, New York, USA and Cairo, Egypt.

Jamaludin, N.M., Mahyuddin, N. and Akashah, F.W. (2016), "Assessment of Indoor Environmental Quality (IEQ): Students Well-Being in University Classroom with the Application of Landscaping", *MATEC Web of Conferences*, Vol. 66 No. 61, available at:https://doi.org/10.1051/matecconf/20166600061.

Joye, Y. (2007), "Architectural Lessons From Environmental Psychology (The Case of Biophilic Architecture)", *Review of General Psychology*, Vol. 11 No. 4, pp. 305–328.

Kaplan, R., Kaplan, S. and Brown, T. (1989), "Environmental Preference: A Comparison of Four Domains of Predictors", *Environment and Behavior*, Vol. 21 No. 5, pp. 509–530.

Kaplan, S. (1987), "Aesthetics, Affect, and Cognition (Environmental Preference from an Evolutionary Perspective)", *Environment and Behavior*, Vol. 19 No. 1, pp. 3–32.

Kazemi, E. and Mohebbi, L. (2014), "The Role of Islamic Architecture in Promoting the Quality of Life", *European Online Journal of Natural and Social Sciences*, Vol. 3 No. 4, pp. 554–565.

Kellert, S.R. (2005), *Building for Life: Designing and Understanding The Human-Nature Connection*, Island Press, Washington, DC.

Kellert, S.R. (2008), "Dimensions, Elements, and Attributes of Biophilic Design", in Kellert, S.R., Heerwagen, J. and L.Mador, M. (Eds.), *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*, John Wiley & Sons, Inc, United States of America, pp. 3–19.

Kellert, S.R. and Calabrese, E.F. (2015), "The Practice of Biophilic Design", *Www.Biophilic-Design.Com*, available at:https://doi.org/10.1063/1.1387590.

Kellert, S.R., Mcvay, S. and Katcher, A. (1993), *The Biophilia Hypothesis*, Island Press, Washington, D.C.

Khalil, M. (2009), "Archive for the 'Birds On Campus' Category", *Neuron, The American University in Cairo*, Vol. 7 No. 1, available at: https://bioclub.wordpress.com/category/birds-on-campus/.

Khalil, S.A., Sheta, S.A. and Tarabieh, K.A. (2019), "Integrated Strategy to Promote Pro Environmental Behavior in University Campuses Case Study of American University in Cairo New Campus", *Mansoura Engineering Journal, (MEJ)*, Vol. 44 No. 1, pp. 24–33.

Knoerzer, L. (n.d.). "What is Circadian Lighting?", available at: https://www.thelightingpractice.com/what-is-circadian-lighting/ (accessed 2 November 2022).

legorreta.mx. (n.d.). "AMERICAN UNIVERSITY IN CAIRO CAMPUS CENTER", *Legorreta, Mexico City*, available at: https://www.legorreta.mx/es/proyecto-universidad-americana-en-el-cairo-campus-center (accessed 20 May 2020).

Leong, L.Y.C., Fischer, R. and McClure, J. (2014), "Are nature lovers more innovative? The relationship between connectedness with nature and cognitive styles", *Journal of Environmental Psychology*, Elsevier Ltd, Vol. 40, pp. 57–63.

Luchetti, R. and Ashraf Salloum. (2004), *The Planning and Design of Learning Environments for the New American University in Cairo*.

Mahmoud, F.M. (2016), "The Aesthetical Aspects for Monumentality of Mamluk Architecture : Reasons and Analysis. (Sultan Hassan Complex in Cairo)", *Architecture, Arts Magazine*, Vol. 4, pp. 1–11.

Maulan, S. and Miller, P. a. (2006), "Landscape Preference and Human Well-Being", *International Journal of Sustainable Tropical Design Research and Practice*, Vol. 1 No. 1, pp. 25–32.

Mcfarland, A.L., Waliczek, T.M. and Zajicek, J.M. (2008), "The Relationship Between Student Use of Campus Green Spaces and Perceptions of Quality of Life", *HortTechnology*, Vol. 18 No. 2, pp. 232–238.

Mezzine, M. (2022), "Qarawiyyin Mosque in Discover Islamic Art", *Museum with No Frontiers*, available at: https://islamicart.museumwnf.org/database_item.php?id=monument;ISL;ma;Mon01;1;en (accessed 11 March 2022).

