

# DESIGN STRATEGIES FOR INTEGRATING BIOPHILIC DESIGN TO ENHANCE THE STUDENTS' PERFORMANCE IN EXISTING PRIMARY SCHOOLS IN EGYPT

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## Abstract

Schools are the most important buildings that affect the generation's way of thinking and way of living. Egypt is one of the countries that experience many problems in its current design practices in their school building's design strategies. Most of the schools are neglecting the impact of linking classrooms with outdoor spaces on the student's behavior and way of learning. Students need to feel free, relaxed and motivated in order to be more effective and productive. There are various types of interior designs that could enhance the classroom's interior space, so that it can be more comfort and interesting to students. Biophilic design is one of the sustainable design solutions that could maintain the ability of having indoor spaces linked with the outdoor space through the use of plants, daylighting, textures, materials and colors. The aim of this research is to propose a set of strategies for integrating Biophilic design to enhance students' performance in exiting primary schools in Egypt. The methodology adopted is divided to three parts. The first part will define the Biophilic design and its impact on the student's health and performance. The second part will clarify the Biophilic design elements and frameworks to identify the suitable elements for the classroom's interior design. The third part will discuss the design considerations to implement these elements in the classroom's interior design. According to the three parts the final conclusion will specify a matrix linking between the Biophilic design strategies and the student's health and performance. The result expected from the matrix will identify the suitable Biophilic design strategies to be

implemented in the school's classrooms to enhance the student's health and performance.

**Keywords:** biophilic design, indoor green spaces, education in Egypt, design strategies, student's performance

## 1. Introduction

Education is one of the main process that has a big influence on the environment. So that enhancing the schools design strategies should be taken in consideration. The design of the school's interior spaces affects the students' performance. Therefore, classrooms should be designed in a manner that stimulates, comforts and, cheers students (Kahn, 1997; Kaplan & Kaplan, 1998; Kellert, 2005; Kellert & Wilson, 1993). They need spaces that will make them more effective, more excited and full of power (Griffin, 2004). In Egypt, school designs are based on traditional designs, which eliminates the idea of feeling the surrounded environment through the indoor spaces "classrooms". Students should be exposed to nature and this could be done by implementing new sustainable design strategies for the school classrooms. This research will introduce one of the sustainable designs "the Biophilic design" that can be implemented in local actual school's conditions. This design can have a positive impact on the student's mental and physical health. Students are affected physically by enhancing their physical activities, reduces the blood pressure, improved the sense of comfort and satisfaction, reduces the signs of illness and improved their health. Mentally by their behavior, attendance, attention and concentration. They are emotionally improved by releasing the stress with calmness and relaxation.

## **2. Biophilic Design and its importance**

According to Kellert and Finnegan study in 2011 Biophilia is defined as the innate biological connection between human kind and nature. The Biophilic design also has another definition a process that can translate the meaning of the attraction of the human to the natural environment into the design of the built environment (Wilson 1984, Kellert and Wilson 1993). Kellert and Elizabeth in 2015 proved that applying the Biophilic design in the educational spaces will affect the student's mental and physical behavior; by allowing the students to feel the nature inside the classrooms. Moreover, the implementation of the Biophilic design is an affordable process that can be used in different school's standards; international or even public schools. For example, something as simple as plants that can be spread in a room, positively change the student mood and provide the feeling of being surrounded by the nature inside the room. In addition to other Biophilic aspects that can be used in the school's buildings such as covering the roofs with green, creating large windows to allow the natural daylighting to enter the space and provide an access to the outdoor environment.

### **2.1. The impact of Biophilic design on the students' health and performance**

The Biophilic design has a great impact on students. According to the studies, the experts have proven that the student's health, performance and mentality are positively influenced by this design strategies (Kellert and Elizabeth, 2015). As there are a strong relation between the nature and the human body systems. These body systems are defined briefly into three senses that are mainly affected the stress, the cognitive functionality and performance and the mood, emotion and preference, and the physiological health and wellbeing as shown in (table 1). Each of which will be explained in more detail in the coming sections.

