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The impact of biophilic attributes on university students level of Satisfaction: Using virtual reality simulation

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ABSTRACT

Biophilic design is a new approach that can enhance human psychological well-being. Most recent studies focus on applying biophilic design to hospitals or office buildings, not academic buildings. While usually ignored, students' level of satisfaction is one of the most important key indicators for a successful learning environment. This paper aims to identify the biophilic design attributes that can potentially contribute to enhancing the students' level of satisfaction. This will be done through an experimental research design using virtual reality in a design studio at The British University in Egypt. Each participant (N = 52) was exposed to the existing condition and then the virtual experience. Before and following each exposure, cognitive and performance assessments were administered, this assessment was analyzed with the use of SPSS. Results show a highly positive impact of Natural Lighting, Natural Ventilation Greenery, Large Windows, Indirect Connection to Nature, and Natural Finishing Material on the student's level of satisfaction.

1. Introduction

According to previous studies, university students experience higher rates of depression than the general population, and they are also more subjected to stress factors due to uncertainties such as their studies, their families, and their financial struggles. Furthermore, the university environment creates intense competition among colleges, and students tend to go through many challenges that increase their stress levels to maintain high academic standards [1]. In addition, students are also subjected to other external psychological pressures from things like relationships, identity, and life circumstances. Studies have shown that biophilic design is one of the best ways to improve student performance on campus. According to the biophilia hypothesis, people are inherently drawn to the natural environment, and being cut off from it harms their physical, psychological, and social well-being [2]. Thus, integrating biophilic design into university campuses is crucial to reducing students' stress levels and improving their performance. Virtual reality (VR) is a new technology that gives users a more immersive experience while exposed to outdoor environments [3]. Thus, virtual reality is considered a reliable tool to measure students' responses in this paper. The majority of the research focuses on the environmental aspects of biophilic design. The deficiency is in focusing on metrics that are classified as space characteristics [4]. The main aim of this study is to identify the biophilic design attributes that can potentially contribute to enhancing the student's level of satisfaction in design studios on the university campus. The study tested the applicability of these biophilic physical attributes in the design of studios on university campuses in the context of Egypt to study their impact on students' performance, cognition, and level of satisfaction. This was accomplished through the use of virtual reality simulations as the primary empirical tool [3] and the assignment of psychological impact via Wisconsin and trailed tests.

2. Literature review

2.1. Biophilia hypothesis and its important characteristics

The Greek roots of the word biophilia are "bio," which means "life," and "philia," which means "love" (Orr, 1993). The biophilia theory states that people have a natural tendency to seek out connections with other living things and the natural world. Erich Fromm, an American psychoanalyst of German descent, coined

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the term "biophilia" in The Anatomy of Human Destructiveness (1973) and defined it as "the intense love of life and of all that is alive." The phrase was later utilized by American biologist Edward O. Wilson in his 1984 book "Biophilia," which made the case that humans' propensity to concentrate on and identify with nature and other living things has, in part, genetic roots. According to the biophilia hypothesis, people are wired to want to engage with nature [5,6].

2.2. Biophilia attributes

There are several advantages to biophilic design for people. Benefits to the body, mind, and behavior could all be directly related to the biophilic elements' successful use. Such benefits might manifest in enhanced health, increased comfort, decreased blood pressure, and physical fitness. Additionally, the advantages of mental health can be summed up as less anxiety, better personal performance, better problem-solving skills, and improved creativity and cognition. In addition to the improvement of behavioral attitude, other benefits include enhanced social interaction, decreased aggression, greater coping and mastery abilities, as well as increased focus and attention field [3]. Applying several design techniques that integrate various experiences using several qualities is required for biophilic [4,6-8]. The direct experience of nature, the indirect experience of nature, and the experience of space and place are the three main experiences that these characteristics are classified under the following (see Fig. 1):

- Indirect experience of Nature:

Relies on direct interaction with environmental elements, such as natural light, air, plants, animals, water, and landscape [7,8].

- Direct Experience with Nature

Is defined as the availability of natural representations or natural pictures. In other words, it is the transformation of nature from its original forms into patterns or forms that have natural properties. This could be done by applying images or artwork, using natural materials for finishing and/or furnishing, creating ornamental pieces that are inspired by forms or shapes found in nature, or by a process that occurs in the environment and is significant to the evolution of humans, such as the passing of time, aging, information richness, or natural geometry [7,8].

- The Experience of space and place

This comprises unique elements of the environment that contribute to improving human health and well-being. Prospect refuge, organized complexity, mobility, and wayfinding are a few examples. As improving all our sensory experiences is one of the key goals of biophilic design. When incorporated into built environments, this multimodal encounter with nature has a significant positive impact on comfort, happiness, enjoyment, and cognitive function [7,8].

2.3. Biophilic design and environmental psychology

The Theory of Environmental Preference is one of the environmental psychology theories that has received the most attention and has been studied extensively for years, according toward wide literature. In addition, environmental psychology promotes the premise that the physical environment influences human behavior, feelings, and perceptions of health [9]. A theoretical tool based on evolutionary psychology ideas is the preference matrix. Humans have been described as information processors by Kaplan, a concept derived from evolutionary psychology [10]. To survive, a person must first be able to identify objects in their environment, then predict the future, and ultimately weigh the implications. This procedure creates a brain structure known as a "cognitive map." According to the theory of preferences, perception, and cognition are the two fundamental requirements that humans have regarding their environment. When these two demands intertwine with these two levels of consciousness, four variables result. Quick and immediate perception and inferential perception are two criteria that might be used to categorize these two states of consciousness. These four elements—coherence (immediate perception), complexity (immediate cognition), legibility (exploratory perception), and mystery—are together referred to as "information variables" (exploratory cognition) [7]. To predict preferences, these four variables have been introduced. There is another classification in addition to the previously mentioned one that divides environmental information into two and three dimensions. As a result, "coherence" and "legibility" are considered as two perceptual factors that help individuals make sense of their surroundings, and "complexity" and "mystery" are considered as two further environmental preference factors that draw people in by offering variety in the environment's content (see Fig. 2).

