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Biophilic Design Elements in Modern Buildings Influenced by Islamic Architecture Features

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Biophilia; biophilic attributes; biophilic design features; Islamic architecture; educational buildings.

Abstract

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. This study aims to examine biophilic design qualities and attributes found in three zones of contemporary learning spaces in the American University in Cairo (AUC) in New Cairo, it is a modern campus influenced by different features of Islamic architecture. To achieve this research's goal two stages are done. First, a subjective analysis of the main twenty-four attributes of biophilic design is done. Next, an online questionnaire for users focusing on biophilia-relevant qualities, followed by psychological, cognitive, and physiological experiences measurements uses a bipolar scale. This aims to verify the effect of biophilic features from the respondents' standpoint. The research findings confirm that many biophilic features inspired by historical buildings are found in the contemporary three study zones but not all were properly functioning. The paper concludes the validity of the argument and what users' responses have revealed regarding the criteria of biophilic design.

1. Introduction

Bio means "life or living things", philia means "love"[1]. According to Erich Fromm (1964), Biophilia can be translated to love of life [1]. Biophilia describes "a psychological orientation of being attracted to all that is alive and vital "[1]. The connection with nature has been found to relate to our wellbeing, productivity, and social relationships. The concept of "Biophilia" can be simply defined according to Kellert (2005) as "the inherent human inclination to affiliate with natural systems and process"[2]. Thus, biophilic design is the deliberated attempt to translate this innate affinity into a building's design [3]. Buildings are considered an outsider to nature. Using inspirations from natural environments and vernacular designs can create a sense of place in Biophilic design. Designers must realize that biophilic design insertion must benefit humans and nature's needs.

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In 2008 Stephen R. Kellert set 6 elements and 75 attributes to biophilic design standards to guide practitioners in the design process [3]. These elements included: environmental features; natural shapes and forms; natural patterns and processes; light and space; place-based connections; and evolved human relationships to nature. There have been several theories connecting human and natural systems as can be seen in Table 1 [2]. 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.

Table 1. The principles of Restorative Environmental Design

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

In (2015) Kellert updated the conceptual framework of biophilia into three experiences and 24 attributes [4]. The updated framework of Biophilic design can be shown in **Table 2** [4].

Table 2. Experiences and Attributes of Biophilic Design

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

Later, Terrapin (2015) set 14 patterns of biophilic design to address human health and well-being [5]. These patterns are found to link to stress reduction, cognition performance, and emotional, mood & preference [5]. Currently, university life may be more stressful than ever before [6]. Recent reports on universities and colleges indicate that university students suffer from many mental health problems as anxiety, depression, and mental fatigue [7]. As a result, many studies determine that 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 [8]. Integrating biophilic design patterns and attributes in university settings has a positive impact on student's physical health, psychological well-being, and social relationships [9].

Biophilic design is not considered a new phenomenon, ancient architects inspired their designs from natural creatures [5], thus these buildings already contain the biophilic design qualities from hundreds of years [10-11]. According to a study in 2018, the Alhambra, a palatine complex in the city of Granada, Al-Andalus (Spain now), which one of the most famous examples of Islamic architectural heritage in Europe, successfully fulfills six patterns of biophilic design: visual connection with nature, thermal and airflow variability, presence of water, biomorphic forms and patterns, material connection with nature, and complexity and order [12].

In Islamic architecture the historical mosque-madrassa, is a symbol of Islamic educational

architecture. 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 [13]. There are many examples of the "Madrassa" in many countries, one of the best examples in Egypt is Sultan Hassan representing madrassa-mosque in Cairo built-in 1363 AC during the Mamluk Bahri period. This building incorporated many Biophilic Design patterns: order and complexity, change and metaphor of biomorphic forms, prospect and refuge, enticement, and risk and peril [14]. This research starts by explaining the evolution of biophilia and biophilic design, it continues by analyzing biophilic design in a new educational building influenced by Islamic architecture. Users are questioned on the biophilic attributes, strategies and elements used. Followed the evaluation from the psychological, cognitive, and physiological perspective is done. This deductive methodology uses a diagnostic approach through a case study strategy.