#### **2.1.1. Cognitive functionality and performance**

The cognitive function enhances the student's memory restoration, ability of thinking and learning. In addition it has the ability to increase the student's attention, which is required mainly for tasks such as filling paperwork, reading and carrying out calculations or analysis (Kellert, 2008). However, the students are under pressure to have a high concentration which requires a lot of energy consumption and high attention and this may cause weakness in their mentality and unusable cognitive resources (Van den Berg, 2007). Therefore, having a direct connection with nature can provide some mental restoration and this helps in increasing the brain's capacity to focus on tasks.

#### **2.1.2. Mood, Emotion and Performance**

Research indicates that the experience of nature inside the classrooms, has a great impact on the student's psychological mentality (Alcock, 2013). The psychological part includes their adaptability, emotion and mood. The natural environment can reduce the student's ability for being tension or having anxiety anger, hesitation, exhaustion and the whole mood disturbance (Barton & Pretty, 2010; Hartig, 2003). Adapting the Biophilic features inside the classrooms can affect the student's mood by implementing some natural features. The students can feel happier and relaxed through the sense of nature inside the room by the use of some plants such as green walls, pots of flowers or even some portraits with natural pictures on the walls (Hartig, 1991).

#### **2.1.3. Psychological Health and Wellbeing "Stress reduction"**

The human physical reactions includes the sense of hearing, breathing through the respiratory systems, daily systems and total physical comfort. The reaction of the physiological respond to the nature may cause the relaxation of the muscles, reduces the blood pressure and cortisol is a hormone of stress in the blood flow (park, 2009). Therefore, allowing the natural environment design in the built environment have the ability to reduce the psychological stress (Steg, 2007).

Table 1. Conclusion for the Biophilic design impact on student's health and performance (Terrapin Bright Green ,2014).

### 3. Biophilic Design Elements and

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
Lower heart rate	Improve memory restoration	Improve perception of special pleasure
		Improve comfort and safety
		Strong pleasure response

#### Frameworks

Kellert, Elizabeth, and Terrapin Bright Green were the first to introduce the Biophilic design strategies, principles, elements and attributes. In order to define a framework for the designers to apply the Biophilic design to the built environment. Kellert framework was provided to demonstrate the Biophilic design in six elements and 72 attributes. The second framework was developed by environmental consulting and strategic planning firm Terrapin Bright Green (2014). This framework discussed the Biophilic design in principles that combines the nature with the built environment. The third framework was developed in 2015 by Kellert and Elizabeth as they updated the first framework of Kellert. This new framework identifies three categories for the experience of nature and clarifies 24 elements. This research will focus on the third and the last updated framework as it enables designers to more focus on users' physical, mental, or psychological well-being

by using the 24 attributes through the space rather than only focusing on natural characteristics.

### 3.1. Developed Biophilic Design: The Kellert & Elizabeth Framework

In 2015, Kellert and Elizabeth updated framework based on Kellert's first introduced Biophilia framework. This new framework had three categories of experience of nature, classified into 24 attributes of Biophilic design experiences. Three kinds of natural experience called the direct experience of nature, the indirect experience of nature, and the experience of space and place, which are then classified into 24 elements .This research will focus on some of these elements that can be implemented in the classroom's interior design to enhance the student's performance. The highlighted elements inside the table below shows the chosen elements to be discussed in this research.

Table 2. Experiences and attributes of Biophilic design (Adapted by Kellert & Elizabeth, 2015)

Direct Experience of Nature	Indirect Experience of Nature	Experience of Space and Place
- Light - Air - Water - Plants - Animals - Weather -Natural Landscapes and Ecosystems	- Image of nature - Natural materials - Natural Colors - Simulating natural light and air - Naturalistic shapes and forms - Natural Geometries - Biomimicry	- Prospect and refuge - Organized complexity - Integration of parts to wholes - Transitional spaces - Mobility and wayfinding - Cultural and ecological attachment to place

### 3.2. Biophilic design elements in the classroom's interior design

This part will clarify the Biophilic design elements that are chosen to be implemented for this type of buildings “schools” interior design, and how it can be adapted to enhance the student’s health and performance. Knowing that there are other elements that can positively affects the student’s performance as well. These elements are: Air “natural ventilation, daylight, plants and natural landscapes and ecosystems as a direct experience of nature. Natural colors, natural materials, Image of nature and naturalistic shapes and forms as an indirect experience of nature. Mobility and wayfinding as an experience of space and place.

