Using VR to Enrich Architectural Biophilic Education

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Abstract:

Exposure to the natural patterns of living forms has been shown to hasten recovery after surgery, making biophilic design a powerful tool in clinical settings. The calculated effect is perceptible and can potentially improve modern building design. This study aims to develop a high-quality, modern architectural design by employing biophilic architecture to address a gap in current architectural products: a lack of attention to detail in creating spaces that foster a meaningful connection with nature. Humans have always had a special connection to nature, and this affinity has only deepened as human civilizations have spread across the globe. This connection is the basis for the "biophilic design" concept, a novel approach that can improve the design experience by incorporating natural elements. Case examples illustrate biophilic design, showing the potential and possibilities of making the best use of the space to realize biophilic architectural designs. For modern Egyptian architecture to develop a specialized vocabulary in line with the biophilic design concept, many parameters defined as healing aspects are used in this research. The methodology follows a combined strategy between experimental and case study methods. The empirical section describes a virtual reality experience examined by a group of senior architecture students who visited the cases of the study virtually to inspire them with high-quality architectural design ideas. To extract the most important design considerations from this experiment, they collected data through a questionnaire; the outcome is a framework of biophilic design considerations in architectural education.

Keywords:

biophilia; virtual reality; design enhancement; architectural design; designing from nature

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1- Introduction:

Biophilic architecture is a relatively new idea that draws inspiration from ancient civilizations; it primarily works with sustainability in mind and is defined as loving nature or life, originating from ancient Greek terms. Another definition states that it is the possession of other lives. It came into use in the late seventeenth century. Thus, the theory is relatively old, but applications of the idea from an architectural perspective are novel [1].

From this perspective, "biophilia" refers to a human dependence on nature that transcends mere physical awareness to achieve fulfilment and spiritual values [2]. Over the past three decades, many studies have demonstrated that natural compositions support physiological and psychological functions. These studies showed that natural compositions have good effects and lessen symptoms of tiredness [3]. Our research question centered on how a design might be contemporary and still respect the concept of biophilia in varied architectural surroundings, even though some architects raise the concern that those biophilic shapes in the architecture might reduce its link to modern living style [4].

Experiments focusing on the biophilia effect in architecture have shown that incorporating natural elements or courts into a building can positively affect occupants' health and wellbeing. This does not only apply when connected to natural environments, as similar results have been seen when the man-made landscape integrates natural elements, meaning that architects can mimic nature to produce suitable buildings that can heal both humans and nature, which can enhance social and economic activities without stifling either [5].

Some users may view taking design cues from nature as out of date, but the researchers behind this study are confident that a happy medium can be found between modern architecture and biophilia. This is because humans have an innate affinity for and need to incorporate natural elements into the built environment [6].

2. Biophilia in Practice

Biophilia techniques that have been used in practice are clearly defined and identified to the stakeholders who approve such designs in their investments through three steps: (1) creating a visible connection to nature, (2) using natural

ventilation and lighting, and (3) using natural elements such as water and greens in the internal spaces of their designed buildings. It is important to have a smooth transition from outside to inside to make the most of the space [7].

Bill Browning, an experienced environmental strategist, along with architects Rick Cook and Bob Fox of COOKFOX Architects, launched Terrapin Bright Green in 2006. An architect of considerable skill and experience in sustainable design, Chris Garvin, joined the team shortly after. As a result of this collaboration, Terrapin is now a go-to consultant for big firms, developers, governments, and other organizations grappling with the issue of using 21st century high-performance design to recommit to social and ecological ideals [8].

The company mentioned above detailed a few examples of biophilic design's success across various contexts and scales, demonstrating the firm's way of thinking and biophilia's capacity for application. This study draws parallels between the firm's work and traditional Islamic architecture to demonstrate the benefits of combining the two styles [9].

As one of the most promising lines of development in architectural engineering, "biophilic" design centers on drawing spiritual inspiration from the natural world to foster a physically and mentally healthy man-made environment [10].

2.1. Patterns of Biophilic Design

In total, we identified fourteen new ways of accomplishing biophilia, many of which have been practiced in various guises within our Islamic culture but were known by different names. Those fourteen patterns are grouped into three categories as follows (see Figure 1).

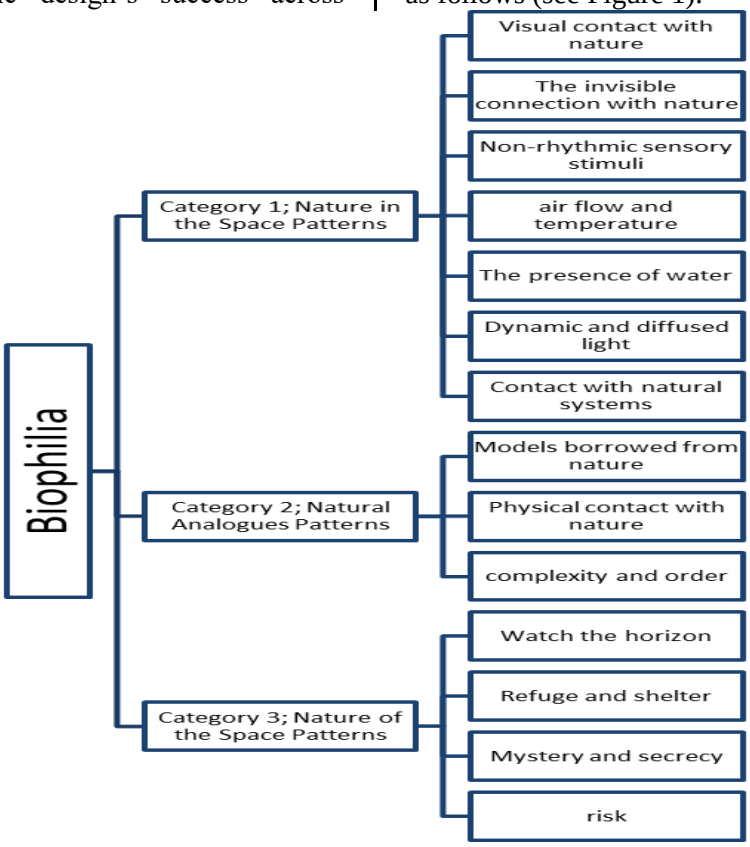


Figure 1. Biophilic hierarchy of patterns.

2.1.1. Category 1: Nature in the Spatial Patterns

One: The ability to see nature, an observation of natural phenomena, including biological systems and the processes by which they operate.

Two: A link to nature that does not rely on sight. Sensory experiences that intentionally and favorably allude to nature, biological systems, or natural processes (via hearing, touching, smelling, or tasting).

Three: Sensational inputs without a rhythm; connections with nature are fleeting and unpredictable but may be examined analytically.

Four: Variations in temperature and wind direction, temperature, humidity, air movement, and surface temperature are subtle but reminiscent of natural settings.

Five: Indications of water availability, a circumstance that improves the enjoyment of a location by hearing, seeing, or touching water.

Six: Motion and dispersed illumination utilizes the ever-changing ratio of light to dark to simulate natural phenomena.

Seven: Relating to nature, observation and comprehension of the natural world, especially the seasonal and temporal shifts that characterize a stable ecosystem [11].

2.1.2. Category 2: Natural Analogue Patterns

Eight: Biomorphic shapes and designs. Alludes to persisting natural shapes, patterns, textures, or numbers.

Nine: Realization of nature by material means. Natural resources and components that, with minimal modification, convey the local ecology or geology and establish a unique identity.

Ten: Arrangement and complexity. Intense sensory details are organized in a spatial order that mirrors real-world experiences [12].

2.1.3. Category 3: Nature of the Spatial Patterns

Eleven: Prospect. Clear sight at a great distance, useful for monitoring and setting up operations.

Twelve: Sanctuary. An area where one can get away from the pressures of their surroundings or the main flow of activity and have their backs and heads covered.

Thirteen: Enigma. The enticement to explore further into an area by offering more data, usually through partially blocked views or other sensory gadgets.