2.4. Biophilic design and university campus

According to Kellert, one of the most crucial factors in improving the performance of a space is the use of natural materials, including vegetation in the interior, as well as the allowance of natural ventilation and lighting. The physical and mental health of a person is significantly influenced by their surroundings, whether they are natural or artificial; as a result, his or her well-being will be improved [6]. Human well-being can be enhanced by residing in a green environment that promotes a healthy lifestyle, which has a direct impact on people's behavior, productivity, performance, and learning abilities. Students that study in a biophilic atmosphere are more successful and have excellent learning capacities, as claimed by Grinde & Grinde-Patil (2009) [11].

According to the international literature, there are four main indicators of the quality of life of university students: physical health, psychological well-being, social relationships, and environmental comfort. These factors have a direct impact on students' cognition and performance This paper focuses on psychological well-being and environmental comfort (Table 1) [12-19].

International literature claims that exposure to nature improves focus and activates the brain more during the learning process. Furthermore, biophilic designs have been shown to stimulate the senses, which improves student performance. Nature's aesthetic beauty sparks our interest, curiosity, creativity, and imagination. Where the visual sense is present, whether directly or indirectly, it improves cognitive reactions. Thus, the absence of visual contacts, such as in rooms without windows, results in feelings of boredom, exhaustion, and physical and psychological abnormalities. The same argument can be made for the sensations of hearing and scent, which directly affect our mental and emotional health. In general, research has demonstrated that spaces that feature elements of the biophilic design have positive effects on both physical and mental health. These qualities include using natural materials, adding more plants indoors to bring nature indoors, providing green roofs, and maximizing green spaces around buildings. They also include more levels of daylighting than are typically required, good window placement that can frame exterior views, different lighting levels, and using natural materials. Students may experience less stress and be better able to concentrate on their studies in educational settings that incorporate these biophilic design elements [2].

Biophilia Themes and Attributes

Indirect experience of Nature		Direct Experience of Nature		The Experience of space and place	
Light	Exposure to natural light is essential for human health and welfare because it enables us to distinguish between day and night and different seasons in response to the sun's position and cycle. Being aware of natural light might make it simpler to navigate and find your way. A person may feel more relaxed and content as a result	Natural Images	The representation of nature in the built world, including plants, animals, landscapes, water, and geological features, can provide both an emotional and an intellectual sense of fulfilment	Prospect Refuge	Prospect and shelter both have advantages that were complementary, which is how people evolved to be adaptive. Prospects are broad perspectives of the immediate environment that allow people to see both opportunities and hazards, whereas refuges provide places of safety and protection.
Air	Natural ventilation enhances productivity and human comfort. The perception of natural ventilation in the built environment can be improved by changes in air flow, temperature, humidity, and air pressure.	Natural Material	The positive visual and tactile reactions that natural materials typically produce when they are altered are hard to duplicate in man-made materials. Natural construction and ornamental materials including wood, stone, wool, cotton, and leather are well-known examples.	Organized Complexity	People are drawn to both natural and artificial environments because they are brimming with possibilities and opportunities. But convoluted approaches are frequently disorganized and perplexing. The most gratifying surroundings have elements of complexity, but complexity that is viewed in a systematic and orderly manner
Water	A variety of design elements, including views of prominent water features, fountains, aquariums, constructed wetlands, a nd others, may sate the need to touch water. Water is frequently the aspect of the built environment that people like the most when it is perceived as being clean, in motion, and experienced via multiple senses	Natural Color	Because humans are a daytime creature, color has long been a crucial tool for locating these resources. Given today's ability to produce artificial hues, especially vibrant ones, using color effectively in the built environment can be difficult	Integration of Parts to Wholes.	People are drawn to settings where various components combine to create a harmonious whole. The perception of an emerging whole can frequently be caused by distinct and unambiguous borders, as well as the sequential and successional connectivity of regions.
Plant	The utilization of vegetation, especially flowering plants, is one of the most efficient ways to integrate the direct experience of nature into the built world.Plants can lessen stress while enhancing comfort, physical health, performance, and productivity	Simulating Natural Light and Air	Indoor lighting and purified air are already commonplace due to advances in building technology and design. Static conditions have frequently been the trade-off, which can be physically and mentally taxing. Artificial lighting can mimic the spectrum and dynamic features of natural light.	Cultural and Ecological Attachment to Place	A preference for familiar places demonstrates this territorial inclination, which can be boosted through both cultural and ecological causes. Culturally relevant designs encourage a sense of place and the distinct human identity of a setting. Ecological linkages to a place, such as knowledge of local flora and wildlife, native landscapes, and particular weather patterns, can also foster an emotional attachment to a place
Animals	Positive interactions with animal life can be facilitated by design elements like feeders, green roofs, gardens, and aviaries as well as creative application of modern technologies like web cams, video, binoculars, and spotting scopes.	Naturalistic shape and form	These naturalistic forms can be immensely diverse,ranging from the leaf-like patterns on columns to the plant shapes on building facades to the animal impersonations woven into fabrics and coverings.		
weather	Direct exposure to outdoor conditions or creating weather-like conditions by altering the airflow, temperature, barometric pressure, and humidity can enhance humans mood and performance	Natural geometry	Natural geometry is the study of mathematical properties that occur frequently in nature. Hierarchically organized scales, fluid artificial geometries rather than rigid ones, self-repeating but distinct patterns, and more are examples of these		

Fig. 1. Biophilia Themes and Attributes [4 3,6].