Mifflin, H.H. (2005), "The New Dictionary of Cultural Literacy", *Houghton Mifflin Harcourt Publishing Company*, available at: https://www.dictionary.com/browse/islam (accessed 12 May 2021).

Modi, K. and Parmar, S. (2020), "Understanding Biophilia and Its Integration with Architecture", *International Journal of Scientific & Engineering Research*, Vol. 11 No. 5, available at: ISSN 2229-5518.

Mossad, G., Ezzat, H. and Talaat, N. (2016), "Natural Ventilation in Old Islamic Houses The Study of Courtyard in old Cairo (Case Study: Zeinb Khatoun House)", *Journal of Al-Azhar University Engineering Sector (JAUES)*, Vol. 11 No. 39, pp. 601–615.

Moustafa, W.S., Hegazy, I.R. and Eldabosy, M.M. (2018), "Roof Geometry As a Factor of Thermal Behavior : Simulation Based Study of Using Vaults and Domes in The Middle East Zone", *International Journal of Low-Carbon Technologies*, Vol. 13 No. 3, pp. 204–211.

Movahed, K. (2015), "Study People and Nature Connection in Built Environment to Verify Aqa-Bozorg Mosque as Biophilic Design", *Urban Managment*, Vol. 40, pp. 241–252.

Muñoz Cantero, J.M., García Mira, R. and López-Chao, V. (2016), "Influence of Physical Learning Environment in Student's Behavior and Social Relations", *Anthropologist*, Vol. 25 No. 3, pp. 249–253.

Nahedh Al-Qemaqchi. (2013), "Sustainable Architecture Through Islamic Perspective (A Case Study in Old Mosul Residence Area)", *Middle East Conference on Sustainability and Human Development*, Abu Dhabi.

"nature-explorations.com". (2019), , available at: https://nature-explorations.com/070809_1215-web/ (accessed 5 November 2022).

Naz, K. and Epps, H. (2004), "Relationship between color and emotion: a study of college students", *College Student J*, Vol. 38 No. 3, pp. 396–405.

Nazel, T. (2009), "Deterioration of The Floor of Interior Courtyard of Sultan Hassan

Mosque in Cairo, Egypt", *Mediterranean Archaeology and Archaeometry*, Vol. 9 No. 1, pp. 115–122.

Norazman, N., Ani, A.I.C., Ja'afar, N.H. and Khoiry, M.A. (2018), "Indoor Air Quality (IAQ): Accuracy of Natural Ventilation for Temperature, Air Flow Rate and Relative Humidity (RH) in School Building Classrooms", *International Journal of Engineering and Technology (UAE)*, Vol. 7 No. 3, pp. 42–45.

Northeast Energy Efficiency Parterships Inc. (2002), *Lighting for Classrooms: Combining Quality Design and Energy Efficiency*, available at: https://www.lightingassociates.org/i/u/2127806/f/tech_sheets/Classroom_Lighting_Guide.pdf.

Nu'Man, S. (2016), "A Unified Architectural Theory for Islamic Architecture", *Archnet-IJAR*, Vol. 10 No. 3, pp. 100–112.

"officesnapshots.com". (2013), , available at: https://officesnapshots.com/2013/11/19/random-studios-homelike-amsterdam-offices/ (accessed 2 November 2022).

Omer, S. (2010), "A Conceptual Framework for Sustainability in Islamic Architecture: The significance of the Islamic concepts of man and the environment.", *Inernational Conference on Technology & Sustainability in the Built Environment*, Riyadh, Suadi Arabia, pp. 486–497.

Perera, A.S. and Coppens, M.O. (2019), "Re-designing materials for biomedical applications: From biomimicry to nature-inspired chemical engineering", *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, Vol. 377, pp. 1–11.

Peters, T. and D'Penna, K. (2020), "Biophilic Design for Restorative Uuniversity Learning Environments: A Critical Review of Literature and Design Recommendations", *Sustainability*, Vol. 12 No. 17, p. 7064.

"pixabay.com". (2016), , available at: https://pixabay.com/photos/fireplace-fire-home-interior-warm-1464166/ (accessed 2 November 2022).