Fourteen: Danger, the last pattern. The architecture combined with a clear and present danger [13].

There has been a significant shift in how architectural engineering is taught because some members of the present generation acquired their elementary education through innovative technology with new instruments that make the old teaching techniques obsolete. Implementing cutting-edge technological methods of instruction, such as virtual reality, augmented reality, and so on, into Egypt's architectural curriculum is difficult because government-funded universities rarely make such investments. Despite this, this research suggests presenting the concept of biophilia as an educational experience by incorporating virtual reality into the teaching of architectural engineering, in light of realizing its genuine usefulness and even its inescapable demand in the future [14].

2.2. Involving Virtual Reality in Education

The ability of today's students to use complex technological resources effectively is crucial to the success of educational technology. A person's ability to transform the information provided to them into true comprehension increases in proportion to their level of expertise with such instruments. Students can participate in an innovative learning experience using their mobile devices to explore their local communities while equipped with subject-specific knowledge. Therefore, students are urged to take their VR experiences outside [15].

Virtual reality creates an environment nearly identical to the user's real-world surroundings. It was first offered as an alternative to the real world by Myron Kruger in 1974. The development of virtual reality applications allows for meaningful social and environmental interactions between users. Three-dimensional effects, tactile and auditory feedback, and surround-sound systems (or headphones) all work together to produce a realistic feeling of immersion in a digital world [16].

The level of immersion a user experiences in a virtual world mostly depends on their display technology, which is why there is such a wide range of options in VR systems. Museums have ceased to be places that house artifacts or exhibits and instead have become a medium through which information and entertainment are disseminated to the public, as the traditional display method has evolved from silent and static realistic shows to animated and interactive virtual shows (see Figure 2) [17].

Figure 2. The virtual experiment of the senior students to perceive biophilia.

The students can take in the virtual world while standing still. However, modern technical developments have allowed users to examine the simulated world while wandering about virtually and even see other users with them in the same area. As it is dependent on human sense factors (vision, hearing, and sensation), virtual reality in this experience shattered all barriers of knowledge

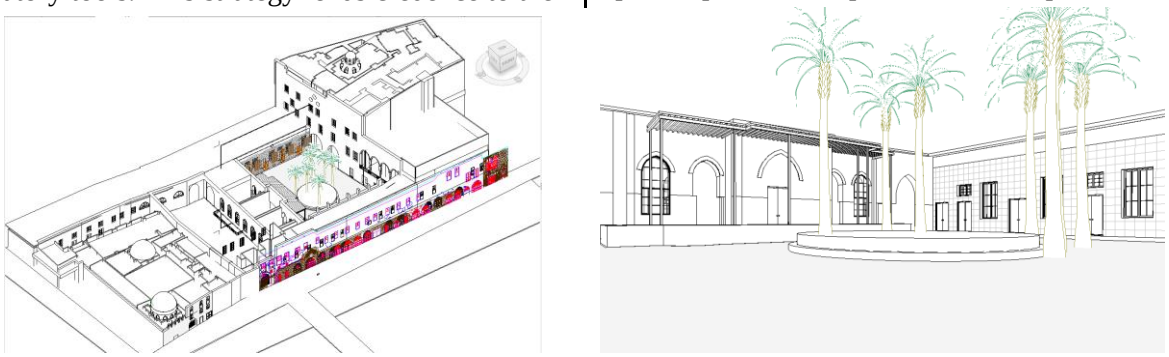
and clarified information in a way that the imagination of the human mind imagines by processing and displaying it (rendering) directly, while showing it visually to the rest of the visitors [18].

3. Experiment Scenario

Three case studies were constructed as part of the experiment (see Figures 3–5); one represented a historical structure to glean biophilic lessons from the past (the Palace of Prince Taz, an Islamic Mamluk Palace), another represented a contemporary biophilic structure (the Kickstarter headquarters), and the third represented a non-biophilic structure (the Solar Boat Museum).

Seniors from the Zagazig University Department of Architectural Engineering's Design Studio Course experimented using the department's virtual laboratory tools. This strategy lends credence to the idea that teaching architecture effectively necessitates an appreciation for traditional and digital teaching methods so that students can improve their ideas through on-site research and simulation visits. This concept was employed in order for students to extract the related design considerations linked to biophilic categories from every building, in addition to understanding what can be expressed directly and indirectly in their design while brainstorming with the course staff during the VR experiment.

Each of the 78 graduating seniors was able to walk through the three buildings and listen to the effects over three days of instruction, during which time they were also allowed to ask questions and view videos to help them fully grasp all of the concepts used concerning biophilia in the buildings, and the philosophical concept of the non-biophilic one



a) b)

Figure 3. a the whole mass while b is the main courtyard of Prince Taz Palace [19].

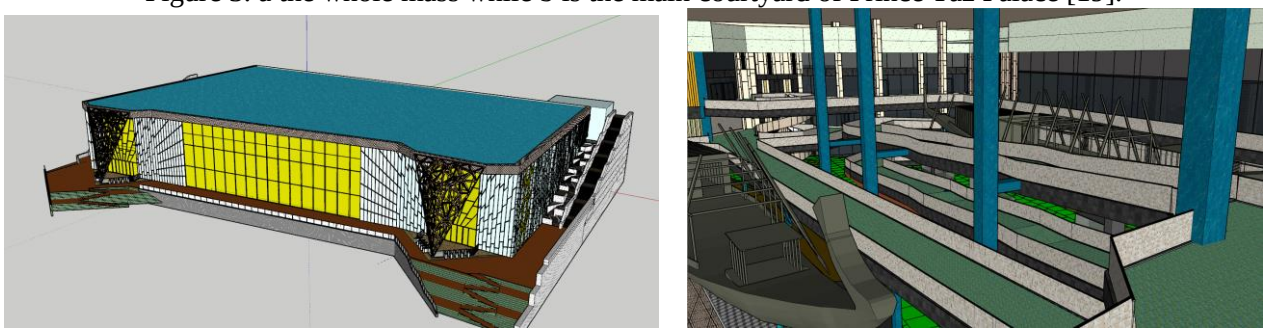


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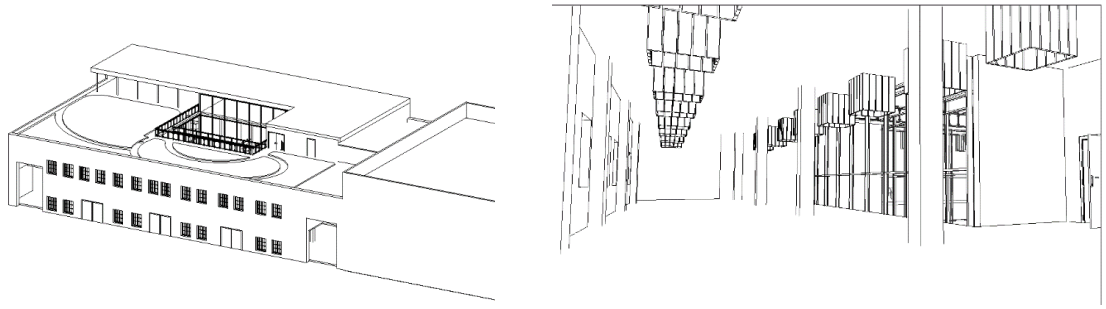
Figure 4. Solar Boat Museum building, a represents the building while b shows the interior[20].



a) b)

Figure 5. Kickstarter headquarters, a represents the building while b shows the interior [21].