Additionally, the university environment is one of intense competition and high academic standards, which makes it more challenging for many students to manage their stress levels. There are also internal pressures from things like relationships, identity, and life circumstances. University students can benefit from incorporating biophilic design elements into classroom spaces by creating stress-relieving environments that also foster creativity and cognitive development [4]. It has been noted that workplaces, primary schools, and healthcare settings are the main focus of recent studies on the biophilia theory. Other research also focuses only on the advantages of biophilic architecture in harsh regions regarding natural connectedness and energy savings. Studies on the benefits of biophilic design in the academic setting are, however, scarce. The main focus of this research is the application of biophilic design in a university context to improve student performance and cognition. According to studies and evidence from the international literature, there are key characteristics that directly improve pupils' academic achievement. These elements are Visual connection with the nature [20 21 22 23 24], the Presence of Water [25 26], Dynamic and Diffuse light [27 28], Connection of natural

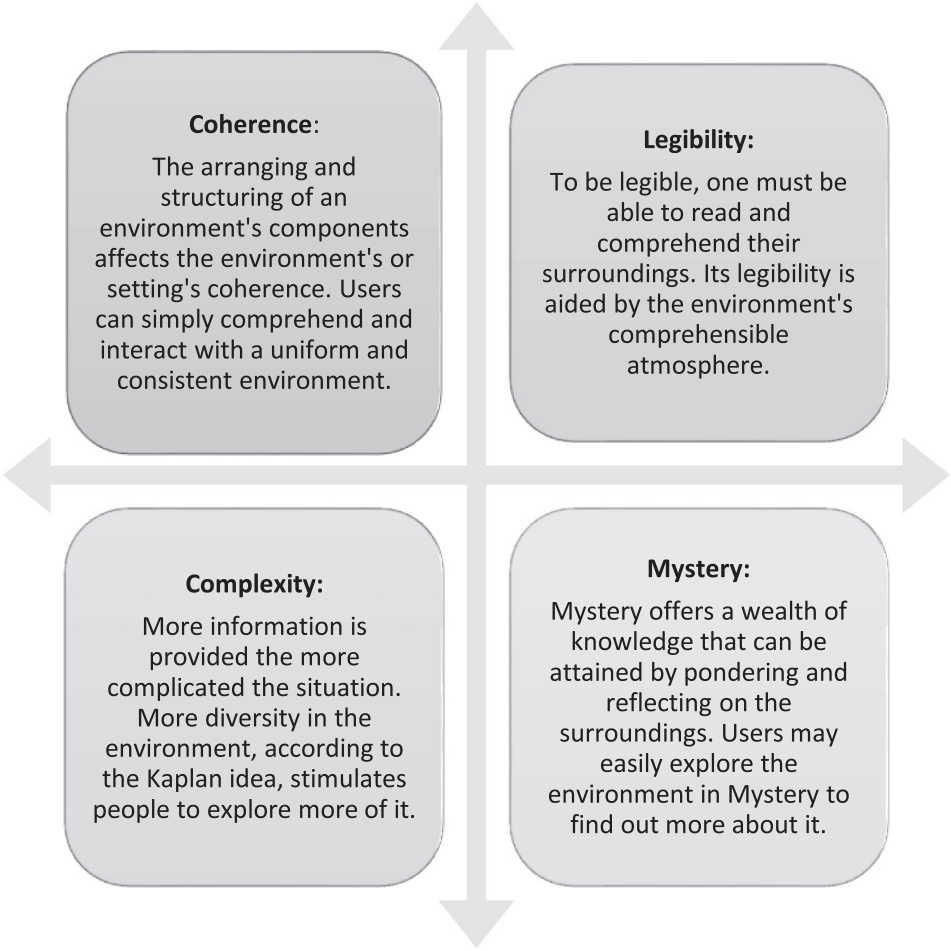


Fig. 2. Biophilia and Human Psychology.

Table 1
Correlation between Biophilic Attributes and PRS and Level of Satisfaction.

Biophilic Attributes	PRS	Level of Satisfaction
Artificial Lighting	0.063	−0.148
Natural Lighting	**0.368****	**0.888****
Artificial Ventilation	0.183	0.023
Natural Ventilation	**0.301***	**0.320***
Presence of Greenery	**0.466****	**0.872****
Presence of water features	−0.101	0.151
Large Windows	**0.372****	**0.799****
High Ceiling	−0.029	0.175
Indirect Connection to nature	**0.378****	**0.814****
Natural Finishing material	**0.367****	**0.715****
Sound of nature	−0.18	0.076

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

system [28 29], Material connection to nature [19;30;31], Prospect/Refuge [24;32], and Thermal and airflow variability [29;27;16;33;34], as shown in the Fig. 3 below examples for the biophilic patterns presentation in the built environment.

3. Research design

Stress reduction, as assessed by heart rate, blood pressure, cortisol levels, and psychological response, has been a major focus of biophilia research. The cognitive response has been the subject of more investigation. The idea that the brain behaves differently when exposed to nature dates back to the 1800 s. It was often believed that the brain functions at a level of "soft fascination" when in nature [35]. This subsequently served as the foundation for the Attention Restoration Theory (ART), which proposed that when in nature, certain areas of the prefrontal cortex go into deep sleep [7]. Humans can think more clearly after this mental break.

This paper used an experimental design (single-group interrupted time-series design), this was due to the requirement of testing virtual-world parameters of the designed setting in the British University in Egypt to one group of selected architecture students through a pretest and protest [36]. The independent variables in this study were the presence or absence of the biophilic attributes and the demographic variable of gender added because it received attention in the literature as an area of interest in the VR research [36,37].

