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Strategies for Implementing Biophilic Design to Improve Academic Performance Among Students in Existing Primary Schools in Egypt

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ABSTRACT
Educational institutions hold paramount significance in shaping the cognitive and behavioral patterns of successive cohorts. Egypt is among the nations that encounter numerous challenges in their present design practices pertaining to the design strategies employed in school buildings. A considerable number of educational institutions are disregarding the potential influence that connecting classrooms with outdoor environments can have on students' behavior and learning processes. In order to enhance their effectiveness and productivity, it is imperative that students have a sense of freedom, relaxation, and motivation. There are a multitude of interior design approaches that have the potential to enhance the interior space of a classroom, hence creating a more comfortable and engaging environment for students. Biophilic design represents a sustainable design approach that facilitates the integration of indoor areas with the external environment by using elements such as plants, daylighting, textures, materials, and colors. The objective of this study is to provide a series of ways to incorporate Biophilic design in order to improve the academic performance of kids in existing primary schools in Egypt.

Keywords: *Biophilic design; Primary schools in Egypt; Design strategies.*

1. Introduction

Biophilic design is a human-centered approach that designs nature back into our built environment to improve the spaces we live and work in [1]. The design approach is derived from the Biophilia Hypothesis (meaning love of life), a hypothesis that focuses on the human's innate attraction to nature [2, 3] .Biophilic design applications became a necessity because of the growing disconnection from the natural world due to the process of urbanization [2]. Many theories have arisen to study aspects of nature that impact the most on our satisfaction within the built environment.

The implementation of a biophilic design approach - biophilia applied in the human-built environment- in various fields has become more commonplace, as the benefits of natural environments show stronger links to positive health benefits, well-being, and productivity [4]. Positive health benefits also lead to huge beneficial financial outcomes for companies and institutions, as stated by Terrapin Bright Green in their report *The Economics of Biophilia* [5].

Education plays a significant role in shaping and impacting the environment. It is imperative to explore the implementation of measures aimed at improving the design of schools. The configuration of the school's interior spaces has an impact on the academic achievement of the students. Hence, it is imperative to construct classrooms in a manner that fosters stimulation, comfort, and a sense of encouragement among pupils.[3, 6]. Spaces are required to enhance effectiveness, increase excitement, and instill a sense of empowerment. In Egypt, the architecture of schools is influenced by traditional architectural styles, resulting in a lack of emphasis on creating a connection between indoor spaces, such as classrooms, and the outside environment.

It is imperative to provide students with opportunities to engage with the natural environment, which can be achieved through the integration of innovative sustainable design approaches within school classrooms. This study aims to present the concept of Biophilic design as a sustainable approach that may be applied to real-life educational environments.

The implementation of this concept has the potential to yield beneficial effects on the mental and physical well-being of students. The physical well-being of students can be positively influenced through

increased engagement in physical activities. This can lead to a reduction in blood pressure, an enhanced sense of comfort and contentment, a decrease in the manifestation of sickness symptoms, and an overall improvement in health. Mental states can be inferred through observations of individuals' behavior, attendance patterns, as well as their levels of attention and concentration. Individuals experience emotional enhancement through the process of stress reduction, achieved through cultivating a state of tranquility and relaxation.