4. The Questionnaire

The questionnaire consisted of three categories. Every category included the biophilic patterns as shown previously in Figure 1; fourteen patterns of biophilia distributed into three categories. The students, by the end of every section, extracted the design considerations in each category in addition to examining the best way to express the items in

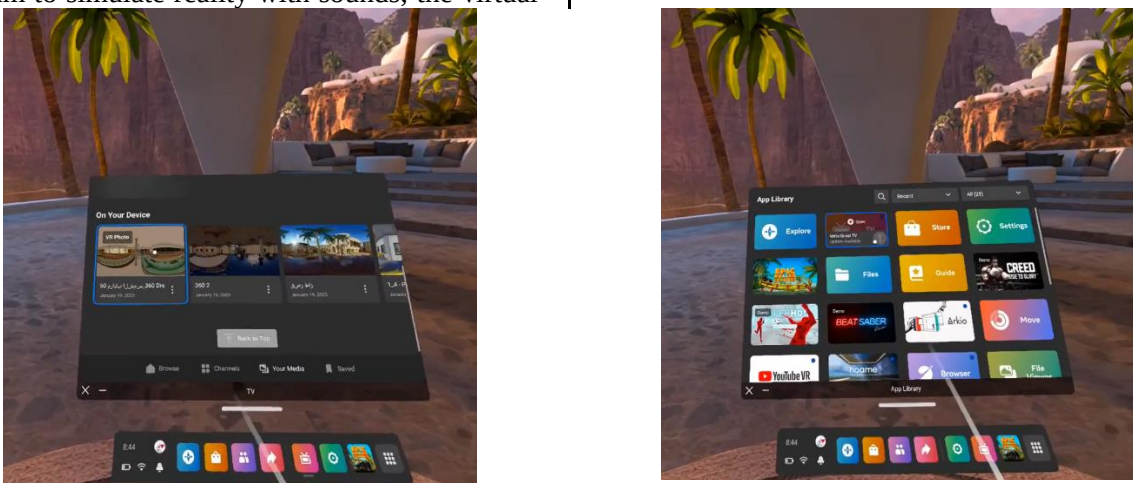
the category directly or indirectly. Every pattern was represented by a set of questions produced by mentors, experts in architectural design, for students to answer what can be considered suitable to achieve a pattern in the design. Over three rounds, students completed the answers for each pattern in the questionnaire form.

After the model was constructed, all the materials, water features, and effects were added to the model to allow the students to examine the look and feel of the buildings in virtual reality (Figure 6)

a) b) c)

Figure 6. Simulations of the three buildings, a represents Taz palace, b represents solar boat museum, while c represents Kickstarter building

The walkthrough experience was tested by the research team and was prepared in the Meta Quest program to simulate reality with sounds; the virtual reality experience showed the buildings to the students as they exist in reality (Figure 7).



a) b)

Figure 7. Meta Quest software interface, a represents start menu while b is operation screen

5. Results and Discussion

When virtual reality was used in the educational experience, the levels of understanding and perception increased by a percentage that varied from one indicator to another, as calculated by the sub-questions for each pattern [22].

Joining the three buildings, which represent three different design concepts, let the students perceive the benefits of biophilia, how it was originally formulated (seen from the historic case), how it can be applied, and what the non-biophilic building is missing; all of those items together helped link the information provided in every case to enrich the students' architectural knowledge. The differences are clear when comparing the responses for every building in the same category, in which positive responses were almost doubled in the biophilic cases and greater in the historic case, meaning that sometimes, the application of biophilia in modern design is missing some considerations [23].

Below are the detailed results of the students' responses to the three buildings. The first category, "Nature in the Spatial Patterns," contains a large number of patterns because it is the first tested pattern in terms of existence and expression. The visual contact with nature pattern contains five indicators of contact; for example, the living nature pattern is mostly focused on planting, which exists in abundance in the Taz Palace and Kickstarter headquarters, and all cases emphasized the significance of having windows with a proper size overlooking a good natural setting. Table 1 and Figure 8 show the results.

Table 1. The responses regarding visual contact elements in the cases.

	Biophilic Patterns	Response	Taz Palace	Biophilic	Solar Boat Building
Visual contact with nature	The presence of elements of living nature inside the building	yes	34	25	20
		no	2	5	13
	The presence of windows overlooking live nature	yes	29	29	27
		no	7	1	6
	The presence of a natural flow of water	yes	14	23	18
		no	22	7	15
	The presence of sand, soil, or natural terrain in the ground	yes	16	13	11
		no	20	17	22
	Highly designed landscape work	yes	29	26	14
		no	7	4	19

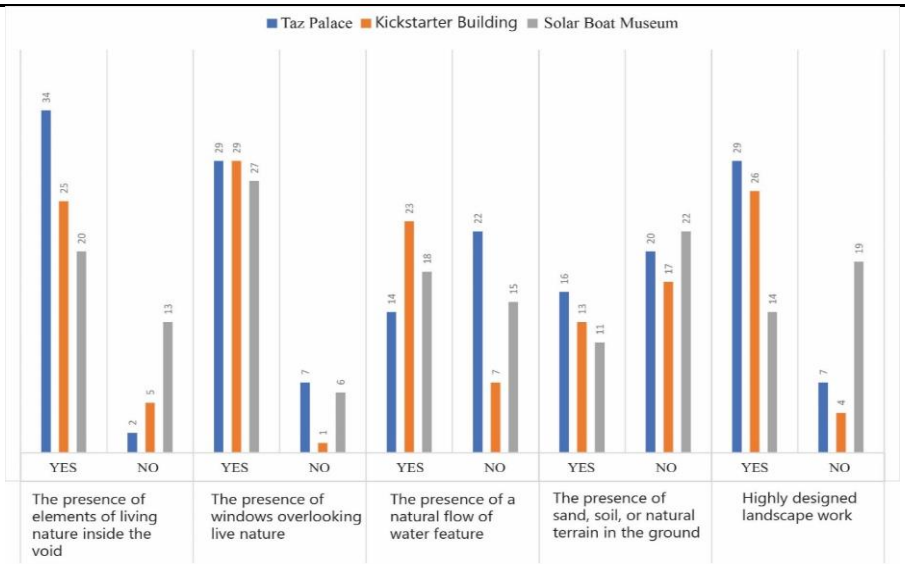


Figure 8. Visual contact with nature elements compared for the three cases.

Hearing the sound of nature achieved little in these cases, but the building with the highest scores was Kickstarter. Natural ventilation was mostly present in the Taz palace; all cases permitted touching stone and natural materials. Table 2 and Figure 9 show results.

Table 2. The responses regarding invisible connection with nature elements.

	Biophilic Patterns	Response	Taz Palace	Biophilic	Solar Boat Building
The invisible connection with nature	Hear the sound of flowing water	yes	9	19	11
		no	27	11	22
	Natural ventilation: windows open to let in the breeze	yes	29	27	22
		no	7	3	11
	Touch natural materials (stone, wood, fur)	yes	33	27	26
		no	3	3	7

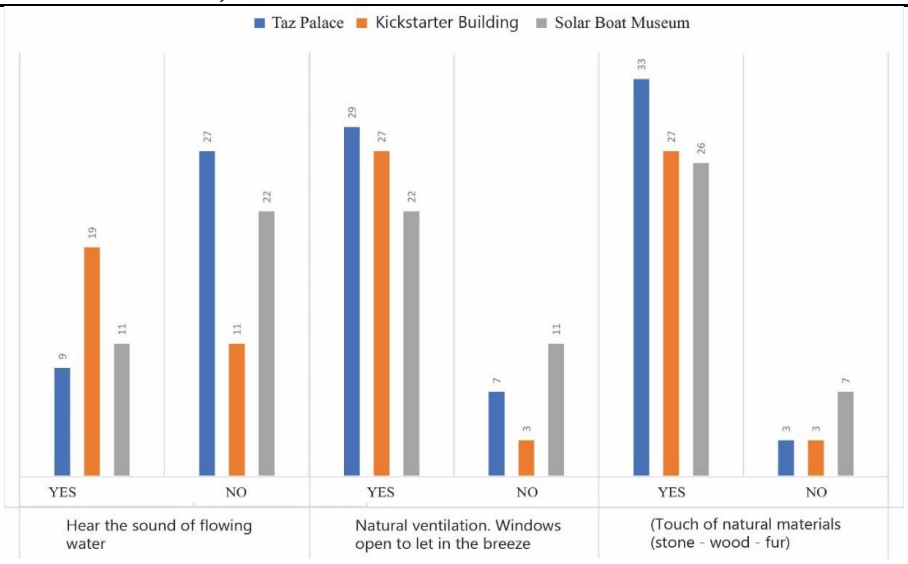


Figure 9. Invisible connections with nature: compared scores.