"pixabay.com". (2021), , available at: https://pixabay.com/photos/forest-trees-sunlight-dark-forests-6364913/ (accessed 2 November 2022).

"pixnio.com". (2017), , available at: https://pixnio.com/nature-landscapes/forest/wood-tree-nature-root-oak-leaf-landscape-environment#img_info (accessed 2 November 2022).

Qingjiu, S. and Maliki, N.Z. (2013), "Place Attachment and Place Identity: Undergraduate Students' Place Bonding on Campus", *Procedia - Social and Behavioral Sciences*, Elsevier B.V., Vol. 91, pp. 632–639.

Rabbat, N. (2012), "What is Islamic Architecture anyway?", *Journal of Art Historiography*, Vol. 6, pp. 1–15.

Ragab, A. (2015), "Reclaiming the Past : The (New) Bimāristāns of Egypt", *The Medieval Islamic Hospital Medicine, Religion, and Charity*, Cambridge University Press, pp. 76–105.

Ramzy, N.S. (2015a), "Biophilic Qualities of Historical Architecture: In Quest of The Timeless Terminologies of 'Life' in Architectural Expression", *Sustainable Cities and Society*, Vol. 15, pp. 42–56.

Ramzy, N.S. (2015b), "Sustainable Spaces With Psychological Connotation: Historical Architecture As Reference Book for Biomimetic Models with Biophilic Qualities", *Archnet-IJAR*, Vol. 9 No. 2, pp. 248–267.

"rare-gallery.com". (n.d.). , available at: https://rare-gallery.com/458685-nature-landscape-flowers-trees-forest-plants-clouds.html (accessed 2 November 2022).

Rashid, M. (2020), *Islamic Architecture : An Architecture of the Ephemeral*, USA, available at: http://hdl.handle.net/1808/30156.

Rea, M.S. (2000), *The IESNA Lighting Handbook (Reference & Application)*, Ninth Edit., Illuminating Engineering Society of North America (IESNA), New York.

"refurbandrestore.co.uk". (n.d.). , available at: https://refurbandrestore.co.uk/circadian-rhythm-sleep-and-smart-home-technology (accessed 2 November 2022).

Ridoutt, B.G., Ball, R.D. and Killerby, S.K. (2002), "Wood in The Interior Office Environment: Effects on Interpersonal Perception", *Forest Products Journal*, Vol. 52 No. 9, pp. 23–30.

Roetzel, A., DeKay, M., Nakai Kidd, A., Klas, A., Sadick, A.M., Whittem, V. and Zinkiewicz, L. (2020), "Architectural, indoor environmental, personal and cultural influences on students' selection of a preferred place to study", *Architectural Science Review*, Vol. 63 No. 3–4, pp. 275–291.

Ruck, N., Aschehoug, Ø. and Aydinli, S. (2000), *Daylight in Buildings (A Source Book on Daylighting Systems and Components)*.

Ryan, C.O., Browning, W.D., Clancy, J.O., Andrews, S.L. and Kallianpurkar, N.B. (2014), "Biophilic Design Patterns: Emerging Nature-Based Parameters for Health and Well-Being in The Built Environment", *Archnet-IJAR*, Vol. 8 No. 2, pp. 62–76.

Salama, H.M. (2019), "The role of Sacred Geometry in forming Islamic art", *مجلة العمارة والفنون*, Vol. 14, pp. 13–35.

Salingaros, N.A. (2012), "Fractal Art and Architecture Reduce Physiological Stress", *Journal of Biourbanism*, Vol. 2, pp. 11–28.

Samani, S.A. (2011), "The Influence of Light on Student's Learning Performance in Learning Environments: A Knowledge Internalization Perspective", *Journal of World Academy of Science, Engineering and Technology*, Vol. 81, pp. 540–547.

Seixas, C.T., Merhy, E.E., Baduy, R.S. and Slomp Junior, H. (2016), "Integrality in the health care perspective: an experience of the Unified Health System in Brazil", *Salud Colectiva (English Edition)*, Vol. 12 No. 1, pp. 113–123.

Shi, S., Man, Y., Wang, Z., Wang, L. and Zhang, X. (2017), "On Site Measurement and Analysis on Indoor Air Environment of Classroom in University Campus", *Procedia Engineering*, Elsevier B.V., Vol. 205, pp. 2200–2207.