According to the selected restorative objectives (compatibility and fascination), the corresponding design patterns were imitating scenes of nature, imitating water in nature, stimulation of senses, activities, and functions, and the space character. Due to its limitations, a water feature was difficult to implement as a movable object in the Virtual Reality (VR) model, so it was added as a sound only. The use of those biophilic attributes was based on the international case study analysis and the participants' choices from the previously mentioned questionnaire for the alternatives to the redesign. The experiment took place in October when the weather was moderate to avoid any seasonal mood swings. It was carried between the days 15/10 till 30/10. Due to the limitation of the VR equipment (this experiment was carried out with one VR pair

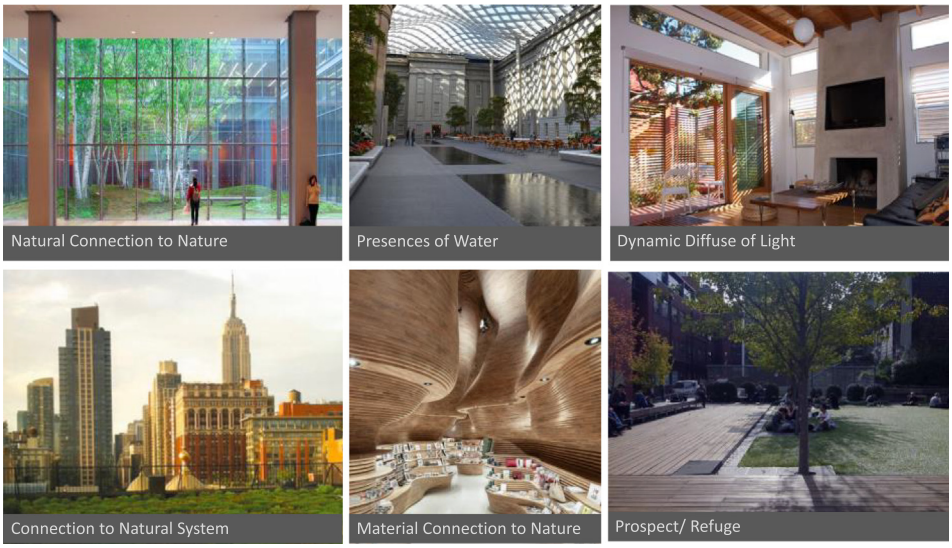


Fig. 3. Biophilic Attributes Concluded from the International Literature.

of glasses), participants were divided into groups, and each day, 10–15 participants were examined. Each of the participants was subjected to 10 min of working in the room as is, and then a questionnaire based on the PSR scale was given to each of them to rate the existing condition. Then, cognition and performance tests were given to the participant under the supervision of psychologist Habiba Mahrous (psychologist at El-Mahsfa Hospital) and Prof. Anssam (a professor in the psychology department at The British University in Egypt) (see Fig. 4).

3.1. Procedure

A survey was conducted among the users of the design studios at the British University in Egypt to evaluate them. An evaluation of the drawing studios at the British university took place to evaluate the studios' status. 68 participants engaged in this survey, of which 52% were students and 47% were staff members at the university. In addition, 88% of the sample are frequent users of the drawing studio daily, and 12% use the drawing studio a few times per week. And this makes the sample a reliable source due to the high usage of the room and the consensus among the students and staff members that the room's poor condition made it more attractive for the study. The survey shows that 64% of the participants (n = 68) agree on the poor condition of room (001), located in building A, in comparison to the other rooms, which were rated at a higher satisfaction level than this room. The survey showed that drawing room 1, located in building A, was the least preferred studio by students and staff members. The room was selected due to its poor condition; this paper aims to enhance the room's performance in terms of the level of satisfaction and students' cognitive performance using biophilic attributes (see Fig. 5). The microclimatic and geometrical data were calculated for the selected design studio. The experimental analysis shall be subjected to participants that are users of the space, with stratified random sampling into one group (n = 52). Participants vary according to gender and degree year.

3.2. Research methodology

This paper aims to identify the main biophilic design attributes that have the potential to enhance students' satisfaction in design studios on university campuses. This mainly relies on experimental simulation methodology that encompasses the use of VR tool as the primary simulation tool in reference to previously used experimental approaches on graphical environments [3,38]. The study investigates the room's performance in terms of the level of satisfaction and students' cognitive performance through the use of biophilic attributes. Furthermore, to test the proposed designed biophilic setting, the British University in Egypt was selected as the setting for the experiment. through virtual reality world parameters, this study relied on an experimental design strategy, in reference to previously used experimental approaches on the

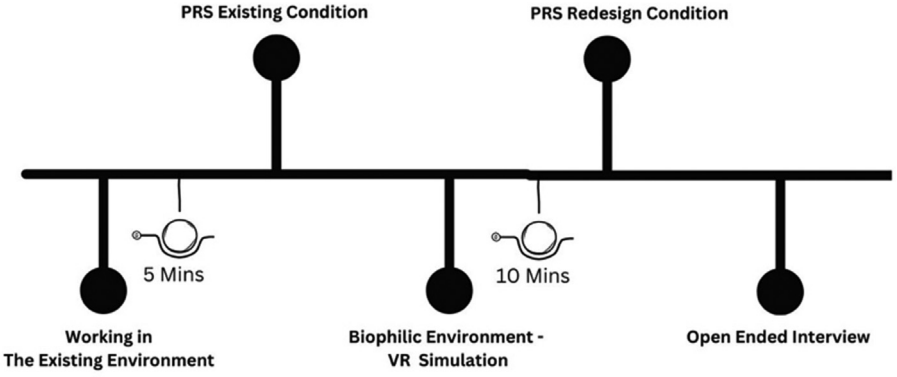


Fig. 4. Single-group interrupted time-series design for the selected design studio.

Fig. 5. Existing Condition Design Studio 1.

graphical environment. Additionally, most of the recent studies show that the use of VR can give the same results as physical environment exposure [39-43].