The historic building had the highest scores because it is the case closest to the sky, and the aerodynamics of the architecture can be felt. Following the design philosophy, many shadows appeared, not just from large trees or artificial shading elements, but also from the relation of the masses. The Solar Boat Museum had the highest scores, and the crowdfunding website Kickstarter's building was in the middle. Table 3 and Figure 10 show results.

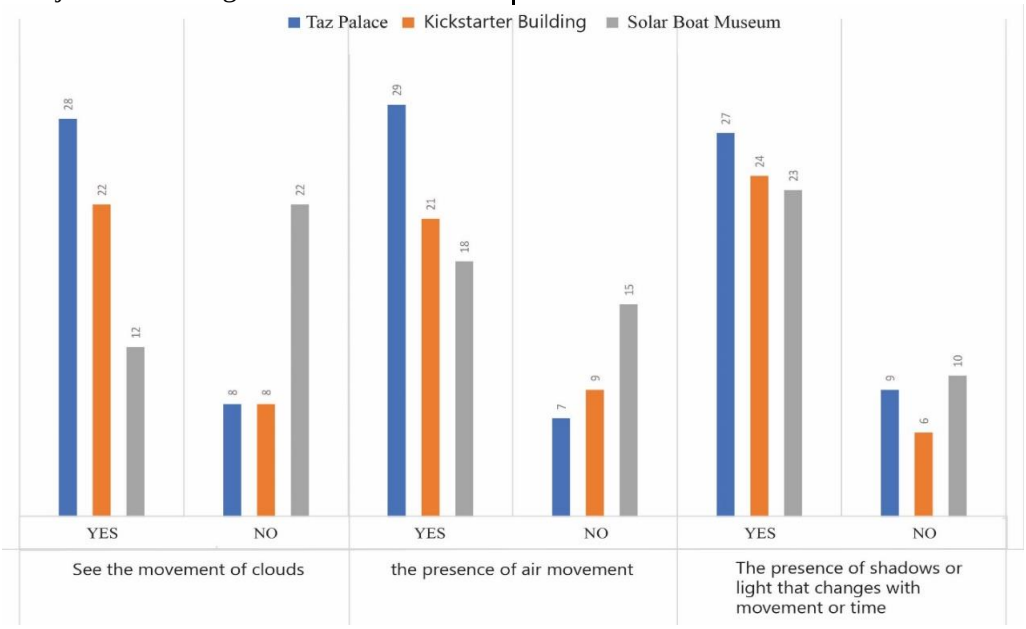


Figure 10. Non-rhythmic sensory stimuli elements: the historic building had high scores.

Table 3. Non-rhythmic sensory stimuli elements.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Non-rhythmic sensory stimuli	See the movement of clouds	yes	28	22	12
		no	8	8	22
	The presence of air movement	yes	29	21	18
		no	7	9	15
	The presence of shadows or light that changes with movement or time	yes	27	24	23
		no	9	6	10

Another pattern concentrates on airflow and temperature, including six indicators in which the historic building showed high a performance when concerning solar gain, shade, and shadows and the proper orientation of the void, but the lowest scores for the other three indicators, as vegetation did not cover not enough, in addition to not having enough control or window treatments. Results are shown in Table 4 and Figure 11.

Table 4. Airflow and temperature indicators statistics.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Airflow and temperature	Solar heat gain	yes	32	21	21
		no	4	9	12
	Shade and shadows	yes	30	22	24
		no	6	8	9
	Proper orientation of the void	yes	34	27	22
		no	3	3	11
	Vegetation cover and its relationship to the seasons	yes	28	24	13
		no	10	6	20
	Systems controls	yes	21	17	18
		no	15	13	16
	Glazing and window treatments	yes	29	23	25
		no	7	7	8

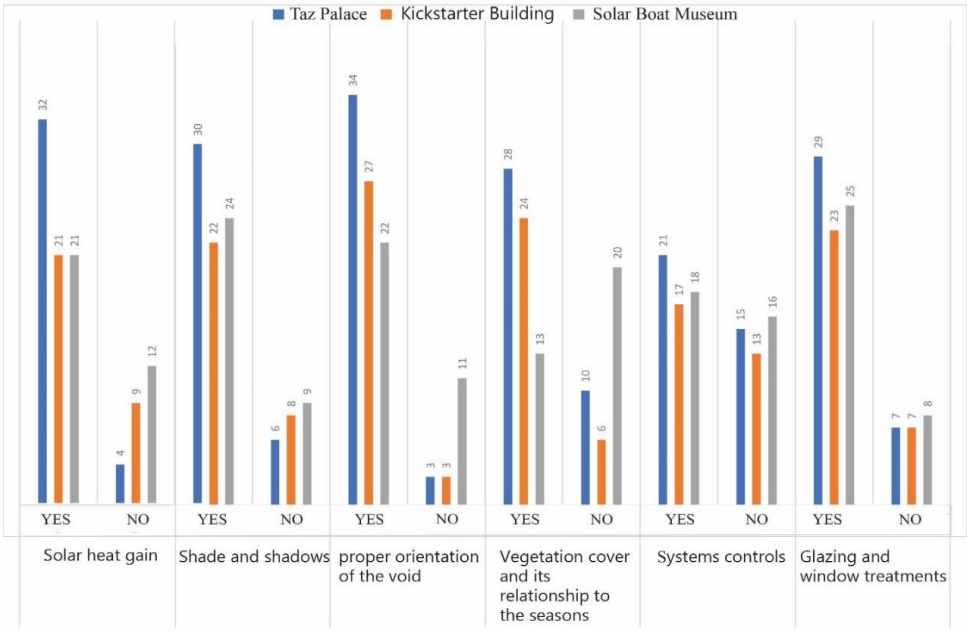


Figure 11. Airflow and temperature indicators.

The water presence indicator focuses on natural and artificial elements; most of the responses related to the fountain, while the water wall was unclear. Results are shown in Table 5 and Figure 12.

Table 5. The presence of water indicators.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
The presence of water	A river, stream, ocean, or pond	yes	19	13	17
		no	17	17	16
	Visual access to precipitation and streams	yes	26	20	14
		no	10	10	19
	Water wall	yes	9	19	11
		no	27	11	22
	Fountain	yes	15	18	7
		no	21	12	26

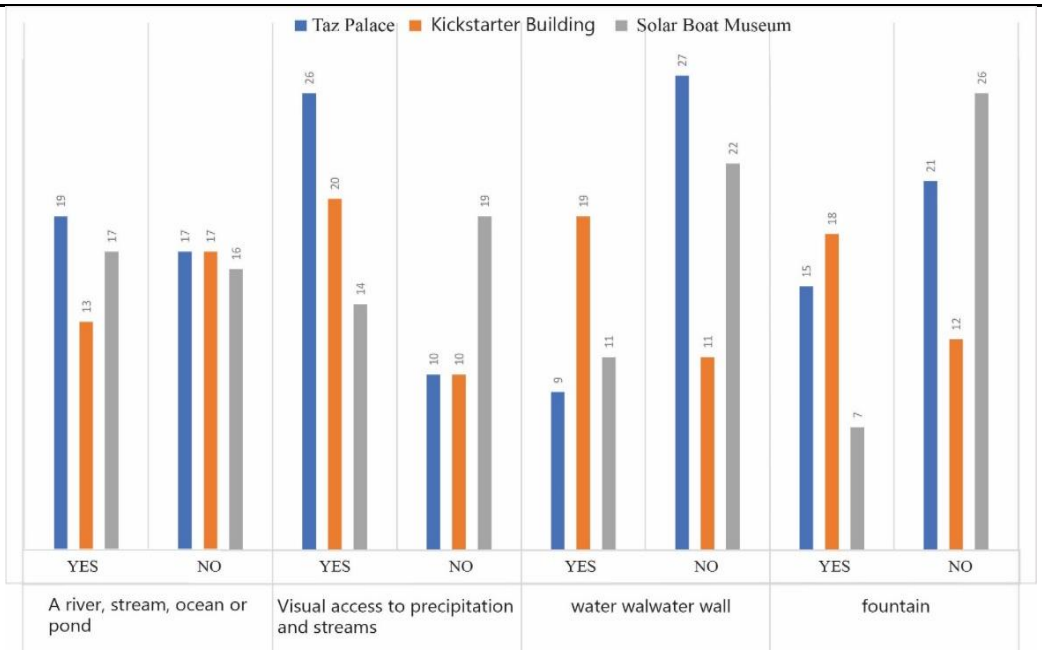


Figure 12. The presence of water scores.