"slideplayer.com". (2018), , available at: https://slideplayer.com/slide/14148670/ (accessed 5 November 2022).

slideserve.com. (2014), "تاريخ العمارة الاسلامية", available at: https://www.slideserve.com/zia/4351151 (accessed 5 February 2020).

slideshare.net. (2016), "Architecture of Islamic Cairo", available at: https://www.slideshare.net/NedaaMahboub/architecture-of-islamic-cairo (accessed 17 May 2021).

Smith, L.E. (2013), *Attention Restoration Theory and the Open Office: Addressing Mental Fatigue in Low-Stimulus Screeners and Creative-Class Workers through Biophilic Design*, Master thesis, Savannah College of Art and Design.

Soderlund, J.C. (2015), *Biophilic Design: A Social Movement Journey*, Doctoral thesis, Curtin University.

spainthenandnow.com. (2009), "Inside the Great Mosque of Córdoba, Spain.", available at: https://www.spainthenandnow.com/spanish-architecture/inside-the-great-mosque-of-cordoba-spain (accessed 15 February 2020).

Stanke, S. (Dehlinger). (2014), *Connecting to Nature in Interior Dementia Care Environments*, Master thesis, Minneapolis College of Art and Design Spring.

"stock.adobe.com". (n.d.). , available at: https://stock.adobe.com/images/fire-in-the-woods-fire-burning-in-the-dusk-at-a-campsite-near-a-river-in-beautiful-nature-with-the-evening-woods-in-the-background-beautiful-firewood-in-the-evening-in-the-forest/506799380?as_campaign=ftmigration2&as_channel (accessed 2 November 2022).

Tabbaa, Y. and Hillenbrand, R. (1997), *Islamic Architecture: Form, Function and Meaning*, *Journal of the American Oriental Society*, Vol. 117, Library of Congress Cataloging-in-Publication Data, New York, available at:https://doi.org/10.2307/605648.

Tahoon, Z. (2018), *Enhancing Human Health through Biophilic Design in the Built Environment*, Master thesis, Menouifia University.

Taylor, R. (2010), "Fractal patterns in nature and art are aesthetically pleasing and stress-reducing", *The Conversation Africa, Inc.*, available at: https://theconversation.com/fractal-patterns-in-nature-and-art-are-aesthetically-pleasing-and-stress-reducing-73255 (accessed 17 May 2021).

The National Institute for Occupational Safety and Health (NIOSH). (2013), "Indoor Environmet Quality", *CDC Centers for Disease Control and Prevention*, available at: https://www.cdc.gov/niosh/topics/indoorenv/default.html (accessed 29 November 2020).

Torky, T. (2021), "'Madrasa and Mosque of Sultan Hasan' in Discover Islamic Art, Museum With No Frontiers", *Museum with No Frontiers*, available at: https://islamicart.museumwnf.org/ (accessed 16 December 2021).

Toyinbo, O.O. (2017), *Indoor Environmental Quality, Pupil's Health and Academic Performance*, Doctoral dissertation, University of Eastern Finland, available

at:https://doi.org/10.13140/RG.2.2.32940.56962.

traveladventures.org. (2007), “Mausoleum of Sultan Hassan: interior of the dome”, available at: http://www.traveladventures.org/continents/africa/sultan-hassan-mosque07.html (accessed 4 June 2020).

TÜMTÜRK, O. (2018), *Improving Adaptive Capacity of Urban Form By Design*, SCHOOL OF NATURAL AND APPLIED SCIENCES, MIDDLE EAST TECHNICAL UNIVERSITY, Master of Science Thesis.

vetogate.com. (2013), “مسجد السلطان حسن بالقاهرة”, available at: https://www.vetogate.com/380889 (accessed 4 June 2020).

wherekat.blogspot.com. (2010), “Here at AUC”, available at: http://wherekat.blogspot.com/2010/08/ (accessed 20 May 2020).

Wilkie, S. and Stavridou, A. (2013), “Influence of environmental preference and environment type congruence on judgments of restoration potential”, *Urban Forestry and Urban Greening*, Elsevier, Vol. 12, pp. 163–170.