2. Experimental Method

This experimental research uses a diagnostic approach for better understanding the setting and reveal valuable preliminary data about the biophilic design qualities in Islamic influenced architecture and propose their application in future educational building design. To meet this aim two parts are conducted. The first part examines the 24 biophilic design qualities shown in Table 1 on a sample of modern educational spaces influenced by different features of Islamic architecture fulfilling biophilic attributes. In the second part, almost 80 users (20 in each semester) are asked to evaluate the biophilic attributes in three recently designed educational zones. The psychological, cognitive, and physiological performance of the spaces is also evaluated by the same 80 users on a bipolar Likert scale to verify findings.

2.1. Research Scope and Study Delimitations

Although biophilic design standards include many experiences and attributes however this research focuses on the last version by Kellert [4] on a new educational campus influenced by Islamic architecture features considering its importance on users' performance, health, and wellbeing. 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.

2.2. Method and Materials

This study analyzes the architectural features in three different 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. For this study, the American University in Cairo (AUC) established in 2008 in New Cairo is chosen as a study sample. The campus planning is inspired by the complex texture of Islamic city urbanism [15]. The urban design of the campus consists of different compacted groups of buildings, oriented along a central pedestrian spine interconnected with open spaces, such as courtyards, and plazas as can be shown in **Fig. 1**. The campus is divided into three different zones as can be shown in **Fig. 2** containing different amounts of Islamic architecture features.

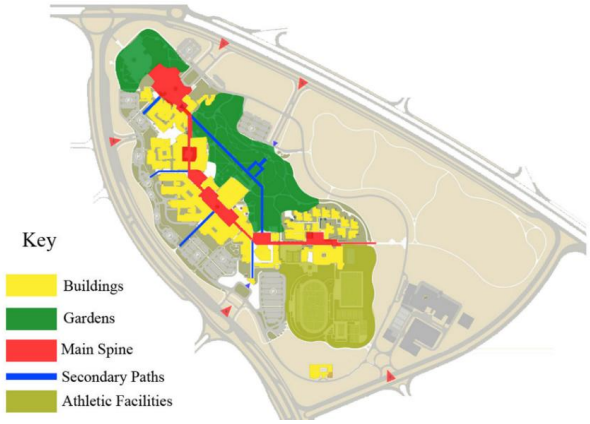


Fig. 1. AUC Campus Urban Analysis

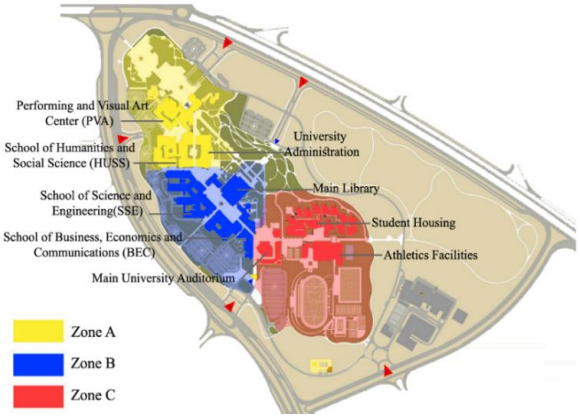


Fig. 2. AUC Campus Study Zones

The first zone (Zone A) is located at the beginning of the campus as can be shown in **Fig. 4**. It accommodates the clusters around two plazas and housed three schools. The clusters and the buildings contain many Islamic architectural features

The second zone (Zone B) is organized around the main public space (Plaza). It accommodates the rest of the campus' schools as can be shown in **Fig. 3**. These buildings were designed by many architects and influenced by mixed Islamic and Mexican styles. The built environment contains various features in harmony with the setting. The last zone (Zone C) includes the main auditorium, athletic buildings, and students' dormitories as can be shown in **Fig. 5**. This zone is designed by Ricardo Legorreta, the design has brought influences from his native Mexico in boldly colors