Another quite important division regards the dynamic and diffused light pattern; this pattern can appears weak in some designs, but in these cases, it appeared important, as shown in the positive scores received. (see Table 6 and Figure 13).

Table 6. The pattern of dynamic and diffused light.

	Biophilic Patterns	Response	Taz Palace	Biophilic	Solar Boat Building
Dynamic and diffused light	Daylight from multiple angles	yes	35	27	22
		no	1	3	11
	Direct sunlight and day or seasonal light	yes	33	26	25
		no	3	4	8
	Light distribution	yes	30	27	29
		no	6	3	4
	Ambient diffused lighting on walls and ceilings	yes	27	23	30
		no	9	7	3
	Window treatments to keep out the daylight	yes	26	22	23
		no	10	8	10

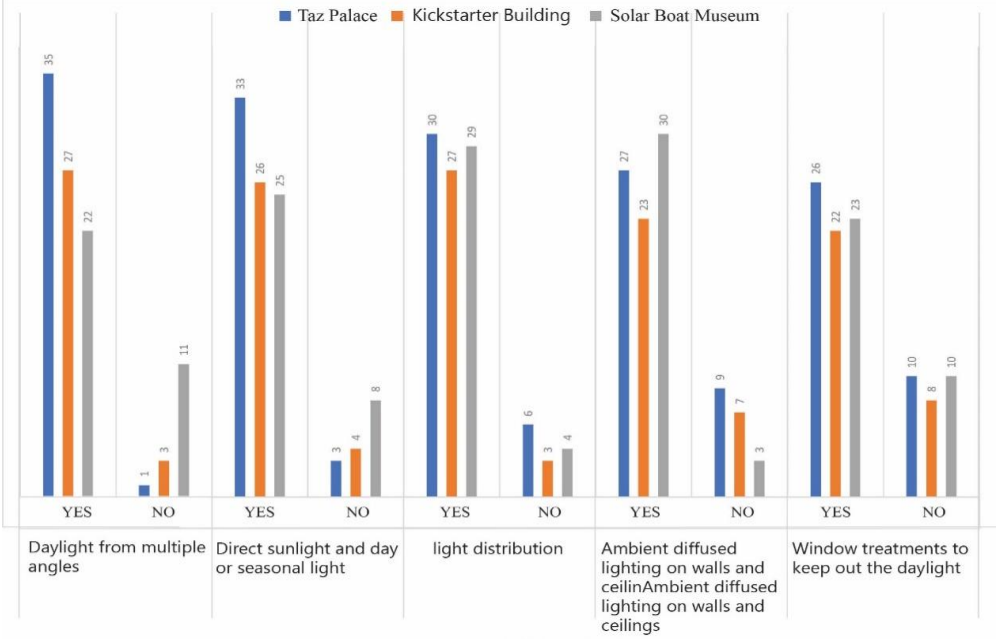


Figure 13. Dynamic and diffused light scores.

This category ends with visual contact with natural systems by seeing weather events, precipitation, and geological evidence; the scores between the Taz Palace and the Kickstarter building were similar, except for the precipitation indicator, as the historic palace has many open spaces, so it has better visual accessibility. Table 7 below and Figure 14 show results.

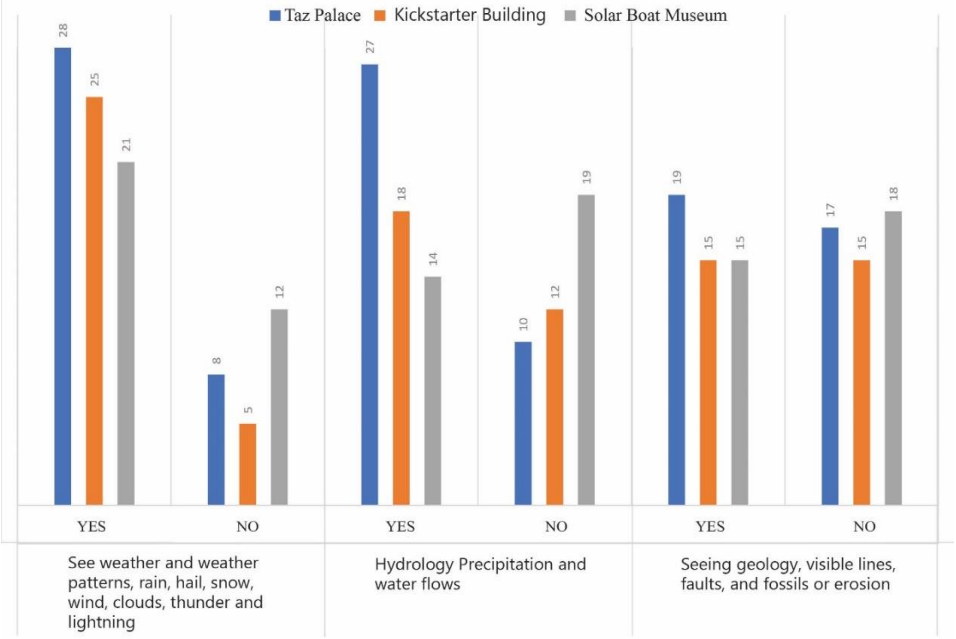


Figure 14. Scores of contact with natural systems.

Table 7. The contact with natural systems pattern.

	Biophilic Patterns	Response	Taz Palace	Biophilic	Solar Boat Building
Contact with natural systems	See weather and weather patterns: rain, hail, snow, wind, clouds, thunder, and lightning	yes	28	25	21
		no	8	5	12
	Hydrology precipitation and water flows	yes	27	18	14
		no	10	12	19
	Seeing geology, visible lines, faults, and fossils or erosion	yes	19	15	15
		no	17	15	18

From this category, students concluded their architectural preference using the following features:

- Using high planting;
- Using windows with proper size overlooking a good landscape;
- Using touchable natural materials;
- Depending on natural ventilation;
- Making open space to connect to the sky;
- Having proper orientation;
- Using masses to achieve shade and shadows;
- Using vertical and horizontal water features;

Ensuring daylighting in most of the space.

The second category focuses on Natural Analogue Patterns, which is divided between borrowing from nature, physical contact, complexity, and order; in other words, it highlights how architectural design lets the user experience natural elements while in the buildings. This category includes the indicators of borrowing from natural designs in the details in carpets, wallpaper, windows, sculpture, furniture, and natural-material columns. These indicators mostly achieved high scores in all buildings, except for freestanding sculpture from natural materials. Table 8 and Figure 15 show results.