3.2.1. Sampling

This study is considered a psychological experiment, and choosing an appropriate setting to conduct the study is crucial to ensuring reliable and valid results from the selected sample. The sample (architecture students) was selected based on a stratified random sampling technique [36]. Participants were initially selected for the aim of this study according to certain criteria as follows:

- Being a user of the selected Design Studio.
- Students should be in year 3 or year 4 to be familiar with the architectural elements.
- They are in a relatively good emotional and physical state.

As a result, this reality required a random sampling method, which led to the creation of an experimental design. However, the research methodology included random assignment to treatment groups to get more significant results. The most effective way to manage validity concerns is through randomization within the group, which takes into account additional external factors that can have an impact on the variables under investigation.

The number of participants was dependent on their presence throughout the experiment and testing and was based on the recommended sample size determined for the independent sample studies that could be employed in power analysis. Because the experiment study relied on the strength of the treatment effect and hypothesis testing rather than population sampling, Participants were as below:

The population for this study consisted of users who are familiar with the Design Studio 001 building A (The British in Egypt), the sample size for the selected group was N = 52. To match participant data across the many data collection tools utilized in the study, participants were number coded. The virtual reality system was familiar to all of the participants. Participants in the experiment were asked to rate their perceived emotional and physical state according to their level of satisfaction (very dissatisfied, dissatisfied, neither satisfied nor satisfied, satisfied, and very satisfied), and it was discovered that there were differences between the groups in the overall emotional and physical state during data collection at the beginning of the experiment.

3.2.2. Procedure

An experimental design (single-group interrupted time series) was applied through a pretest and protest [36]. The independent variables in this study were the presence or absence of the biophilic attributes. The study focuses on the selected restorative objectives (compatibility and fascination), the corresponding design patterns were imitating scenes of nature, imitating water in nature, stimulation of senses, activities, and functions, and the space character. Due to its limitations, a water feature was difficult to implement as a movable object in the Virtual Reality (VR) model, so it was added as a sound only. The use of those biophilic attributes was based on the international case study analysis and the participants' choices from the previously mentioned questionnaire for the alternatives to the redesign see Fig. 6.

3.2.3. Assessment before and after VR simulation

After the demographic data gathering, first was the testing of the satisfactory level of students and their performance and cognitive skills in the existing room conditions, and these readings were taken another time after the VR simulation. Students were asked to rate their level of satisfaction on a Likert scale from 1 to 5, where 1 was the least satisfied and 5 was the most satisfied. Then they were asked to rate the design studio according to the PRS scale mentioned in Fig. 7. Then students were asked to identify which of the selected architectural elements (artificial lighting, natural lighting, artificial ventilation, natural ventilation, the presence of water, large windows, a high ceiling, or an indirect connection to nature) were extracted from international literature as mentioned before and edited by the author after an open-ended interview with students discussing the elements that they need in this room to enhance their performance. The sound of nature, a natural finishing material, influenced their answers and ratings of its impact on the same Likert scale.

After the assessment of the existing conditions, participants went through psychological testing, which was also taken at another time after the VR simulation. This phase consists of two parts: part one was responsible for students' visual accuracy and performance, and A cord sorting test known as Wisconsin Card Sorting, recommended by the psychologist Dr. Anssam, measures executive function and requires the ability to use an appropriate problem-solving strategy across changing stimulus conditions to obtain a goal. It can also be used to measure such higher-level cognitive functions as attention, perseverance, abstract thinking, problem-solving, working memory, visual processing, and set-

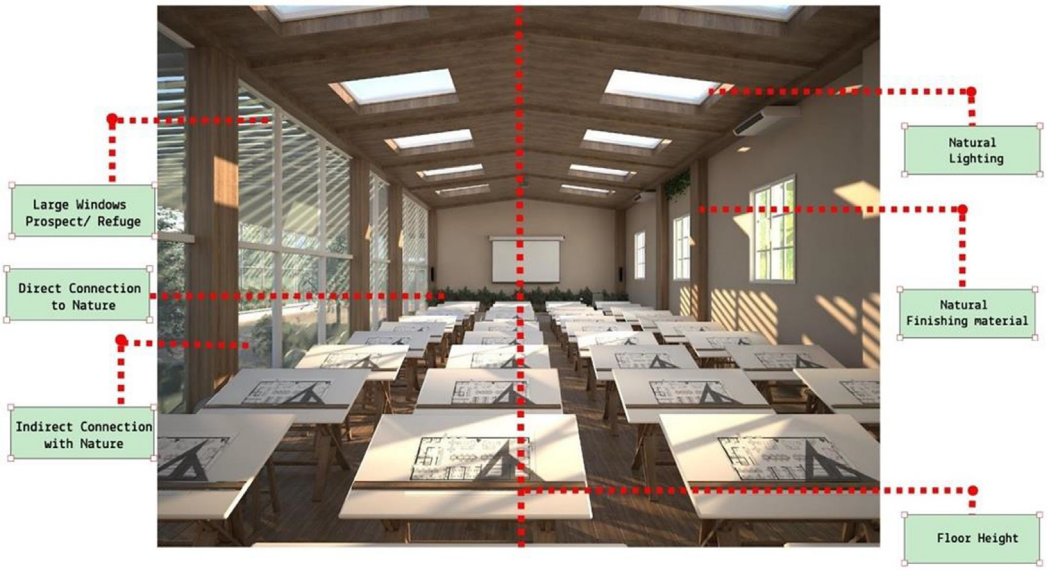


Fig. 6. Proposed Redesign Analysis.