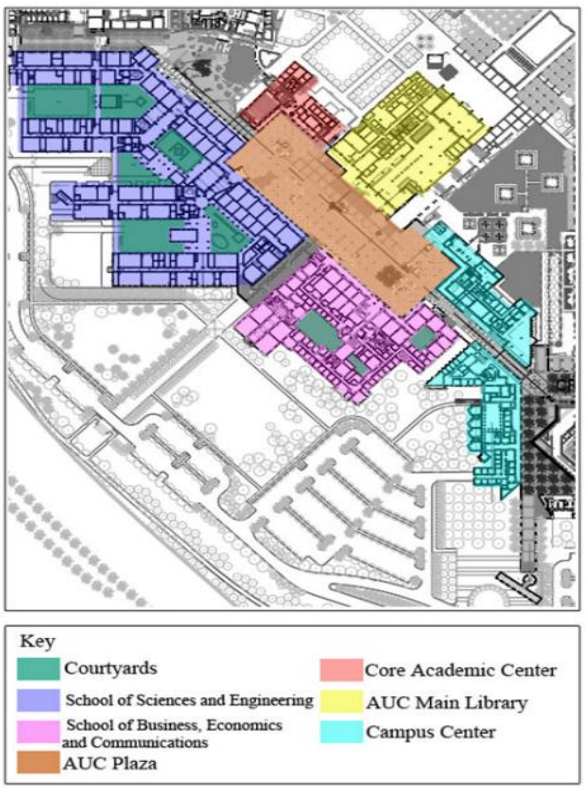


Fig. 3. Master Plan of Zone B, AUC Campus, New Cairo

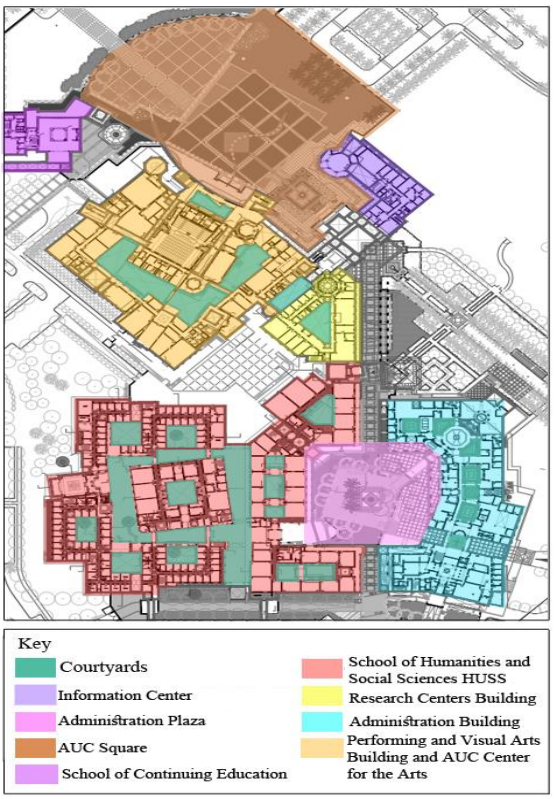


Fig. 4. Master Plan of Zone A, AUC Campus, New Cairo

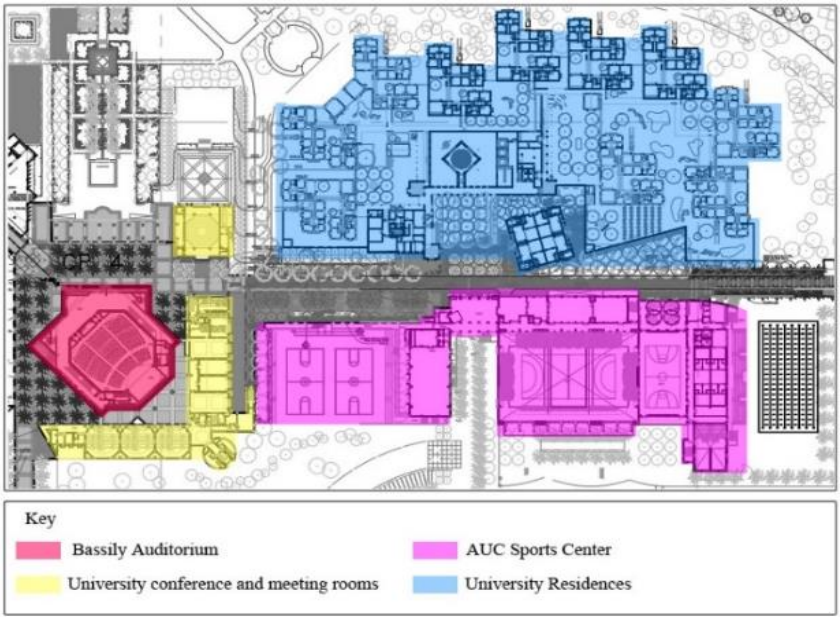


Fig. 5. Master Plan of Zone C, AUC Campus, New Cairo

Evaluation is conducted by observations, transect walks, and finally by online questionnaires of occupants. For the online questionnaire, a 5 bipolar Likert scale is used to indicate the level of agreement to the statement by the respondents, and the data are analyzed using the Relative Indices (RI) technique [16]. 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 3** [16].

Table 3. Benchmarks for RI Ranges of Evaluation

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

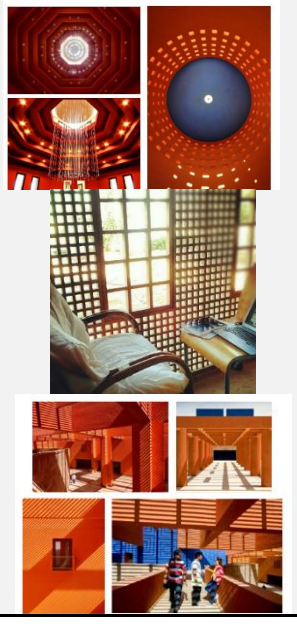