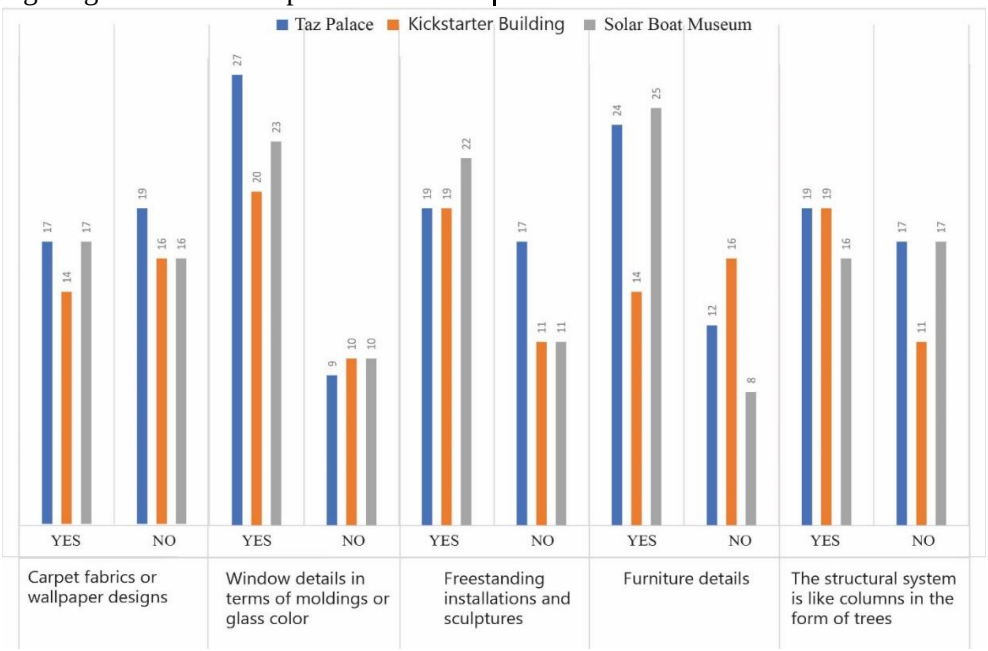


Figure 15. Scores of models borrowed from nature pattern.

Table 8. Models borrowed from nature pattern.

	Biophilic Patterns	Response	Taz Palace	Biophilic	Solar Boat Building
Models borrowed from nature	Carpet fabrics or wallpaper designs	yes	17	14	17
		no	19	16	16
	Window details in terms of moldings or glass color	yes	27	20	23
		no	9	10	10
	Freestanding installations and sculptures	yes	19	19	22
		no	17	11	11
	Furniture details	yes	24	14	25
		no	12	16	8
	The structural system is like trees in the form of columns	yes	19	19	16
		no	17	11	17

The physical contact of the materials is highlighted more in the relation between the user and the walls and facade materials than in the furniture shaping details and the design of paths; this can be reviewed below in Table 9 and Figure 16.

Table 9. Physical contact with nature pattern.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Physical contact with nature	Walls made of wood or stones	yes	29	17	21
		no	7	13	12
	Facade materials	yes	34	24	27
		no	3	6	6
	Furniture shape	yes	25	21	24
		no	12	9	9
	Pedestrian paths	yes	24	14	21
		no	12	16	12

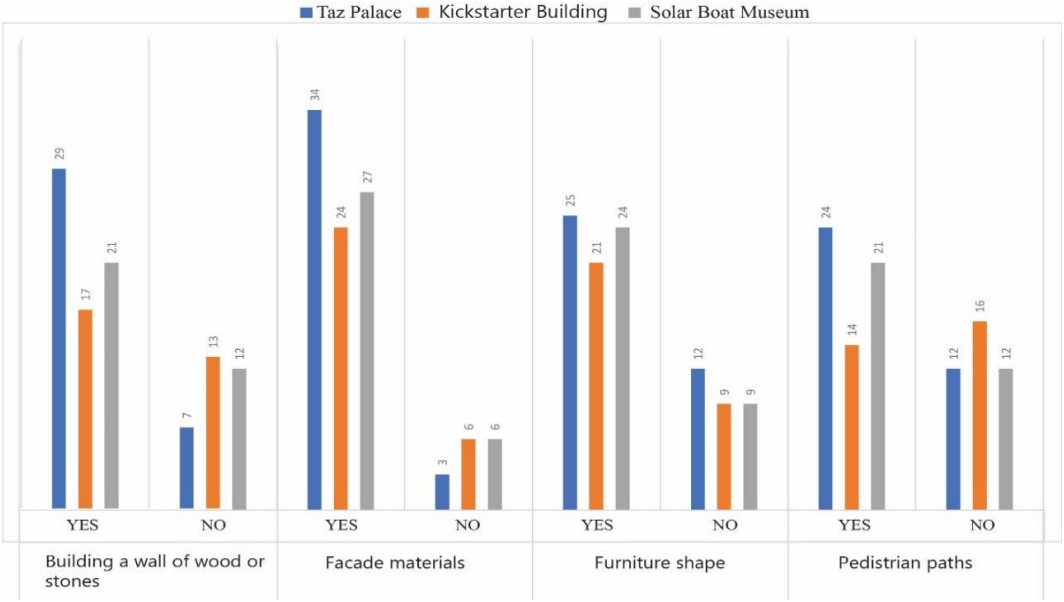


Figure 16. Scores of physical contact with nature.

The complexity and order include natural inspiration in the details of wallpaper, carpets, wall texture, outer structure, mechanical systems, and pedestrian flows; the results are detailed in Table 10 and Figure 17, showing that the highest scores were achieved for wall texture and contour, while the lowest were for the outer structure exposure.

Table 10. Complexity and order pattern.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Complexity and order	Wallpaper, carpet, or other	yes	18	16	17
		no	18	14	16
	Wall texture and contour	yes	30	21	29
		no	6	9	4
	Outer and exposed structure	yes	26	19	19
		no	10	11	14
	Exposed mechanical systems	yes	18	13	17
		no	18	17	16
	Pedestrian and traffic flows	yes	18	18	23
		no	18	12	10

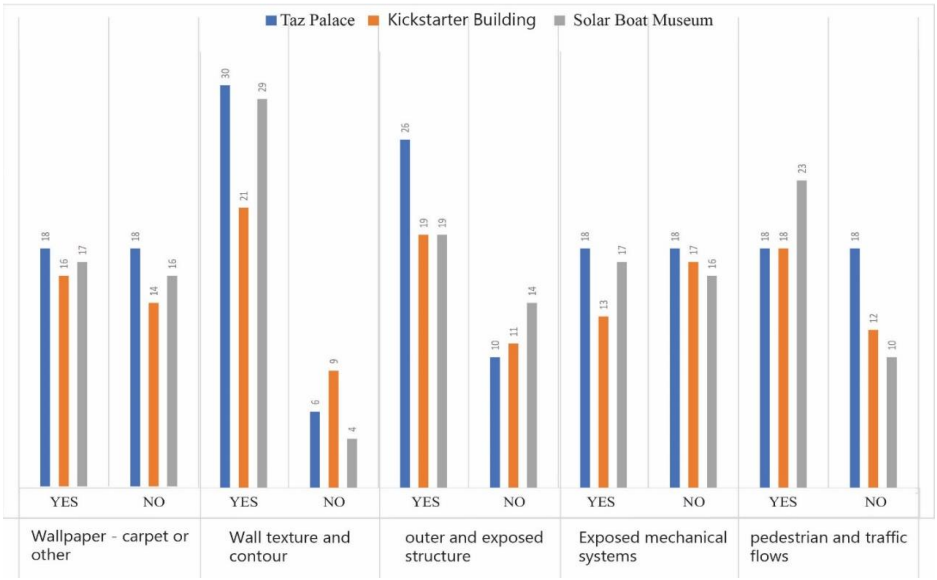


Figure 17. Scores of complexity and order.

From this category, students concluded their architectural preference using the following features:

- Borrowing from nature symbolically;
- Making an area for pedestrians in large-scale projects;
- Using natural materials;
- Designing the flow inside the project.

The third category, Nature of the Spatial Patterns, focuses on the ability of visitors to watch the horizon, refuge and shelter, and mystery and secrecy, while the final indicator is risk. The indicator of watching the horizon mostly regards transparent materials and exposed open plans, which showed the highest scores, in addition to the indicator of mezzanine and landscape shades and bodies of water. Table 11 and Figure 18 show results.