Fascination	
	In places like this my attention is drawn to many interesting things
	Places like that are fascinating
	In places like this it is hard to be bored
Being Away	
	Places like that are a refuge from nuisance
	To get away from things that usually demand my attention I like to go to places like this
	To stop thinking about the things that I must get done I like to go to places like this
Coherence	
	There is a clear order in the physical arrangement of places like this
	In places like this it is easy to see how things are organised
	In places like this everything seems to have its proper place
Extent	
	It is easily to see how things are organized here
	The existing elements belong here
	There is a clear order in physical arrangment in this place to a simulation through design builder software.

Fig. 7. Perceived Restorative Scale [19].

Fig. 8. Example of Virtual Reality Simulation Participants.

shifting. The test can be administered to people aged from 6.5 years to 89 years [44]. It is an online test, and participants were asked to sort cards based on number, color, or shape. The software changes the rule every 10 cards, and it is required that the participant guess the new rule. Some errors are expected from the participants while changing roles, and this was taken into consideration while assessing the scores. as shown in the figure below as an example of the required sorting technique.

The second part of the psychological testing was the Trail Making Test, which is a neuropsychological test of visual attention and task switching. The test consists of parts A and B. Part A measures visual scanning and psychomotor speed, and Part B measures working memory and executive control, such as flexibility of thought. The tests consist of 25 circles that are dispersed throughout a piece of paper in both Parts A and B of the test. The examinee must link the circles in Part A, which comprises circles numbered 1 through 25, in increasing order. The examinee must follow the same rule as in Part A, which is to connect the circles in ascending order, but with the additional task of alternating between both the numbers and the letters, as in 1-A-2-B-3-C and so forth. In part B, the circles include numbers (1 through 13) and letters (A through L). Before starting the test, participants were given a demo to solve to understand how the test worked and to avoid any errors, as shown in the figure below. For the complete test, please check Appendix No. 1 [45].

Students are subjected to virtual reality for 10 min, as shown in Fig. 8; at the same time, they are subjected to some additions, such as adding sounds from nature through the VR handset, as well as using a fan on a low-speed to simulate all of their senses. After spending 5 min in the simulation, participants are asked about their feelings towards the provided setting in terms of light, colors, plantations, ceiling height, finishing materials, sounds of nature, and cross ventilation.

4. Results

The following sections present the results of the analysis of the data collected through the survey questionnaires. It should be noted that the reliability of the ratings was tested with a Cronbach Reliability Test and yielded a relatively high Cronbach's alpha of 0.75.

4.1. Comparing means

The study discovered that the biophilic design has a significant impact on participants' levels of satisfaction and perceived restorativeness in a sample of students in grades 3 and 4. Among the ratings of the students, it was confirmed that the mean of satisfaction and PRS ranged from 1.8 and 2.18, respectively, for the existing condition. And after the study was redesigned according to the biophilic attributes, the mean was changed to range from 4.57 to 4.34. This huge change between means required more investigation to confirm the findings; see Fig. 9. As shown in Fig. 10, there is a clear difference in students' preferences after applying the biophilia attributes.

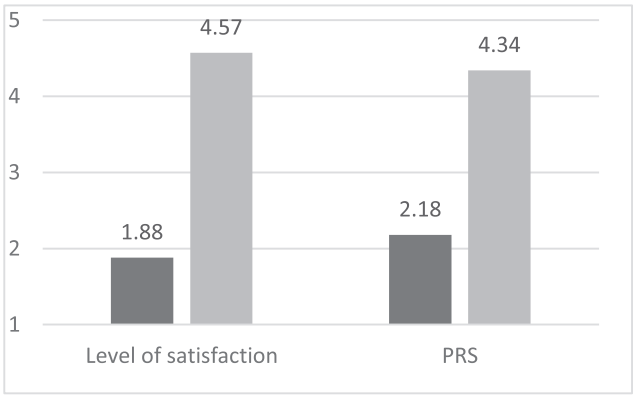


Fig. 9. Comparing Means of Level of Satisfaction and PRS.

4.2. Differences in students' satisfactory level between pretest and protest

The analysis of ratings of the level of satisfaction in the pretest on the one hand and in the protest on the other shows great differences between the two results (see Table 2). There was a significant impact of the biophilic attributes on the student's cognition and performance. As shown in the table below, the 2 psychological tests (Trailing Test A and B) and the Wisconsin Test have a significant impact, as shown below.(SeeTable 3.).

4.3. Correlations between biophilic attributes and level of satisfaction and PRS.

The predictive validity of the level of satisfaction and perceived restoratives was calculated using Spearmen correlation based on the biophilic design attributes as the independent variables. As shown in Table 1, there is a strong correlation between natural light, natural ventilation, the presence of greenery, the availability of large windows (prospect or refuge), an indirect connection to nature, and natural finishing, which has resulted in a high positive correlation with the level of satisfaction (r = 0.888,0.320,0.872,0.799,0.814, and.715) and a moderately positive correlation with the

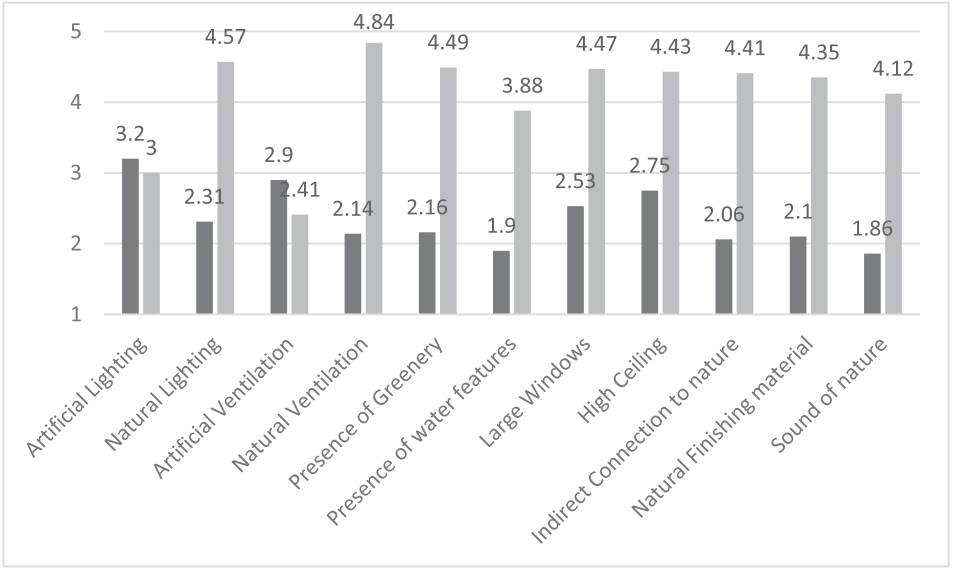


Fig. 10. Comparing Means Between Attributes before and after Applying Biophilic Design.