Windhorst, E. and Williams, A. (2015), “‘It’s like a different world’: Natural places, post-secondary students, and mental health”, *Health and Place*, Elsevier, Vol. 34, pp. 241–250.

Wolper, E.S. (2014), “Islamic Architecture and Institutions in the Late Medieval City”, *History Compass*, Vol. 12 No. 12, pp. 912–923.

Wondu Teshome Beharu. (2018), “Psychological factors affecting students academic performance among freshman psychology students in Dire Dawa University”, *Journal of Education and Practice*, Vol. 9 No. 4, pp. 59–65.

“www.archdaily.com”. (2020), , available at: https://www.archdaily.com/935258/biophilia-bringing-nature-into-interior-design (accessed 5 November 2022).

“www.archdaily.com”. (2021a), , available at: https://www.archdaily.com/963706/back-to-basics-natural-ventilation-and-its-use-in-different-contexts (accessed 2 November 2022).

“www.archdaily.com”. (2021b), , available at: https://www.archdaily.com/963987/phase-dance-takeshi-hirobe-architects (accessed 2 November 2022).

“www.archipanic.com”. (2019), , available at: https://www.archipanic.com/10-egg-shaped-architectures/day-14-city-hall-tower-bridge-london/ (accessed 2 November 2022).

“www.architonic.com”. (2022), , available at: https://www.architonic.com/en/microsite/find-design-fair-asia/10003773 (accessed 2 November 2022).

“www.britannica.com”. (2008), , available at: https://www.britannica.com/technology/stoa (accessed 2 November 2022).

"www.centerpointmedicine.com". (n.d.). , available at: https://www.centerpointmedicine.com/blog/the-role-of-a-fish-tank-in-therapy (accessed 2 November 2022).

"www.chandramauli.org". (n.d.). , available at: https://www.chandramauli.org/aranyaka-upanishad.html (accessed 2 November 2022).

"www.clantonassociates.com". (2021), , available at: https://www.clantonassociates.com/post/light-health (accessed 2 November 2022).

"www.dpreview.com". (2013), , available at: https://www.dpreview.com/galleries/1308090898/photos/2439504 (accessed 2 November 2022).

"www.facebook.com". (2022), , available at: https://www.facebook.com/photo/?fbid=10162308343233009&set=pcb.10162308347538009 (accessed 27 December 2022).

"www.hikingphotographer.uk". (2022), , available at: https://www.hikingphotographer.uk/2021/12/nature-walking-good-health-mental-physical.html (accessed 7 November 2022).

"www.lifespan.io". (2018), , available at: https://www.lifespan.io/news/is-aging-natural-or-a-disease/ (accessed 2 November 2022).

"www.mentalfloss.com". (2013), , available at: https://www.mentalfloss.com/article/54073/why-are-eggs-egg-shaped (accessed 2 November 2022).

"www.michaels.com". (n.d.). , available at: https://www.michaels.com/decorative-bird-nest/10167017.html (accessed 5 November 2022).

"www.prophototips.today". (n.d.). *Squarespace*, available at: https://www.prophototips.today/photography-tips-and-tricks/light-quality (accessed 2 November 2022).

"www.re-thinkingthefuture.com". (n.d.). , available at: https://www.re-thinkingthefuture.com/article/transition-spaces-and-how-they-translate/ (accessed 7 November 2022).

"www.rootedinnature.org". (2006), , available at: https://www.rootedinnature.org/3-information-richness (accessed 2 November 2022).

"www.silumen.com". (n.d.). , available at: https://www.silumen.com/en/content/43-lighting-color-temperatures (accessed 2 November 2022).

"www.tripadvisor.com.sg". (2021), , available at: https://www.tripadvisor.com.sg/LocationPhotoDirectLink-g1586908-d10377921-i323887939-Szalajka_Valley-Szilvasvarad_Heves_County_Northern_Hungary.html (accessed 2 November 2022).

"www.turismoroma.it". (n.d.). , available at: https://www.turismoroma.it/en/places/saint-peter's-square (accessed 5 November 2022).

"www.west-crete.com". (2008), , available at: https://www.west-crete.com/dailypics/crete-2008/1-29-08.shtm (accessed 5 November 2022).

"www.worldatlas.com". (2019), , available at: https://www.worldatlas.com/articles/what-animals-live-in-the-ocean.html (accessed 2 November 2022).