Biophilic experiences and attributes proposed by Kellert & Calabrese (2015) shown in **Table 2** are used in this study for evaluation [4]. The respondent groups' age ranged from 21 to 38 years of which 62% were female and 38% were male. 70% of the respondent group were post-graduate students who have used the study area.

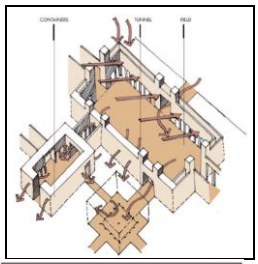
3. RESULTS

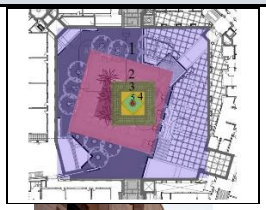
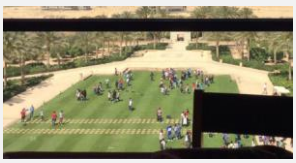
3.1. Elements of Design Fulfilling Biophilic Attributes in General

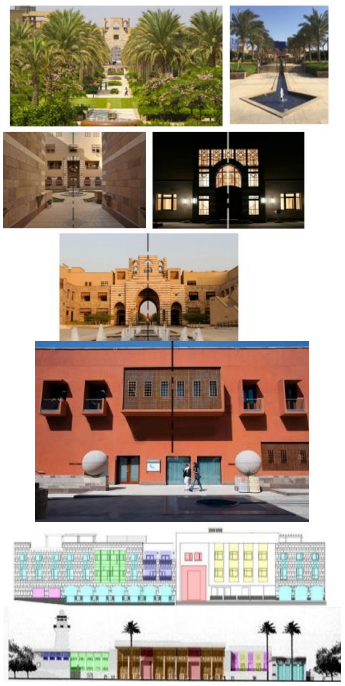
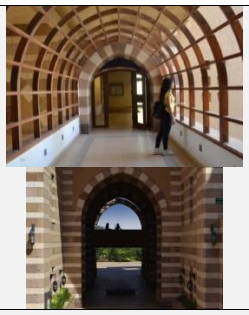
Eight architecture design elements are found in the study zones/spaces as can be shown in **Table 4**. The architecture elements are analyzed and applied as strategies fulfilling biophilic design attributes in the three study zones A, B, and C. The design elements and their strategies applied in the three study zones fulfilling Biophilic design attributes are shown in **Table 4**.