Table 2
T-TEST for Psychological Testing.

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Trailing Test (A)	Equal variances assumed	7.513	0.007	4.380	100	0.000	0:09:55.06	0:02:15.87	0:05:25.50	0:14:24.61
	Equal variances not assumed			4.380	90.452	0.000	0:09:55.06	0:02:15.87	0:05:25.15	0:14:24.96
Trailing Test (B)	Equal variances assumed	9.469	0.003	5.592	100	0.000	0:24:03.76	0:04:18.20	0:15:31.51	0:32:36.02
	Equal variances not assumed			5.592	62.481	0.000	0:24:03.76	0:04:18.20	0:15:27.72	0:32:39.81
Wisconsin Test	Equal variances assumed	12.727	0.001	3.830	100	0.000	3.863	1.009	1.862	5.864
	Equal variances not assumed			3.830	76.226	0.000	3.863	1.009	1.854	5.872

Table 3
Correlation between Biophilic Attributes and PRS and Level of Satisfaction.

Biophilic Attributes	PRS	Level of Satisfaction
Artificial Lighting	0.063	−0.148
Natural Lighting	**0.368****	**0.888****
Artificial Ventilation	0.183	0.023
Natural Ventilation	**0.301***	**0.320***
Presence of Greenery	**0.466****	**0.872****
Presence of water features	−0.101	0.151
Large Windows	**0.372****	**0.799****
High Ceiling	−0.029	0.175
Indirect Connection to nature	**0.378****	**0.814****
Natural Finishing material	**0.367****	**0.715****
Sound of nature	−0.18	0.076

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4
Multiple regression test validation.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.739a	0.546	0.417	0.48114

Table 5
Multiple Regression Test.

	Perceived Restoratives	Level of Satisfaction
Artificial Lighting	0.3969	2.1904
Natural Lighting	13.5424	78.8544
Artificial Ventilation	3.3489	0.0529
Natural Ventilation	9.0601	10.24
Presence of Greenery	21.7156	76.0384
Presence of water features	1.0201	2.2801
Large Windows	13.8384	63.8401
High Ceiling	0.0841	3.0625
Indirect Connection to nature	14.2884	66.2596
Natural Finishing material	13.4689	51.1225
Sounf of nature	3.24	0.5776

perceived restoratives (r = 0.368,301,466,372, Furthermore, the correlation with the rest of the attributes of the artificial lighting, artificial ventilation, presence of a water feature, high ceiling, and sound of nature shows a weak or no correlation with the PRS and level of satisfaction since they did not fall into the critical region of $p < 0.01$.

4.4. Multiple regression test

Accordingly, a multiple regression test took place to identify the impact of each attribute for quantifying them.

R may be thought of as one measure of the quality of the dependent variable's prediction, indicating that the sample has a high degree of prediction as shown in Table 4.

As results show (Table 5) that natural lighting, natural ventilation presence of greenery, large windows, indirect connection to nature, and natural finishing material yielded the highest percentages in their positive impact on students' level of satisfaction on the university campus.

5. Discussion

According to the SPSS analysis of the responses of participants towards the perceived restoratives scale and Biophilic attributes, results show that Natural lighting, the Presence of Greenery, Large Windows, indirect connection to Nature, and Natural Finishing material yielded the highest impact on the student's level of satisfaction and perceived restoratives as well. The highest impact was for the availability of natural light, the presence of greenery, and the large windows, according to students' interviews, it was mentioned that these elements put them in the mood of relaxation and give them the chance to focus more on the selected tasks. The sound of nature, some of the students reported that it is a little bit distracting to their attention. In addition to, the low score of the ventilation could be defined due to its impossible to be added as a factor in a VR simulation but on the other hand, students reported that the whole experience could be better if there was cross ventilation. The availability of large windows was one of the attributes that also yielded the highest percentage of impact because it gives them the experience of openness to the external natural views, and this helps a lot in their cognition and performance. As the study found that students prefer to be overlooking a natural view other than the availability of greenery indoors this could be defined because some students have fear of the availability of insects due to the direct contact of greenery inside the design studies and others reported their fear also from the humidity due to the availability of the indoor plantation. students prefer the perception of natural elements and finishing material other than the explicit form of nature making the indirect connection to nature one of the best solutions for applying biophilic elements in a university building. Students reported that the availability of natural finishing material simulates all their senses, especially the visual and the olfactory senses.

According to the study findings, the multiple regression test shows that the natural lighting, presence of greenery, large windows, indirect connection to nature, and the natural finishing materials yielded the highest percentage according to the level of satisfaction by enhancing their satisfaction by 78%, 76%, 63%, 66%, and 51% respectively. For natural ventilation, the presence of water features, and the sound of nature don't have a high impact on the student's level of satisfaction, these attributes only affect satisfaction by 10%, 2.28%, and 0.5% respectively. This could be due to the students' need for quietness during working so that the presence of water features and sounds of nature such as birds sound and air breeze could distract the students will using the design studio. For the natural ventilation, this weak impact could be due to the hard application into the physical or virtual environment during the experiment, but according to international literature, natural ventilation is one of the main attributes that have a high positive impact on students' satisfaction and performance as well.