#### 3.2.1 Natural Ventilation

Air is the Natural ventilation, which can have a great impact on human comfort and productivity. There are various ways of ventilation that can be experienced inside the building; variation in temperature, humidity, airflow and barometric pressure. This could be done through the use of windows or more complex engineering strategies in order to have an access with the outside environment (Alencar, 2010; Kellert, 2005).

#### 3.2.2. Daylighting

There are different studies that allows the using of daylight strategies in classrooms and determined the student’s impact. For example, a study by Yacan (2014) shows that there is a huge impact on the student’s behavior and cognitive skills, due to the effect of the daylight on the students in the classrooms. Gelfand and Freed have also asked for the use of daylight in classrooms in order to allow the students to connect with the outdoor environment to enhance the student’s and teacher mood (2010). Figure (1) shows an example for daylighting in a classroom, Carshalton, UK



Fig. 1:Daylighting in a classroom, Carshalton, UK (Gower,2019).

Design considerations according to (Gower, 2019).

- Maximize the size of the Windows.
- It could be placed on either sides or on the ceilings.
- Place the seating and tables close to the windows to make the best natural daylighting.
- Move any storages located near the windows, to increase the use of daylight in the spaces.
- Open any shades or remove any signage or artworks that is able to block the daylight from entering.

#### 3.2.3. Plants

Other studies have observed the impact of the use of the interior plants in classrooms on the student’s performance and perceptions (Doxey, Waliczek, & Zajicek, 2009). According to these studies they concluded that classrooms with plants is able to increase the rate of performance of the students and enhancing the teacher’s feelings by being more involved (Doxey, Waliczek, & Zajicek, 2009).Actually, these studies was able to advise the use of Biophilic design elements inside the classrooms indifferent ways to positively affect the students. The plants can be adapted in the classrooms through the use of green pots, green walls or even cladding the floors with green patterns as shown in (figure 2).



Fig. 2: Classroom design by Stephen Gower in 2019.

### 3.2.4. Landscapes and ecosystems

People usually have a strong inclination toward the natural views over the urban landscapes, as it seems more positive to their emotions and psychological states. In order to increase the linking of natural views in the classrooms, windows should allow the students to be able to watch an urban science including trees and other vegetation. According to the expert's analysis, they clarified, that the movement of the natural views seems to be more positively than the mechanical movement and shifting our attention to something natural is beneficial for attention restoration (Stephen Gower, 2019).

### 3.2.5. Natural Colors

According to the experts color is the third most influential element on students' behaviors in special classrooms behind daylighting and window views. For current the most used colors in schools are the white and brown; white for the floors and ceilings, brown as most of the classrooms are wood. Colors allows the students to feel comfort and relaxed and behave as if they are staying at home. There are two types of colors; warm colors and soft colors as shown in figure (3) (Gower, 2019).

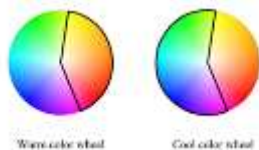


Fig. 3: warm and cool color wheel (Gower, 2019).

Some of the experts clarified that it is better to use the soft, warm and calm colors than the

cool, dark and high saturated colors in schools. As the harmony of warm colors is able to provide the students with comfortable atmosphere. Moreover, the interaction of the colors with the daylighting, allows the atmosphere to positively affect the teachers perceptions, not only the student's ability of learning (Gower, 2019).

### Design considerations:

- Use warm and calming natural harmonies tones of color pallets (Miller, 1997).
- Use colors that affects the emotions (Birren, 2006), as shown in figure (4).



Fig. 4: Colors that affects the emotions (Birren, 2006).

### 3.2.6. Natural Materials

According to the reference of the Biophilic natural materials and patterns, textures or colors, when they are inspired from the nature they can affect our feeling with positive physiological effect. For example, the use of wood in the interiors can be able to decrease the blood pressure and maximize the feeling of comfort (Tsunetsugu, miyazaki & Sato 2007). Wood can be used in classrooms; in desks, chairs, flooring and shelves (Gower, 2019).

### 3.2.7. Image of Nature

Image of nature is an indirect way to feel the nature features; plants, water, animals, through the use of portraits, paintings, photographs, sculptures and other means of art (Alencar, 2010).