2. The Significance of Biophilic Design

According to the study conducted by Kellert and Finnegan in 2011 [7], the concept of biophilia is characterized as an inherent biological bond that exists between human beings and the natural world. The biophilic design method involves the application of the biophilia hypothesis and related theories to the design of the built environment [8]. This translation facilitates an environment that fosters human flourishing and nurtures their inherent affinity towards the natural world and its activities. Consequently, this resulted in favorable reactions to their psychological and physiological welfare. In a study conducted by Kellert and Elizabeth in 2015 [9], it was demonstrated that the implementation of Biophilic design principles in educational environments has a significant impact on the cognitive and physiological behavior of students. This is achieved by creating an atmosphere that fosters a connection with nature, enabling students to experience a sense of natural surroundings within the confines of the classroom. Furthermore, the incorporation of Biophilic design is a cost-effective approach that may be applied to various educational institutions, including both international and public schools. For instance, the presence of plants inside an indoor environment has the potential to elicit a good impact on the emotional state of students, fostering a sense of connection with nature and enhancing their overall mood. Furthermore, the incorporation of various Biophilic elements within the school's infrastructure can enhance its overall design. For instance, the installation of green roofs can contribute to the integration of nature within the building. At the same time, the inclusion of expansive windows can facilitate the entry of natural daylight, creating a more conducive learning environment. Additionally, providing access to the outdoor environment can further promote the connection between students and nature. The book "Creating Biophilic Buildings" [10] defines Biophilic design as the intentional integration of natural components into constructed spaces. The "14 Patterns of Biophilic Design" by Terrapin's Bright [11] Greens categorize biophilic design into three main themes: Nature in Space, Natural Analogues, and Nature in Space, as seen in Table 1. The text delves into three overarching themes, examining specific patterns and elaborating on their advantages, drawing inspiration from the research conducted by Kellert and Calabrese [9].

Table 1. Fourteen Patterns of Biophilic Design adapted from Terrapin Bright Greens [4]

Theme	Pattern
Nature in the Space (Direct Experience)	**[P1]** Visual Connection with Nature
	[P2] Non-Visual Connection with Nature
	[P3] Non-Rhythmic Sensory Stimuli
	[P4] Thermal and Airflow Variability
	[P5] Presence of Water
	[P6] Dynamic and Diffuse of Light
	[P7] Connection with Natural Systems
Natural Analogues (Indirect Experience)	**[P8]** Biomorphic Forms and Patterns
	[P9] Material Connection with Nature
	[P10] Complexity and Order
Nature of the Space (Indirect Experience)	**[P11]** Prospect
	[P12] Refuge
	[P13] Mystery
	[P14] Risk/Peril

3. The effect of Biophilic design on the health and performance of students

Extensive research has consistently shown that the use of biophilic design contributes to the enhancement of both welfare and learning outcomes. For instance, scholarly investigations indicate that the engagement of children and students with natural environments has been found to facilitate the restoration of attentional capacity, a crucial aspect of cognitive functioning. Consequently, those who interact with nature exhibit less susceptibility to distractions and enhanced abilities to effectively handle their everyday duties. Based on empirical research, scholars have demonstrated that the implementation of design methods has a good impact on the physical well-being, academic achievement, and psychological state of students [9]. There exists a significant correlation between the natural environment and the many systems within the human body.

The body systems can be categorized into three basic senses, namely stress, cognitive functionality and performance, and mood, emotion, and preference. The physiological health and well-being are demonstrated in Table 2.

Table 2. Conclusion for the Biophilic Design Impact on Student's health and performance.

Stress Reduction	Cognitive Performance	Emotion, mood & Preference
Reduce stress	Improve performance	Improve mental health
Lower Blood pressure	Increase attention of exploration	Positive emotional response
Increase visual comfort	Increase concentration	Positive impact on attitude
Increase visual comfort	Improve memory restoration	Improve perception of special pleasure
		Improve comfort and safety
		Strong pleasure response

4. A Case Study of the Biophilic Design of Children's Primary Schools.

Numerous authors have engaged in discussions regarding Biophilic Design Patterns in Primary Schools situated internationally [12-15] and domestically in Egypt [16, 17].

This section focuses on the implementation of Biophilic design principles in a selection of five elementary schools. Three foreign primary schools have been recently introduced, namely Fenton Primary Centre, The Garden School, and WeWork's micro school. Subsequently, two national elementary schools were presented, namely New Capital English Schools and Cairo American College. Finally, a comparative analysis was conducted on the biophilic design patterns that were adopted in the five schools.