Table 11. Horizon watching indicators.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Watch the horizon	Use of transparent materials	yes	22	20	25
		no	14	10	8
	Exposed open plans	yes	30	16	14
		no	6	14	19
	Open levels—mezzanine	yes	24	18	26
		no	12	12	7
	Landscape includes shade of trees or bodies of water	yes	31	22	17
		no	5	8	17

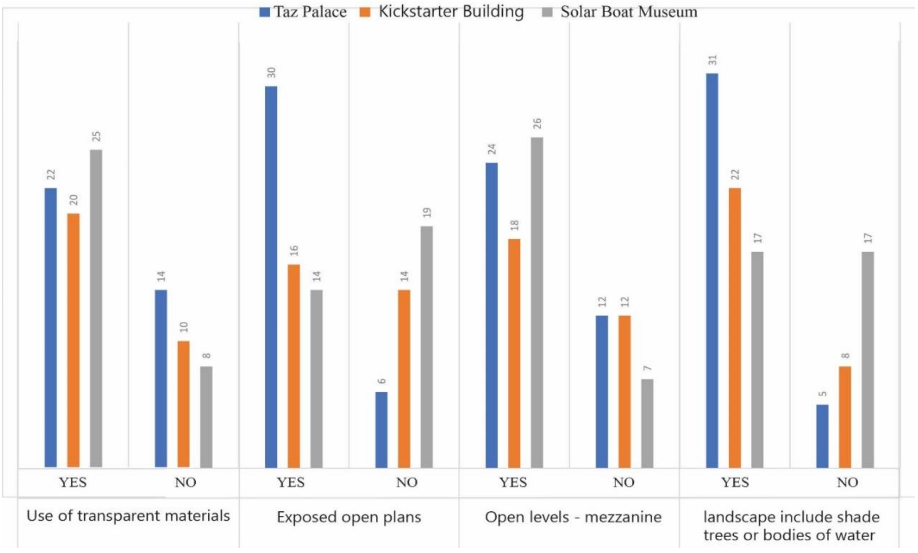


Figure 18. Scores of horizon watching.

Refuge and shelter are considered missed aspects of design, as they focus on spaces to hide from weather events with the ability to watch them, as well as meditation and relaxation spaces, which exist not in purpose but for users' pattern of use, transforming them for this function. Results appear in Table 12 and Figure 19.

Table 12. Refuge and shelter indicators.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Refuge and shelter	Spaces protected from weather or climate	yes	28	21	22
		no	8	9	11
	Spaces for meditation or rest and relaxation	yes	33	25	19
		no	3	5	14

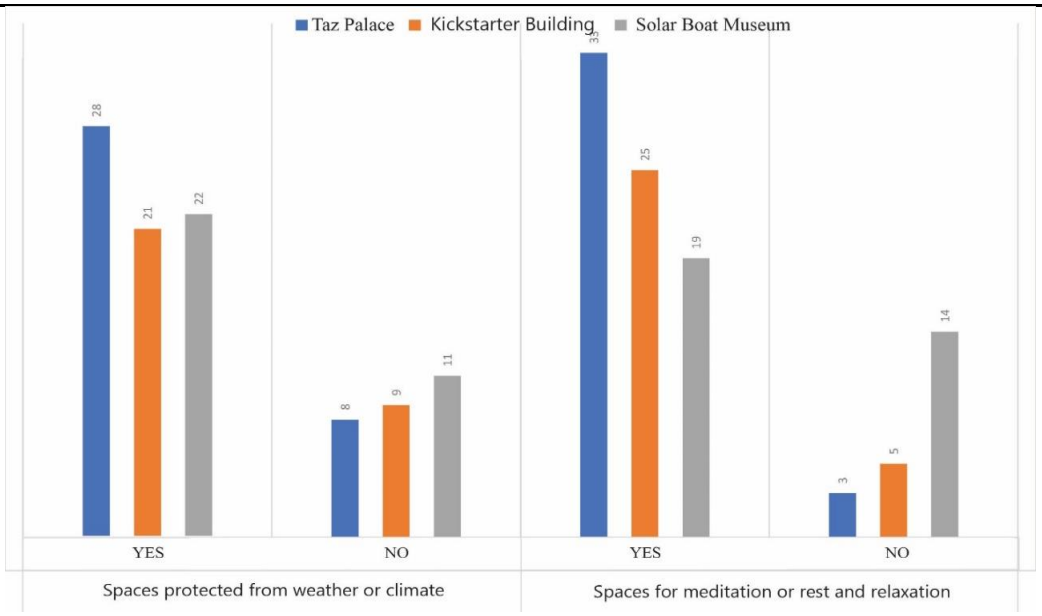


Figure 19. Scores of refuge and shelter.

Many unusual elements exist in the following pattern, which is related to mystery and secrecy, as it includes non-tangible sources, peek windows, and curving edges which hide the walls behind them, in addition to winding paths; all of these items are very present in the Taz Palace, and moderately present in the Kickstarter building, while the Solar Boat showed low rates. Results appear below in Table 13 and Figure 20.

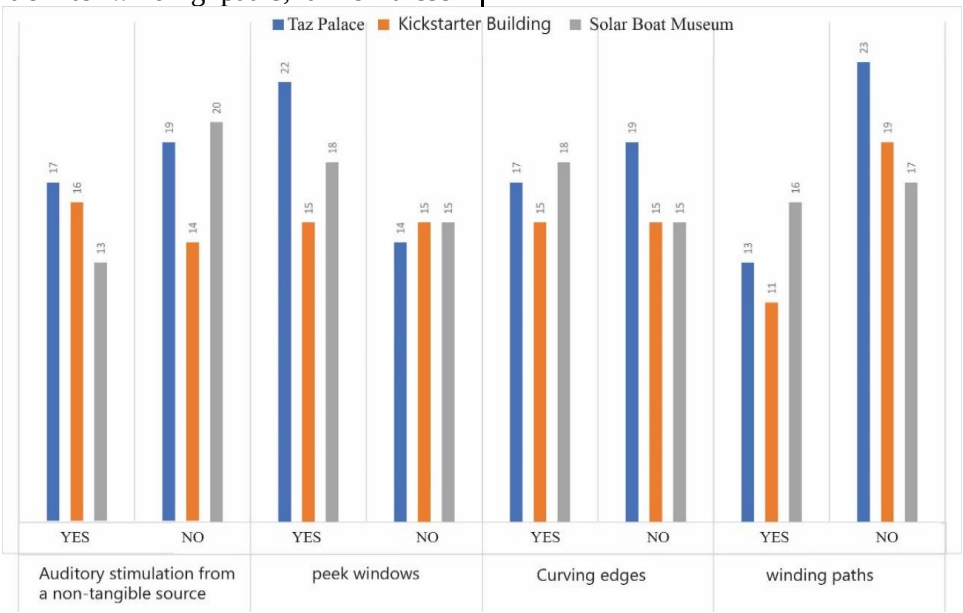


Figure 20. Scores of mystery and secrecy indicators.

Table 13. Mystery and secrecy indicators.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
Mystery and secrecy	Auditory stimulation from a non-tangible source	yes	17	16	13
		no	19	14	20
	Peek windows	yes	22	15	18
		no	14	15	15
	Curving edges	yes	17	15	18
		no	19	15	15
	Winding paths	yes	13	11	16
		no	23	19	17

Risk represents the end of this category and consists of double-height spaces, cantilever, infinity edges, completely transparent floors, and ends that defy gravity; those items are highlighted with scores in Table 14 and Figure 21.

Table 14. Risk indicators.