### **3.2.8.Natural shapes and forms**

Naturalistic shapes and forms could be used on the decoration of the Building's interior or exterior facades. In case of maintaining the Biophilic design it should be inspired from nature; for examples shapes of animals or plants as patterns on an exterior façade or a column. The creation of these shapes could be able to transform a space from a static state to a dynamic living system with a spiritual feeling of movement (Alencar, 2010; Kellert, 2005).

### **3.2.9.Mobility and wayfinding “Space Layout”**

Mobility and wayfinding is the way of movement through the building is very important to be easy and flexible, so that people can feel comfort and satisfied (Kellert and Calabrese, 2010). The flexibility of movement can be adapted in the classrooms according to the layout furniture arrangement. In practice, one of the studies explained that a rectangular layout increases space utilization, while a circular layout is useful for better communication between students and the teacher. They also demonstrated that when the furniture was in a circular layout arrangement, the students showed a sense of collaboration and high concentration.

## **4. Research Method**

This research adopts a mixed method approach where both qualitative and quantities approaches will be used into three parts. These parts are the factors that affects the student's health and performance and they are collected from the literature review according to the studies and analysis to implement a checklist matrix. In order to help the researcher or a designer to identify the suitable Biophilic design strategies to be adapted in the classroom's interior design to enhance the student's health and performance.

The first part analyze how stress affects the student's performance using Biophilic design

strategies. The second part analyze the student's cognitive performance through the impact of the Biophilic design elements to enhance the memory restoration, attention, concentration and performance. The last part clarifies how the student's emotion, mood and preferences could be affected from the Biophilic elements. The last part identifies the Biophilic nine elements. The three parts are grouped with the Biophilic design elements deduced from the literature review in a matrix. This matrix will be filled by the researcher to deduct a guidelines to use the Biophilic design elements in an efficient way to enhance the student's health and performance.

		Biophilic Design Strategies													
Biophilic Design Elements		Stress Reduction			Cognitive Performance			Emotion, mood & Preference							
		Reduce stress	Lower blood pressure	Increase visual comfort	Lower heart rate	Improve performance	Increase attention of expectation	Increase concentration	Improve memory retention	Positive impact on attitude	Improve mental health	Positive emotional response	Improve perception of special pleasure	Improve comfort and safety	Strong pleasure response
Landscapes and ecosystems	Garden Views	●			●	●				●					
	Natural Colors						●								
	Cool color wheel	●	●								●	●		●	●
Plants	Pots of Flowers and plants	●	●		●					●					
Natural Ventilation	Windows on both sides							●						●	●
Daylighting	Large size windows		●	●					●		●				
	Skylights	●	●	●							●				
	Curtain walls "Full height glazing"			●							●				
Images of Nature	graphics that feature trees, leaves, forests.	●					●	●	●		●	●	●		
Mobility and wayfinding "Space Layout"	Rectangular furniture layout													●	
	Circular furniture layout													●	
Natural shapes and forms	Biomimicry										●				
	Arches, Vaults, & domes										●				
Natural Materials	Natural wood		●								●			●	
	Stones		●											●	

Fig. 5: Final checklist (matrix) linked the Biophilic design elements with the student's health and performance according to the literature review.

### 5. Guidelines for integrating Biophilic design elements according to the matrix results.

There are different studies that has discussed the Biophilic design frameworks and how it affects the human health and wellbeing .On the other hand, neither one of them focused on the specific Biophilic design elements to be adapted in the classroom's interior design to enhance the student's health and performance. This research aim is to provide a matrix according to the literature review data that is

able to help the designer to implement the Biophilic design strategies in the classroom's interior design. The results of this matrix was to identify the efficient Biophilic design strategies and how it can be implemented in the classrooms according to the student's stress reduction, cognitive performance and emotion mood and preferences. The results according to the matrix are classified into eight points according to the Biophilic elements; Landscapes and ecosystems, Natural colors, plants, Natural ventilation, daylighting, images of nature, natural materials, natural shapes and forms and the space layout. In order to implement the

suitable Biophilic design strategies according to the student's comfort and satisfaction.