4.1 Fenton Primary Centre.

Fenton Primary Centre is an educational institution situated in the city of Fenton, Michigan, catering to elementary school students [18]. The institution caters to children ranging from pre-kindergarten through fifth grade. The educational institution received a significant restoration throughout the early 2010s to enhance its facilities and integrate a greater presence of natural elements. Biophilic components were strategically incorporated into the refurbishment. Natural materials such as wood, stone, and other organic substances are commonly employed in the construction of various architectural elements, including flooring, walls, and furniture. The integration of live plants within educational environments, such as classrooms, communal areas, and the cafeteria, is referred to as indoor greenery.

The provision of outdoor access entails the incorporation of outdoor courtyard classrooms, gardens, and play areas, which effectively engage children in a natural environment. Water elements, such as fountains, offer a serene auditory experience with the gentle sounds of flowing water.

The incorporation of nature imagery, such as animal and plant murals and artwork, serves to strengthen the biophilic motif. The objective was to establish a stimulating and nurturing atmosphere conducive to the intellectual and personal development of pupils. It is widely believed that the incorporation of biophilic features has the potential to mitigate stress levels, boost overall well-being, and optimize the educational experience.

Figure (1): Fenton Primary Center.

4.2 The Garden School.

The Garden School is a highly regarded educational institution catering to individuals between the ages of 4 and 16 who possess unique educational requirements, particularly those with autism, located in Hackney [19]. The school employs textured carpets featuring diverse pile heights, as well as wallpaper adorned with woodland imagery, to offer tactile and visual stimuli inspired by nature.

The school presented a challenge to Biophilic Designer Oliver Heath and flooring manufacturer Interface. Their task was to convert an underused room within the school into a secure and restorative environment for students with autism. This place would be situated far from the typical noise and commotion of the nearby playground. Oliver, a renowned authority in the field of biophilic design, employed a selection of colors, textures, and patterns inspired by nature to establish an environment that

fostered a reconnection between the pupils and the natural world. Oliver chose to emulate natural aspects by including textures, patterns, and colors in the design, as well as integrating images of nature on the wall coverings. Previous studies have provided evidence that the utilization of design elements inspired by nature can have a beneficial effect on both perceptual and physiological responses to stress.

Figure (2): The Garden School.

4.3 WeWork's Micro School.

This educational facility, spanning an area of 10,000 square feet, is designed to cater to children between the ages of three and nine. It is situated within WeWork's headquarters in the Chelsea neighborhood of Manhattan. The utilization of diverse spatial environments enables youngsters to engage in unrestricted movement and acquire knowledge from their surroundings and peers. The learning environment promotes collaboration through the prioritization of transparent and communal areas, which encompass a majority of the school's facilities. These spaces include four classrooms, flexible workshops, a community space, a multi-purpose studio, an art studio, a music room, and other areas designed to facilitate creativity and foster a sense of unity among students [20].

Most partitions in the educational facility consist of child-height shelves, allowing natural light to penetrate the interior. Three shelving levels for each age group create diverse activity areas, fostering comfort, safety, and community, while enabling teachers to have a clear view of the space. Acoustic clouds made of felt reflect patterns from nature and are enhanced by Ketra bulbs that adjust color and intensity with the time of day. Each learning station features furniture designed by BIG to enhance the educational environment. Modular classrooms encourage movement and collaboration, with puzzle tables and chairs from Bendark Studios suitable for children and parents. A vertical garden with Swiss-made tiles from Laufen accommodates various plants based on their shade needs. Mushroom shelves and a magic meadow create a tranquil atmosphere for better concentration, and reading hives offer an immersive library experience. In the lobby, a whimsical felt nook serves as a versatile space for work, socializing, and waiting. Children can engage with a felt brain puzzle lounge, which can be disassembled for play and educational purposes. We Grow uses Gople Lamp and Alphabet of Light by BIG Ideas and Artemide, ensuring comfortable lighting from the lobby to the classrooms. The facility promotes a playful, transparent environment that encourages introspection, exploration, and discovery.

Figure (3): WeWork's Micro School.

4.4 A comparative analysis of biophilic design patterns across three international schools.

The comparative analysis shows that biophilic design concepts are used differently in each place based on culture and environment. Despite their different approaches, all schools integrate nature into teaching settings, which may improve student well-being and engagement. However, green space maintenance and expense are significant implementation hurdles. Table 3 compares biophilic design trends in three global schools.