Biophilic Patterns		Response	Taz Palace	Biophilic	Solar Boat Building
risk	Double-height space with balcony or platform	yes	25	17	24
		no	11	13	9
	Architectural cantilever	yes	14	12	15
		no	22	18	18
	Infinity edges	yes	14	15	16
		no	22	15	17
	Transparent facade from floor to ceiling	yes	19	20	19
		no	17	11	14
	Designs that defy gravity	yes	20	18	16
		no	16	12	17

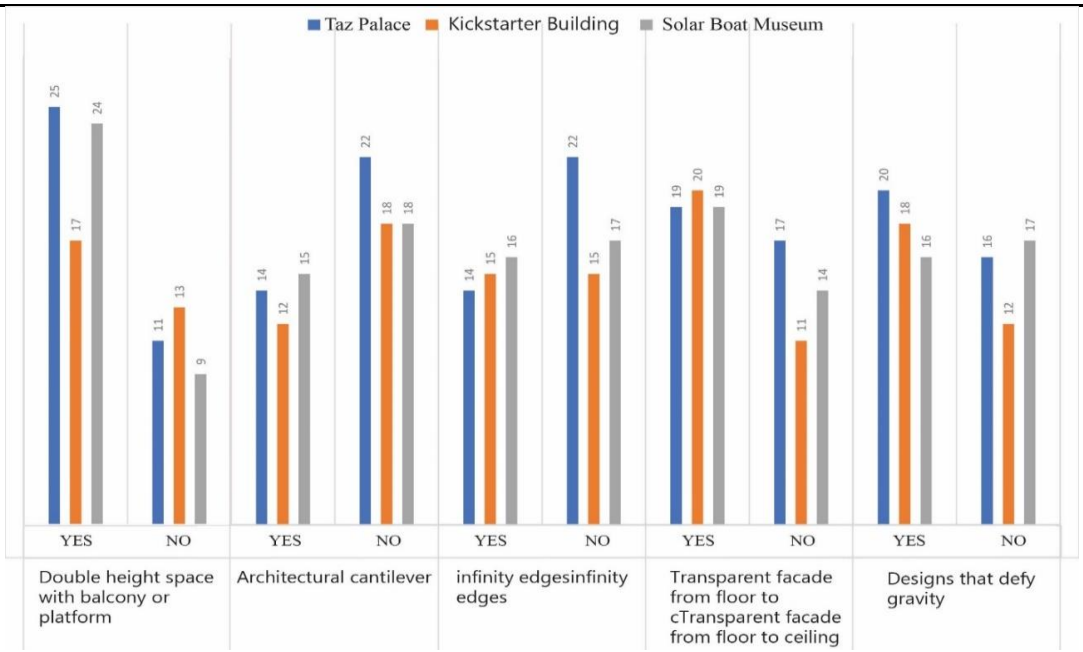


Figure 21. Scores of risk indicators.

From this category, students concluded their architectural preference using the following features:

- Transparent materials;
- Exposed open plans;
- Open levels- mezzanine;
- Spaces for meditation or rest and relaxation;
- Auditory stimulation from a non-tangible source;
- Double-height space with balcony or platform;
- Architectural cantilever;
- Infinity edges;
- Transparent facade from floor to ceiling.

The accumulative outcome of students understanding of biophilic applications in architecture, focused in the following framework as a guide to teach this topic to architectural department students as shown in figure 28.

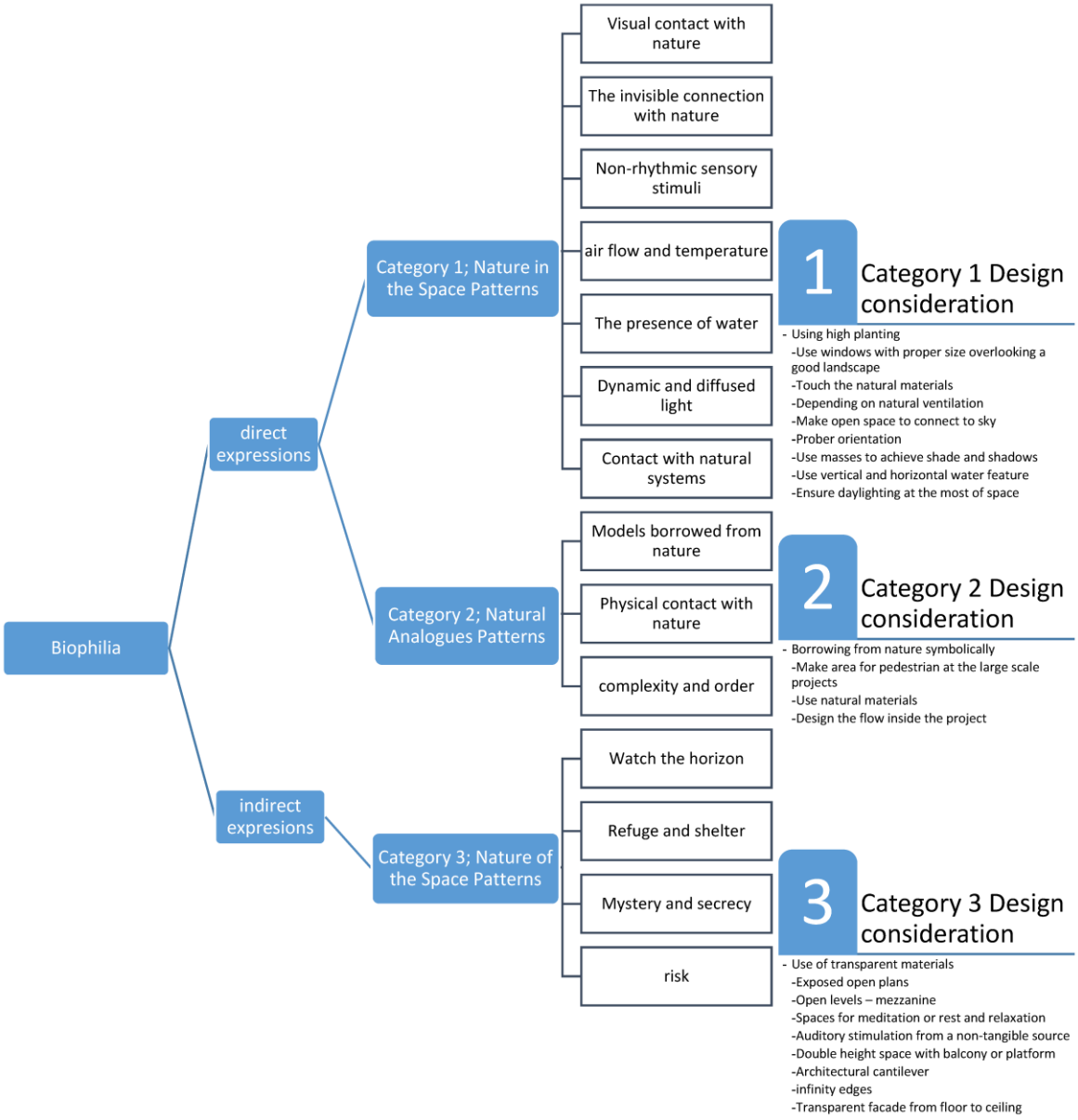


Figure 22. Framework for students' understanding of applying biophilia to their designs.

6. Conclusions

The senior architecture students who took part in the VR experience gleaned fresh insights into the cases they were studying and extracted design considerations to meet every category of biophilic pattern and its proper style of architectural expression, whether to be expressed in their designs either direct or indirect. By focusing on what matters most in design, this study generated a questionnaire-based framework for biophilic design considerations in architectural education which had to be taken in consideration while dealing with teaching biophilia.

The students learned a great deal about expressing design aspects in a contemporary manner as they progressed from the traditional structure, which typically adheres to the extracted considerations, to the Kickstarter building, and finally to the Solar Boat building.

The first category, "Nature in the Spatial Patterns," has many examples because it was the first pattern tested for its existence and expression. The second category, "Natural Analogue Patterns," is broken down into sections on the following themes: borrowing from nature, physical contact, complexity, and order; in other words, it emphasizes how the architectural design allows the user to feel a connection to the natural world while interacting with manufactured structures. The third category, Nature of the Spatial also connected the students to very rich elements to be considered in design.

The final outcome of this research focused in framework of the consideration of teaching biophilia to architecture students highlighting the main considerations and expression methods, they have reached great depth in understanding the philosophy.

Student replies revealed a profound understanding of how to use biophilia to design better architecture

which is both sustainable and beautifully communicated to nature.

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