Table 4. Design Elements and their Strategies Applied in the Three Study Zones Fulfilling Biophilic Design Attributes

Design Strategies				Biophilic Attributes
Lighting	***Zone A***	• Inner courtyards in all buildings. • Different patterns of "Mashrabiya" (screened windows). • Lattice canopies to shade pedestrian walks		**Light**
	Zone B	• Inner courtyards in schools' buildings. • Light shelves and other shaded devices in south and west facades. • Open glazing windows in north elevations. • Lattice pergolas in the main plaza.		
	Zone C	• Inner courtyards in student housing. • Use upper openings "Shokhshikha" and "Clerestories". • Open glazing windows in the north elevations. • Lattice windows in student housing. • Manipulation of natural light that create dynamic and sculptural forms in campus center		

		Design Strategies		Biophilic Attributes
	Zone A, B & C	• Integrates daylighting and electric lighting with appropriate illumination levels using indirect lights in classrooms (indoor) • The variation of light and shadow and the color lighting (outdoor).		**Stimulating Natural Light**
Natural Ventilation	***Zone A***	• Use "thermal unit"; that consist of the container (the high-pressure element), the field (the low-pressure element), and the tunnel (the connective element). • Use passive venting and cooling techniques as wind towers in many buildings.		**Air**
	Zone B	• Use "thermal unit" in school buildings.		
	Zone C	• Inner courts in the student housing. • Use a wind catcher in the sport center.		
Interior & Exterior Landscape	***Zone A, B & C***	• The main garden uses native and non-native vegetation, which support animal life, and water bodies. • Inner courtyards and plazas use natural elements as trees and water bodies. • All indoor spaces relate to the outdoor by windows, porches, and colonnades.		**Water** **Plants** **Animals** **Natural landscape & ecosystem** **Weather**

		Design Strategies		Biophilic Attributes
Form	***Zone A***	• Use square form as a principal shape in the design. Also used in the floor-tiles with a geometrical pattern related to the squares. • Repetition of architectural elements such as arcades and colonnades. • Use local materials with earth tone color. The use of the "Eblaq", which is the technique of alternating courses of light and dark stone.	   	**Natural Materials** **Natural colors** **Naturalistic shapes and forms** **Natural geometries** **Information richness**
	Zone B	• Use a rectangular shape with proportion 1:3 in the plaza and some buildings. • Repetition of architectural elements such as arcades and colonnades. • Use earth tone colors finish in some buildings.	 	
	Zone C	• Repetition of architectural elements such as colonnades. • Use earth tone colors finish in some buildings.		
Opening in Space	***Zone A***	• All the rooms have one or more operable window connected to the courtyards, plaza, or garden.		**Weather** **Prospect and refuge**
	Zone B	• All the rooms have one or more operable window connected to the courtyards, plaza, or garden. • The openings in the library facade provide a secured and protected shelter to the students with a plaza view.		
	Zone C	• All the rooms have one or more operable window connected to the courtyards, plaza, or garden.		

Design Strategies				Biophilic Attributes
Ordering	***Zone A, B, C***	• The campus buildings and garden are oriented along central axes in a symmetrical manner. • Symmetrically designed façades give a clear grid of openings indicating rhythm and structure. • Hierarchy of public spaces are organized orderly in scale along the axes. • Hierarchical order of openings by size in school's elevations. • Opening rhythm in building's elevations. • The compacted groups of buildings using centralized and linear organization.		**Organized complexity** **Integration of parts to wholes** **Prospect and refuge**
Circulation Elements	***Zone A & B***	• Entrances, lobbies, vestibules, lounges, multi-use spaces, galleries, and corridors, are used for inner circulation. • Use bridge connectors between building rooftops as a circulation element.		**Mobility and wayfinding** **Prospect and refuge** **Transitional spaces**
	Zone C	• Entrances, lobbies, vestibules, lounges, multi-use spaces, galleries, and corridors, are used for inner circulation.		
Vernacular Design	***Zone A***	• Plan organization and massing of the building fabric relative to historic patterns. • Use environmental design strategies depends on vernacular architecture. • Use native and adapted plants. • Use local materials.		**Cultural and ecological attachment to place**
	Zone B	• Vernacular architecture features. • Use native and adapted plants. • Use local materials.		
	Zone C	• Vernacular architecture features the sport center building. • Use native and adapted plants.		