Table 3. Comparison between three international schools.

No	Pattern	Fenton Primary Centre	The Garden School	WeWork's Micro School
1	Visual Connection with Nature	Existence of mature trees surrounding the site. They are readily visible and available to students.	Window seats provide occupants with a view of the outdoors.	Vast openings to nature.
2	Non-Visual Connection with Nature	Textured use of natural materials.	Ambient nature sounds are performed in the area.	Open facades allow light air inside.
3	Non-Rhythmic Sensory Stimuli	Not evident.	Not evident.	Not evident.
4	Thermal and Airflow Variability	Natural ventilation.	Natural ventilation.	Open facades permit airflow, temperature fluctuations, movement, and humidity.
5	Presence of Water	Not evident.	Not evident.	Not evident.
6	Dynamic and Diffuse Light	Natural illumination from windows facing the courtyard and exterior walls.	Natural lighting inside is controlled with blinds.	Open facade design that lets in natural light throughout the day.
7	Connection with Natural Systems	Visible view from seats.	Visible view from seats.	Openable facades enable occupants to experience the changing weather conditions.
8	Images of animals and trees on the walls	Images of animals and trees on the walls.	Sitting wallpaper like Honeycomb.	References to nature in symbols.
9	Material Connection with Nature	The school utilizes natural materials extensively.	Materials that invoke nature.	Natural materials and elements
10	Complexity and Order	Observable timber structures.	Not evident.	Interior structural elements.
11	Prospect	The transitional zone at the entranceway connects the interior and exterior spaces.	The corridors enhance visual access to interior and exterior vistas.	Transparent materials.
12	Refuge	Students engage in outdoor recreational activities in the backyard.	Spaces reserved for reflection, meditation, rest, relaxation, reading, or complex cognitive tasks.	Not evident.
13	Mystery	Not evident.	The floor layout has multiple hallways and passages that travel in many directions, forcing visitors to travel through and explore the rooms above it.	Curving edges, as opposed to acute corners, are more helpful in guiding toddlers across a given space.
14	Risk/Peril	The school does not own a substantial quantity of staircases.	There is an absence of risk or hazard inside the school environment.	There is an absence of risk or hazard inside the school environment.

4.5 New Capital English Schools.

The school is located in the New Capital R2, which is well recognized as an innovative and sustainable urban development in Egypt [21]. Although all buildings in the new capital adhere to standard sustainability practices, there has been a lack of building identity and assessment to evaluate the effects of these structures on individuals, the environment, and economic value. This study centers on the implementation of sustainability measures and their influence on the identity of the building. Children play a pivotal role in shaping the future as they represent the forthcoming generation entrusted with the task of fostering progress and advancement. Hence, the primary focus of the case study revolves around the examination and endorsement of the environmental and economic dimensions while simultaneously taking into account the health and well-being of children. The gross floor area of the school measures 13000 square meters. The building will incorporate value management by employing function analysis through the use of the theoretical patterns of biophilic design.

Figure (4): New Capital English Schools.

4.6 Cairo American College (CAC).

The school is a top-tier international school located in Maadi, Cairo, Egypt. that caters to a student body of around 1,400 individuals spanning from Pre-K to 12th grade. As part of a comprehensive master plan study conducted in 2006, CAC undertook the task of campus reconstruction in a phased manner [22]. This involved the construction of a new Middle School building, which incorporated a library serving both the Middle School and High School students. The services of Perkins Eastman were engaged to carry out project verification, planning, and design activities during this phase.

Perkins Eastman sought to design a facility that fosters and promotes the crucial transition a student undergoes as they go from an Elementary level of education toward a more autonomous and self-directed learning environment often found in High School. The architectural design of the building combines the horizontal structure often seen in elementary schools with the vertical structure commonly seen in high schools, as depicted in the diagram. The departmental classroom blocks on each floor are integrated with open locker commons, which serve as spaces for student interaction. These commons are organized based on grade level, aiming to foster relationship-building and cultivate a sense of ownership among students. The library situated on the ground floor of the Middle School / High School serves as a tangible and symbolic connection between the High School building. It fosters collaborative usage by both student cohorts.