Yassin, A.A. and Utaberta, D.N. (2012), "Architecture in the Islamic Civilization: Muslim Building or Islamic Architecture", *Journal of Islamic Architecture*, Vol. 2 No. 2, pp. 52–60.

Youssef, M.E.H. (2017), *The Integration of the Natural Elements in the Built Environment towards Higher Productivity and Human Well Being*, Master thesis, Alexandria University.

"zelmanstyle.com". (2019), , available at: https://zelmanstyle.com/2019/10/24/natures-rustic-color-palette/ (accessed 2 November 2022).

Zolkefli, M.F. bin. (2011), *Spirit of the Place: The Application of Principles of Vernacular Architecture Into the Learning Spaces*, Master thesis, Universiti Teknologi MARA.

Zuhaib, S., Manton, R., Griffin, C., Hajdukiewicz, M., Keane, M.M. and Goggins, J. (2018), "An Indoor Environmental Quality (IEQ) assessment of a partially-retrofitted university building", *Building and Environment*, Vol. 139, pp. 69–85.

Appendix

Appendix A: A questionnaire for the evaluation of the Biophilic Design in AUC campus

I'm currently studying for a master's degree in Architecture at Tanta University and conducting a study on "Biophilic Design in Islamic Architecture". The term "Biophilia", which is derived from Greece, means love of life or living systems. The questionnaire consists of two parts and will take no longer than 10 minutes to complete. The first part is to examine the biophilic qualities of three different learning-built environment zones containing different amounts of Islamic features in the AUC new Cairo, the three zones are illustrated at the beginning of part 1. The second part is to determine the psychological and physiological impacts of these features on its occupants' environment.

Section 1

Age

Gender

- Female
- Male

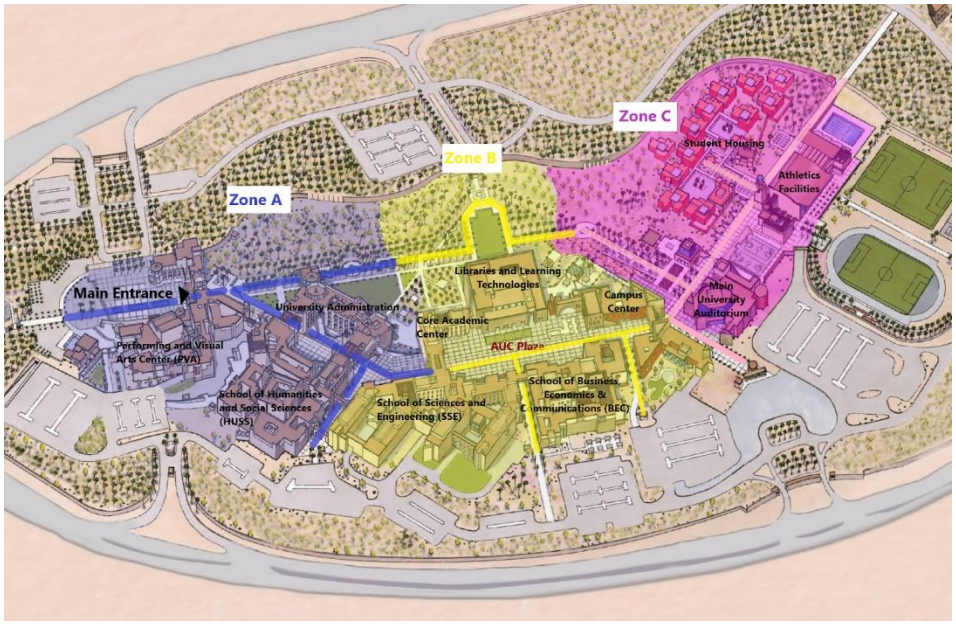
Education

- Bachelor's Degree
- Master's Degree
- Doctoral Degree

Section 2

Biophilic Design attributes evaluation

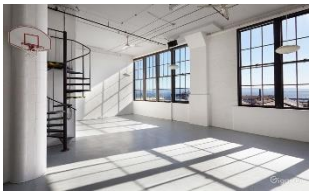
The campus zones map



The new campus zones table

Zone A	Zone B	Zone C
From the AUC main entrance to the administration building and School of Humanity and Social science HUSS	AUC plaza and its surrounding buildings including; library, School of Science and Engineering SSE, School of Business, Economics and Communication BEC, and campus and academic centers	From the southern entrance, main university auditorium, athletics facilities, and student housing