A matrix showing the design elements that fulfill biophilic attributes of the three zones together is shown in **Table 5**.

Table 5. Summary of the Design Elements and Strategies that fulfill the Biophilic Attributes of the Three Study Zones

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					●				
Evolving 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									●

2.1. Users Evaluation of the Architectural Design Elements Fulfilling Biophilic Attributes

Online questionnaire results of the biophilic design framework: the direct experience of nature, the indirect experience of nature, and the experience of space and place of the three campus zones A, B, and C can be shown in **Fig. 6.** Based on the online questionnaire it is found that almost 58% of the direct experience of nature are found in zone A, 45% of the indirect experience of nature, and almost 55% of the experience of place and space. For Zone B almost 46% of the direct experience of nature, 35% of the indirect experience of nature, and almost 51% of the experience of place and space. As for Zone C almost 46% of the direct experience of nature, 28% of the indirect experience of nature, and almost 28% of the experience of place and space. Figure 7 shows the percentages of the three experiences in the three zones/spaces A, B, and C. Each attribute in the category has a unit value. No physical calculations are indicated, only a comparative indication to give an overview of the different zones.

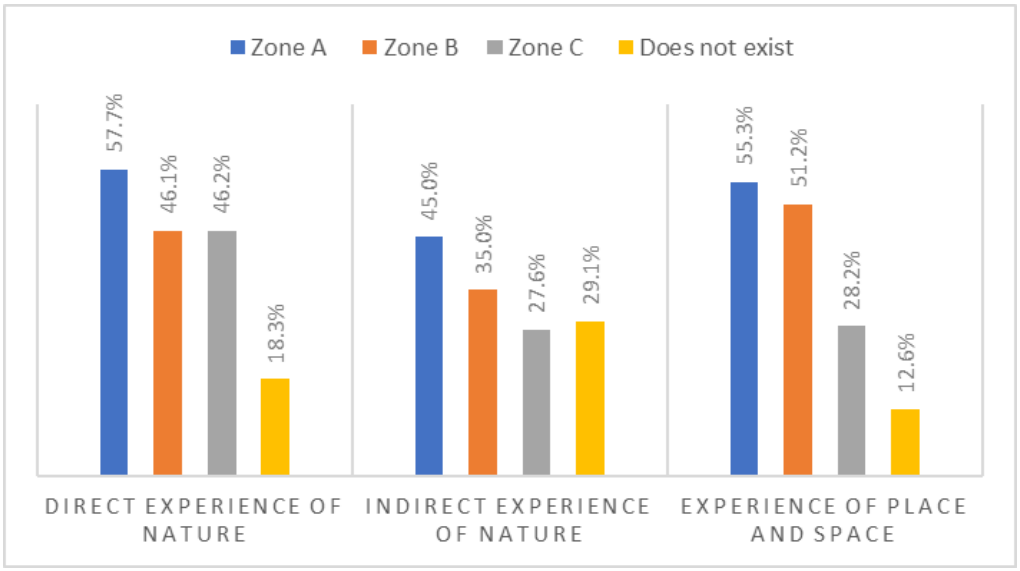


Fig. 6. Schematic Percentages of Experiences According to Questionnaire Results for Zone A, B, and C

Next the users' satisfaction and evaluation of spaces based on psychological, cognitive, and physiological performance is done and can be shown in **Table 6**. The table shows the RI value of some of the evaluation variables collected from various research [17-18] focusing on the psychological, cognitive, and physiological performance averages of the three study zones A, B, and C based on the 5 bipolar Likert scale evaluation of users.