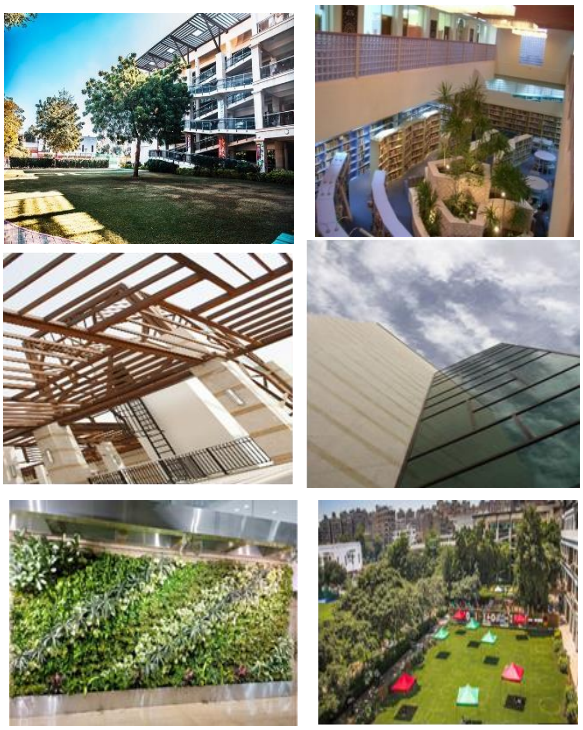

Figure (5): Cairo American College (CAC).

4.7 A comparative analysis of biophilic design patterns implemented in two primary schools located in Egypt.
The comparison analysis of biophilic design patterns between two Egyptian primary schools is presented in Table 4.

Table 4. Comparison between two Egyptian primary schools.

No	Pattern	New Capital English School	Cairo American College
1	Visual Connection with Nature	Large glass windows provide a direct connection with outdoor green areas.	Existence of large amounts of trees and green areas surrounding the school and indirect contact with students.
2	Non-Visual Connection with Nature	- Using materials from nature like wood in facades. -Using colors to invoke nature inside the classes, like yellow and blue.	-Using materials from nature like wood in ceilings and facades. -Using colors invoke nature inside the classes, like green and blue.
3	Non-Rhythmic Sensory Stimuli	Not evident.	Not evident.
4	Thermal and Airflow Variability	Natural ventilation.	Natural ventilation.
5	Presence of Water	Not evident.	Not evident.
6	Dynamic and Diffuse Light	Natural illumination from large glass windows.	-Natural illumination from large glass windows -Natural illumination in the library from the ceiling.
7	Connection with Natural Systems	Visible view from seats.	Visible view from seats.
8	Images of animals and trees on the walls	Images of animals.	Images of sun and clouds on the wall.
9	Material Connection with Nature	Materials that invoke nature.	The school uses natural materials in facades and ceilings.
10	Complexity and Order	Not evident.	Observable timber facades and structure.
11	Prospect	Not evident.	The interior spaces and directly connected to the exterior spaces.
12	Refuge	Students engage in outdoor recreational activities.	Students engage in outdoor recreational activities.
13	Mystery	Not evident	Not evident.
14	Risk/Peril	Not evident.	Not evident.

5. Conclusions

The objective of this study is to apply Biophilic design concepts and determine the most acceptable and effective approach for enhancing the health and performance of students in school classrooms. This study aims to elucidate the effectiveness of incorporating biophilic features in educational settings to optimize student well-being and academic achievement. Furthermore, the utilization of New Capital English School and Cairo American College serves as a case study to exemplify the incorporation of nature

6. References

[1] O. Heath, Jackson, V., & Goode, E., "Creating Positive Spaces-Using Biophilic Design," 2018a.

[2] P. Downton, D. Jones, J. Zeunert, and P. Roös, "Biophilic design applications: Putting theory and patterns into built environment practice," *KnE Engineering*, pp. 59-65, 2017.