- Landscapes and ecosystems: according to the literature review data it has a great impact on the student's satisfaction. The classroom's seats should be oriented towards the windows to allow the students to feel the outside environment through views of the gardens. As the results of the matrix clarified that the garden views as able to lower blood pressure, lower heart rate, improve performance, increases the concentration and positively affects the student's mood (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007).
- Natural Colors: According to the matrix it is better to use the soft, warm and calm colors than the cool, dark and high saturated colors in schools. As the harmony of warm colors is able to provide the students with comfortable atmosphere due to the studies of Gower in 2019.
- Plants: There are two ways to use the plants inside the classrooms either natural plants in pots or artificial plants. The use of natural plants and flowers pots inside the classrooms is better according to the matrix, as it is able to enhance the air and atmosphere inside the classroom and increase the student's productivity, memory restoration and reduce the stress. The matrix result was done due to the studies of Heerwagen in 2006.
- Natural ventilation: according to the literature review data it is better to use large size of windows on both sides of the classroom to enhance the natural ventilation (Gower, 2019). In
- a space from a static state to a dynamic living system with a

addition to the matrix results, which shows the impact of the natural ventilation on the student's comfort and enhanced the concentration (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005).

- Daylighting: The research literature review clarified the different ways to implement the suitable daylighting. This could be done according to having skylight openings in the ceilings, large windows on both sides of the classroom, full height glazing. According to the matrix using large the size of windows on both sides will be better than the other two solutions to eliminate the sense of glare and increases the visual comfort. As the daylighting has a great impact on the student's behavior and cognitive through the increase of concentration, positive emotional response and improve the perception of spatial pleasure (elyezadi, 2012; Kim & Kim, 2007).
- Images of Nature: The results of the matrix shows how to allow the sense of nature indirectly by the use of graphics that feature trees, leaves, forests inside the classrooms. In order to allow the students to feel comforted and surrounded by the outdoor environment. Therefore, Images of nature is able to reduce the student's stress, improve their memory restoration and increased their attention according to the matrix results due to the studies of Berman, Jonides and Kaplan in 2008.
- Natural materials: wood is the main feature that is mostly used in the classroom's floors and furniture. Wood can be used in classrooms; in spiritual feeling of movement. The matrix results shows that the use of



natural shapes and forms has a positive emotional response due to the studies of vessel in 2012 and Joye in 2007.

- Space layout: The matrix shows that it is better to arrange the furniture in a circular layout as it affects the student's sense of collaboration and high concentration (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006).

## 6. Applicable Study

The chosen case study is an international school called "Malvern Collage Egypt" one of the high quality standard schools established in 2016 and located in the New Cairo, Egypt. The project is a large U shaped building surrounded by a green area and large swimming pool. The school education levels starts from kindergarten till the high school level. The criteria for choosing this school as it is one of the few schools in Egypt that adapted some of the Biophilic elements; it focused on enhancing the student's comfort and satisfaction through the use of natural design elements inside the classrooms. In addition to the overall conditions of the school design. In order, to be an example for other schools to adapt a new design ideas in the future to enhance the student's comfort The data collection was classified into two steps .The first step of collecting the data was a field survey to the schools' campus to take the possible photos for the primary classrooms in the real conditions and taking notes. The second step was using these photos and notes to fill the deduced matrix in order to identify how many element of the Biophilic features are present. Finally, according to the filling of the matrix, (table 3) will identify the Biophilic elements that are present in the classroom and what should be added to enhance the Biophilic design natural elements inside the school.



Fig. 6: The main gate for Malvern College School.



### 6.1. Biophilic elements guideline matrix

Biophilic Design Elements		Check if it is present
Landscapes and ecosystems	Garden Views	
Natural Colors	Warm color wheel	✓
	Cool color wheel	
Plants	Potts of Flowers and plants	
Natural Ventilation	Windows on both sides	
Daylighting	Large size windows	✓
	Skylights	
	Curtain walls “Full height glazing	
Images of Nature	graphics that feature trees, leaves, forests	
Mobility and wayfinding “Space Layout”	Rectangular furniture layout	
	Circular furniture layout	✓
Natural shapes and forms	Biomimicry	
	Arches, Vaults, & domes	
Natural Materials	Natural wood	✓
	Stones	



Fig. 8: Malvern Collage Primary classroom.



Fig. 9: Malvern Collage primary classroom from another perspective

### 6.1. Discussion and Recommendations

Table 5: Analysed the present Biophilic elements and what are the recommended elements to enhance the Biophilic design inside the classroom ,according to the case study filling matrix.