1.Presence of natural light throughout the day



- Zone A
- Zone B
- Zone C
- Unavailable

2.Manipulation of natural light to create dynamic and sculptural forms

- Zone A
- Zone B
- Zone C
- Unavailable

3.Presence of natural ventilation
- Zone A
- Zone B
- Zone C
- Unavailable

4.Presence of natural or man-made water b
- Zone A
- Zone B
- Zone C
- Unavailable

5.Presence of natural plants (indoor or outdoor)
- Zone A
- Zone B
- Zone C
- Unavailable

6.Presence of animals: including birds or domestic animals
- Zone A
- Zone B
- Zone C
- Unavailable

7.Variability in the surrounding environment during the change of seasons
- Zone A
- Zone B
- Zone C
- Unavailable

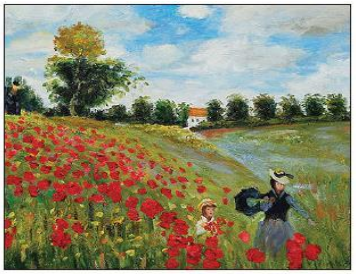
8.Presence of self-sustaining ecosystems (such as wetlands, forest glades and grasslands; green roofs)

- Zone A
- Zone B
- Zone C
- Unavailable

9.Presence of manipulated fire (such as fi

- Zone A
- Zone B
- Zone C
- Unavailable

10. Presence of representational expression of nature such as photographs, paintings, sculpture, and murals



- Zone A
- Zone B
- Zone C
- Unavailable

11. Presence of natural materials

- Zone A
- Zone B
- Zone C
- Unavailable

12. Presence of bright flowering colors, blue skies, glistening water, natural colors; such as earth tones.

- Zone A
- Zone B
- Zone C
- Unavailable

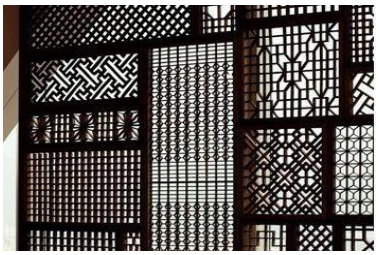
13. Presence of artificial light that mimics the spectral and dynamic qualities of natural light
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

14. Presence of processed air that simulates qualities of natural ventilation through variations in airflow, temperature, and humidity
    - Zone A
    - Zone B
    - Zone C
    - Unavailable
15. Presence of arches, domes, or vaults
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

16. Presence of shapes or forms that simulate plants, such as column supports
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

17. Presence of shapes that resemble or suggest a form of a living organism
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

18. Presence of a set of details contained in an element of the building or a piece of texture, graphic or art
    - Zone A
    - Zone B
    - Zone C
    - Unavailable



19. Presence of natural materials or elements that age, develop patina, and change dynamically over time
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

20. Presence of a design that borrows a functional adaptation concept from other species, such as solar panel system (solar panel system mimics the way leaves harvest energy)
    - Zone A
    - Zone B
    - Zone C

- Unavailable

21. Presence of spaces that provide a feeling of security/protection and have a distant view of the nearby area
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

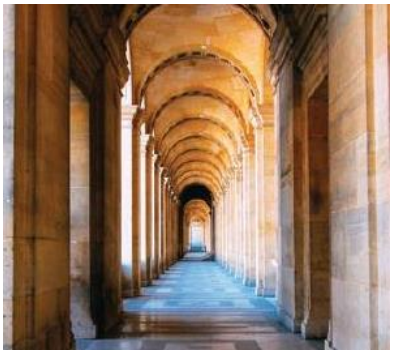
22. Presence of spaces that provide a feeling of vastness and spaciousness specially when it is connected to smaller spaces
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

23. Presence of a set of shapes that are connected in a hierarchical manner, sometimes have a geometrical relation (example: golden ratio and Fibonacci Sequence)
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

24. Presence of satisfying integration spaces where disparate parts comprise an overall whole, such as sequential and successional linking of spaces by clear and discernible boundaries

- Zone A
- Zone B
- Zone C
- Unavailable

25. Presence of clear and discernible transitional spaces (include: hallways, doorways, gateways, and linking areas between indoors and outdoors, courtyards, colonnades



- Zone A
- Zone B
- Zone C
- Unavailable

26. Building that integrates the historical, ecological, and geographical environment of your region/country
    - Zone A
    - Zone B
    - Zone C
    - Unavailable

Have you studied at the campus?