[3] S. R. Kellert and E. O. Wilson, *The biophilia hypothesis*. Island press, 1993.

[4] W. D. Browning, C. O. Ryan, and J. O. Clancy, "Patterns of biophilic design," *New York: Terrapin Bright Green, LLC*, pp. 3-4, 2014.

[5] B. Browning *et al.*, "The Economics of Biophilia [WWW Document]," *URL http://clients. edmullen. com/terrapin/(accessed 9.28. 19)*, 2012.

[6] S. R. Kellert, *Building for life: Designing and understanding the human-nature connection*. Island press, 2012.

[7] S. Kellert and B. Finnegan, "Biophilic design: the architecture of life," *Tamarack Media: Burlington, VT, USA*, 2011.

[8] S. R. Kellert, J. Heerwagen, and M. Mador, *Biophilic design: the theory, science and practice of bringing buildings to life*. John Wiley & Sons, 2011.

[9] S. Kellert and E. Calabrese, "The practice of biophilic design," *London: Terrapin Bright LLC*, vol. 3, pp. 21-46, 2015.

[10] A. Sturgeon, *Creating biophilic buildings*. Ecotone publishing, 2017.

[11] W. Browning, C. Ryan, and J. Clancy, "Patterns of Biophilic Design [14 Patrones de diseño biofílico](Liana PenabadCamacho, trad.) New York: Terrapin Bright Green, LLC," *Trabajo original publicado en*, 2014.

[12] R. Ghaziani, M. Lemon, and P. Atmodiwirjo, "Biophilic Design Patterns for Primary Schools," *Sustainability*, vol. 13, no. 21, p. 12207, 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/21/12207.

[13] I. Mohammed, Z. Onur, and Ç. Çağnan, "An Exploration of Biophilic Design Features within Preschool Interiors," *Sustainability*, vol. 15, no. 15, p. 11913, 2023. [Online]. Available: https://www.mdpi.com/2071-1050/15/15/11913.

[14] A. Almusaed, A. Almssad, and K. Najar, "An Innovative School Design Based on a Biophilic Approach Using the Appreciative Inquiry Model: Case Study Scandinavia," *Advances in Civil Engineering*, vol. 2022, p. 8545787, 2022/06/25 2022, doi: 10.1155/2022/8545787.

[15] A. Almusaed, A. Alasadi, and A. Almssad, "A Research on the Biophilic Concept upon School's Design from Hot Climate: A Case Study from Iraq," *Advances in Materials Science and Engineering*, vol. 2022, p. 7994999, 2022/03/27 2022, doi: 10.1155/2022/7994999.

[16] A. Sayed and G. Nagy, "Design Strategies for Integrating Biophilic Design to Enhance the Students' Performance in Existing Primary Schools in Egypt," *Fayoum University Journal of Engineering*, vol. 3, no. 2, pp. 27-39, 2020, doi: 10.21608/fuje.2020.204935.

[17] H. Ibrahim, M. SalahEldin Elsayed, W. Seddik Moustafa, and H. Mohamed Abdou, "Functional analysis as a method on sustainable building design: A case study in educational buildings implementing the triple bottom line," *Alexandria Engineering Journal*, vol. 62, pp. 63-73, 2023/01/01/ 2023, doi: https://doi.org/10.1016/j.aej.2022.07.019.

[18] F. P. CENTER, "FENTON PRIMARY CENTER." [Online]. Available: https://fpc.fentoncharter.net/.

[19] T. Garden. "The Garden School." https://www.the-garden.org.uk/ .

[20] E. Baldwin. (2018) Bjarke Ingels Designs Micro WeGrow School in New York. *ArchDaily*. Available: https://www.archdaily.com/901974/bjarke-ingels-designs-micro-wegrow-school-in-new-york .

[21] N. C. E. Schools. "New Capital English Schools." https://nces.edu.eg/ .

[22] C. A. College. "Cairo American College." https://www.cacegypt.org/ .