To be kept	Classroom photos	To be added
Warm colors, through the use of the orange color in different tones, the floor was installed with orange and the walls was painted with another bright tone of the orange color.		Images of nature: graphics that feature trees, leaves, flowers
The two large wood windows, allows the natural daylighting to pass through the classroom.		Natural shapes and forms can be used inside the classrooms to design the walls with shapes that are inspired from the nature
Wood was used as a natural material inside the classroom through rectangular wood panels on the walls.		Pots of Flowers and plants
The classroom has a Circular furniture layout to enhance the student's communication and arranged to be close to the windows to enhance the daylighting exposure.		The classroom view should be exposed to the natural environment through the use of landscape around the building.
		Windows should be on both sides of the classroom to enhance the ventilation.

### 7. Conclusion

This research aim to implement the Biophilic design strategies and identify the suitable and efficient way to be implemented to enhance the student's health and performance inside the classrooms, through the use of the deduced checklist (matrix) in Egypt's schools. The matrix was effective to this research as it clarifies the efficient nine Biophilic elements and how it can be adapted to reach the highest satisfaction for the student's health and performance. In addition to the use of Malvern College School as a case study to show an example of one of the Egypt's schools that started to use the natural

elements inside the classrooms to enhance the student's comfort. This case study was used to support the aim of the research to start implementing the Biophilic design elements inside the schools. The Biophilic design elements don't based on the school quality standard, they are sustainable elements that are affordable to be used through different types of schools (international or even public). It is a new design strategy that started to be used in all over the world and expected to be more desired for the future.



Fig. 10: Research Phases

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## دمج وتكامل إستراتيجيات التصميم الداخلي مع التصميم الحيوي (البيوفيليا) بهدف تعزيز أداء الطلاب المدارس الابتدائية في مصر

تعتبر المدارس من أهم المباني التي تؤثر على أسلوب حياة الجيل و طريقة تفكيره،و تعد مصر واحدة من الدول التي تواجه العديد من المشكلات الناتجة عن ممارسات التصميم الحالية وخاصة بالنسبة لمبانيها التعليمية ، حيث تهمل معظم المدارس تأثير إتصال الفصول الدراسية بالبيئة الخارجية وتأثيرها على سلوك الطلاب وأساليب التعلم، ومما يشار إليه ان الطالب يحتاج إلى الشعور بالراحة والإسترخاء حيث يكونون أكثر تفاعلية وإنتاجية. وهناك العديد من إستراتيجيات التصميم الداخلي التي يمكنها أن تعزز فاعلية المساحة الداخلية للفصل الدراسي وذلك بإنتهاج أسس البيوفيليا (Biophilic Design)، بحيث تكون أكثر راحة وإثارة لإهتمام الطلاب. ويعد البيوفيليا هو أحد حلول التصميم المستدام التي يمكن أن تحافظ على إمكانيات وجود مساحات داخلية مرتبطة بالبيئة الخارجية من خلال إستخدام النباتات، وضوء النهار، والمواد والألوان الطبيعيه . ويهدف البحث الى إقتراح مجموعة من الاستراتيجيات لدمج تصميم البيوفيليا لتعزيز أداء الطلاب في المدارس الابتدائية في مصر. وتشمل المنهجية البحثية : ثلاثة أجزاء. حيث يحدد الجزء الأول أسس تصميم البيوفيليا وتأثيره على صحة الطالب وأدائه ، بينما يشمل الجزء الثاني تحليل عناصر البيوفيليا في إطار أسس التصميم الداخلي للفصل الدراسي. و يناقش الجزء الثالث إعتبرات التصميم اللازمة لدمج تلك العناصر في التصميم الداخلي للفصل الدراسي. ووفقاً للأجزاء الثلاثة، ينتج عن هذا البحث استنتاج مصفوفة تصميمية تستخدم في دمج أسس البيوفيليا مع أسس التصميم الداخلي للفصول الدراسية بهدف رفع أداء الطلاب وبحيث يمكن تطبيقها بهدف تطوير وإعادة تصميم الفصول الدراسية.

**الكلمات المفتاحية:** التصميم الحيوي ، المساحات الخضراء الداخلية ، التعليم في مصر ، استراتيجيات التصميم ، أداء الطالب