- Yes
- No

Section 3

Your School .....

Your school is in which zone?

- Zone A
- Zone B

Rate your satisfaction with the built environment in terms of:

1- Odors

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

2- Air quality

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

3- Thermal Comfort

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

4- View

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

5- Natural and artificial lighting

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

6- Your mood and self-esteem

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

7- Your relationships with colleagues

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

8- Your Health

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

9- Your sleep quality

	1	2	3	4	5	
Very good	○	○	○	○	○	Bad

Do you think the campus is ….?

1- Comfortable

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

2- Stressful

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

3- Satisfying

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

4- Interesting

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

5- Safe

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

6- Relaxing

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

7- Increasing productivity

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

8- Increasing creativity

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

9- Increasing concentration

	1	2	3	4	5	
Strongly agree	○	○	○	○	○	Strongly disagree

Thank you for your time and stay safe 😊

مستخلص الرسالة

تم العثور على نموذج التصميم المبتكر الجديد "التصميم البيئي الإصلاحي" للحد من الآثار الضارة للتصميم والتطوير الحديث على النظم الطبيعية وصحة الإنسان. يهدف هذا النهج إلى تطبيق استراتيجيتين هما إستراتيجية ذات تأثير بيئي منخفض والتي تقلل من التأثيرات الضارة على الطبيعة، واستراتيجيات التصميم البايوفيلي والتي تعزز الاتصال الإيجابي بين الناس والطبيعة داخل المباني وفي تصميم الحدائق. يمكن أن يوفر التصميم البيوفيلي للناس فرصًا للعيش والعمل في أماكن ومساحات صحية مع توتر وضغط أقل وصحة ورفاهية أكبر. على الرغم من التأثيرات الإيجابية للتصميم البايوفيلي، إلا أنه لم يحظ باهتمام كبير مثل التصميمات الصديقة للبيئة.

يستخدم هذا البحث فرضية أن التصميم البايوفيلي ليس ظاهرة جديدة حيث يمكن العثور على الخصائص الطبيعية والجمالية في الهياكل التاريخية. لذلك يوصي البحث بالخصائص والميزات المتأثرة بالعمارة الإسلامية والتي تحقق التصميم البايوفيلي، ليتم تطبيقها في تصميم المباني الجامعية الحديثة، من أجل تعزيز الصحة البدنية والنفسية للطلاب ونجاح الأداء الأكاديمي لهم.

يوضح تسلسل الأطروحة الإطار المفاهيمي للتصميم البايوفيلي من خلال توضيح النظريات التي تربط رفاهية الإنسان بالطبيعية، ثم وصف استراتيجية كل سمة من سمات التصميم البايوفيلي وتوضيح كيفية تأثير كل سمه منها على وظائفنا المعرفية والصحة البدنية و الراحه النفسية. بعد ذلك تم تحليل مثال مناسب لمبنى مدرسة من العمارة الإسلامية القديمة باستخدام دليل من ثمانية عناصر لفحص سمات التصميم البايوفيلي في الفراغات التعليمية. أخيرًا تمت زيارة دراسة الحالة لحرم جامعي حديث، وتم تقسيم الحرم الجامعي إلى ثلاث مناطق متأثرة بسمات العمارة الإسلامية المختلفة. قام البحث بفحص سمات التصميم البايوفيلي في كل منطقة من المناطق الثلاث باستخدام تحليل موضوعي وعمل استبيان عبر الإنترنت للمستخدمين لتقييم سمات التصميم البايوفيلي، يتبع ذلك قياس عبرbipolar scale للتجربة النفسية والإدراكية والفيسيولوجية للمستخدمين.

جامعة طنطا
كلية الهندسة
قسم الهندسة المعمارية

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(نحو فراغات تعليمية اصلاحية)

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