Table 6. RI Average Results Based on Users Evaluation of the three Zones A, B, and C

Performance Variables	Psychological Performance	Cognitive Performance	Physiological Performance	RI Value	Category
Mood and self-esteem	√			**0.41**	Good
Relationships	√			**0.39**	Good
Health			√	**0.44**	Good
Sleep quality			√	**0.54**	Neutral
Comfortable	√			**0.43**	Good
Stressful	√	√	√	**0.65**	Bad
Satisfying	√			**0.40**	Good
Interesting		√		**0.33**	Very Good
Safe		√		**0.30**	Very Good
Relaxing	√	√		**0.44**	Good
Increasing productivity		√		**0.42**	Good
Creativity		√		**0.43**	Good
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

4. Discussion

In general, according to the matrix found in **Table 5** the design elements found in the study zones almost fulfill all biophilic attributes, only five attributes are missing; Fire related to direct experience, Images of Nature, Evoking Nature, Patina of Time, and Biomimicry in the indirect experiences. Findings match the user's satisfaction and evaluation results of the zones on the

psychological, cognitive, and physiological performance as can be shown in **Table 6** showing the RI that indicate "good" based on the referenced **Table3**.
These results when reviewed it was found that although Islamic features were found yet they were not all functioning properly for instance lattice windows are covered with glass and water sprinklers are not used. For these reasons, the results rated only "good". The biophilic features 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 properly 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.

5. Conclusions

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. To achieve biophilic standards that contribute to human comfort and well-being it is suggested that more features and strategies 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.
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 discipline in design needs to be examined thoroughly on different types of buildings. It is important to understand biophilic attributes, strategies, and elements well to apply them. Some of the architectural features such as inner courtyards, passive venting, and lighting techniques, outdoor gardens, water elements, natural and vernacular materials, symmetry and clear axes, clear transitional spaces, fractals, and arches, domes, and vaults, can be used in learning spaces to improve biophilic design quality. Future studies can be done to test the impact of biophilic attributes on each of the users' psychological, physiological, and cognitive experiences.

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عناصر التصميم البيوفيلي في المباني المعاصرة المتأثرة بسمات العمارة الإسلامية

الملخص بالعربي:

أوجد الباحثون التصميم البيوفيلي لتقليل الإجهاد وتعزيز الصحة العامة والرفاهية في الفراغات المبنية. فهو له القدرة أيضا على تعزيز صحة الطلاب الجسمانية والنفسية بالإضافة إلى نجاح الأداء الأكاديمي في المباني التعليمية. تهدف هذه الدراسة الى فحص سمات التصميم البيوفيلي الموجود في ثلاث فراغات تعليمية معاصرة داخل الجامعة الأمريكية بالقاهرة الجديدة، فهو حرم جامعي ذو تصميم معاصر متأثر بسمات مختلفة من العمارة الإسلامية. لتحقيق هدف هذا البحث استخدمت الدراسة مرحلتين: الأولى عبارة عن دراسة تحليلية لسمات التصميم البيوفيلي الأربعة وعشرون. بعد ذلك، استخدم استبياناً عبر الإنترنت للمستخدمين لتقييم سمات التصميم البيوفيلي للمكان، يتبع ذلك قياس عبرbipolar scale للتجربة النفسية والإدراكية والفيسيولوجية للمستخدمين. ويهدف ذلك إلى التحقق من تأثير سمات التصميم البيوفيلي من وجهة نظر المستخدمين. تؤكد نتائج البحث أن العديد من سمات التصميم البيوفيلي والمستوحاة من المباني التاريخية موجودة في مناطق الدراسة المعاصرة الثلاث، ولكن لم تكن جميعها تعمل بشكل صحيح. تستنتج الدراسة صحة الفرضية وما كشفت عنه ردود المستخدمين فيما يتعلق بمعايير التصميم البيوفيلي.

الكلمات المفتاحية: بيوفيليا، سمات البيوفيليك، سمات التصميم البيوفيلي، العمارة الاسلامية، المباني التعليمية.