Most of the findings presented in this study were related to the visual connection to nature. The visual connection to nature has a lot of benefits on students' performance as well as their satisfactory level such as:

- Nature exposure has been related to decreased feelings of anxiety, sadness, and stress. Spending time in green places or even observing nature from a window has been proven in studies to boost mood, lower cortisol levels, and promote feelings of relaxation and well-being.
- Nature has been demonstrated to improve innovative abilities and problem-solving abilities. Outdoor adventures or simply being in a green place have been shown in studies to promote cognitive flexibility, creativeness, and imaginative capacity.
- Nature can help with attention and cognitive functioning. Seeing natural scenery or going on a nature walk has been demonstrated in studies to increase working memory, attentional control, and task-switching abilities.
- Interacting with nature may also stimulate physical activity and exercise, which can have several advantages for both physical and mental health.

- Nature-based activities and outdoor experiences can also give possibilities for social contact and community-building, which can boost social support and foster a feeling of belonging.

The primary goal of the study presented in this article was to investigate, in the Egyptian context, the biophilia physical attributes concluded from international literature as being associated with the level of satisfaction and perceived restlessness in university design studios. The data analysis revealed significant correlations between most of the physical attributes investigated and the students' levels of satisfaction and PRS. The results show a strong correlation between Natural Light, Natural Ventilation, Presence of Greenery, Availability of large windows (Prospect/Refuge), indirect connection to nature, and Natural finishing that yields a high positive correlation with the level of satisfaction. It is worth noting that those characteristics are strongly positively correlated and may be related to human nature, as stated in international literature that humans have an intimate relationship with nature [7,10]. This doesn't mean that the presence of a water feature, the sound of nature, and the high ceiling didn't have an impact on the participants, but this is probably due to the hard application of the virtual reality model, although, through an open-ended interview that took place with students as they were experiencing the VR, students have mentioned that the high ceiling with a skylight gave them the impression that they were connected to the outdoors. Furthermore, the sound of nature provided by the VR simulation distracted some of them, while others gave them the impression that they were in a savanna-like environment, which encouraged them to relax. Students may have been unable to relate the importance and impact of the indirect connection to nature for the Large Windows attributes, which reflect the Prospect/Refuge attribute, due to their limited understanding of the impact of other attributes on each other.

6. Conclusion

In conclusion, this study aims to enhance university students' level of satisfaction and perceived restoratives through the use of biophilic attributes. It was confirmed that biophilic design has a strong impact on Egyptian university students' level of satisfaction. This could be done by emphasizing or adding these main biophilic attributes concluded from this study: Natural Light, Natural Ventilation, Presence of Greenery, Availability of large windows (Prospect/Refuge), indirect connection to nature, and Natural Finishing.

Finally, a few limitations of this study are highlighted to provide a better opportunity for future research. Only one design studio was investigated due to time limitations. In addition, the use of augmented reality instead of virtual reality could be a better choice for simulating students' senses while testing, but it was limited by availability and budget. Finally, it is recommended that the study be taken across different universities to confirm the findings.

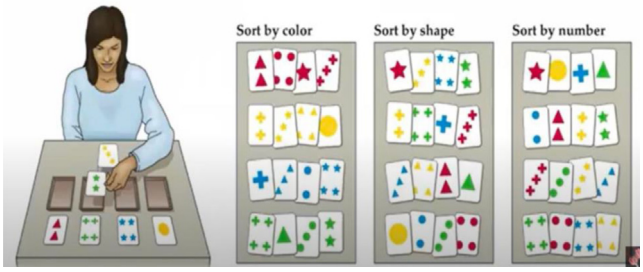
The findings of this paper could benefit first, designers while designing educational facilities to take into consideration the biophilic attributes that can potentially enhance university students' level of satisfaction. Second, it could be an empirical base that can be used by other researchers in testing similar cases and replicating the study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Wisconsin Test.



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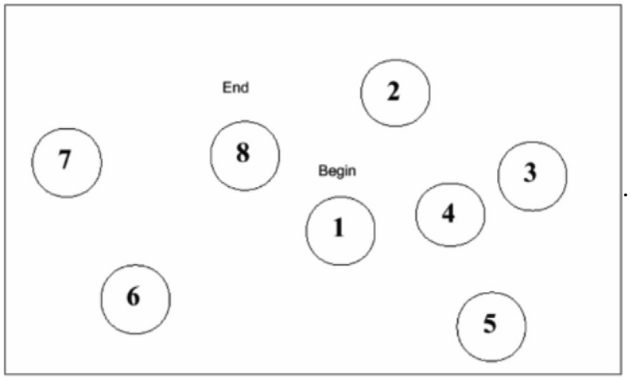
Trailing Test Demo (A).



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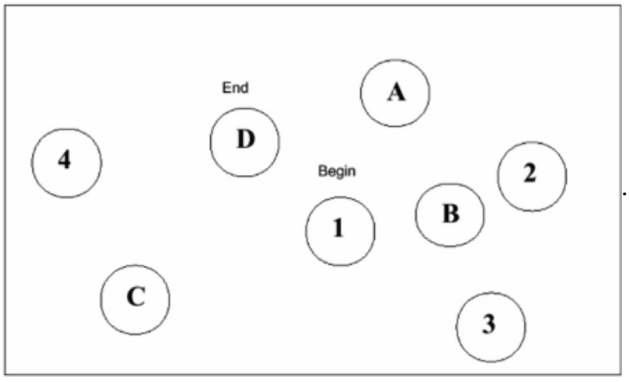
Trailing Test Demo (B).



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