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Enhancing Learning Efficiency in Primary Schools in the New Capital through a Biophilic Design Approach

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Abstract

In recent years, there has been an increasing emphasis on improving educational spaces in Egypt to enhance the learning experience for children. Most schools in the country have standard designs in classrooms that may not be considered the healthiest or most comfortable setting for children to learn in, therefore this research aims to find the best solution for children using a biophilic design approach. Biophilic design is an approach that incorporates elements of the outside environment with the interior of a building. This study explores the features and goals of biophilic design, its effect on children, and how it would be best applied in primary schools in one of the newly generated urban areas in Egypt, the New Capital. This is done by thoroughly researching biophilia and child perception, studying existing school projects, and surveying students and teachers. This research concludes by finding a solution for low motivation in primary schools to adopt in new schools in the New Capital through a biophilic design approach.

Keywords: Biophilia, Child well-being, Classroom design, Learning Efficiency, Alertness levels

1 Introduction

Following the COVID-19 pandemic, schools have faced increasing scrutiny regarding the efficiency of their learning environments. Countless efforts have been made to improve both new and existing school designs all around the globe aiming to create more sustainable spaces that promote the well-being of students. Researchers agree that biophilia enhances cognition and mood, reduces stress, and improves physical health [1, 2]. Unfortunately, Egyptian schools struggle with many design issues, often lacking effective strategies regarding student well-being and cognition [1]. Therefore, this research aims to identify the best biophilic elements to implement to enhance student well-being on school grounds and increase performance rates and attention levels. Moreover, this research has been conducted to promote sustainability in Egypt in new and existing buildings with a newfound focus on the user. A key limitation is the lack of local case studies in Egypt, as statistics could not be gathered from students attending sustainable schools. To address this, the research will first examine existing primary school designs in Egypt and then delve into the effects of indoor spaces on students' behaviour in classrooms. It will then explore biophilic design approaches, uncovering the best applications. The research will conclude by discussing a questionnaire designed to identify the strengths and weaknesses of typical Egyptian school designs. The goal is to compare these findings with biophilic design principles, providing a reference that future researchers and interior designers can use as a practical guide, especially in new schools being constructed in the New Capital of Egypt.

2 Literature Review

2. 1 Existing School Environments

To identify areas that require enhancement and implementation for new schools in the New Capital, it is essential to thoroughly analyse the design elements present in Egyptian schools. This examination will delve into several key aspects, particularly focusing on access to natural daylight, ventilation systems' effectiveness, and appropriate furniture selection. Each of these elements plays a crucial role in creating an encouraging learning environment, and understanding their current state will guide necessary improvements. The upcoming sections will explore these factors in detail, highlighting their significance in the overall educational experience.

2.1.1 Lighting and Ventilation

Many Egyptian schools follow a similar architectural style, in which the main school structure is a simple square or rectangular shape with a massive void in the middle (See Fig.1). This allows efficient natural light entry into classrooms without outside distractions to the students. These inner windows increase natural lighting, supporting the large windows on the building facades. The openings also allow access to natural ventilation, which greatly impacts the comfort, learning effectiveness, and cognitive skills of students [1]. These openings are what connect the students to the outside environment, which is why they should be designed efficiently. Daylight access is crucial for students and teachers to have better moods and concentration [1]. This is successfully applied in countless schools in Egypt. Newer schools have let go of the open-air hallway concept in Egypt but continue to give enough access to daylight in classes. For example, classrooms at GEMS International School Cairo (GISC) allow daylight into the classrooms through big windows on the outer facade, minimising the need for artificial lighting (Fig. 2). According to an attending student, the access to natural lighting in the classroom was very successful, as they seldom needed to turn on the lights. A downside to the classroom design is that they infrequently opened the windows for natural ventilation and heavily relied on the use of HVAC systems. While HVAC systems are good for the thermal comfort of students and staff, they should not be the sole source of ventilation as the natural source is much more beneficial than artificial means.



Fig. 1: Qaitbay International School architectural design, allowing natural lighting from the hallways.



Fig. 2: Large windows allowing sufficient daylight access into classrooms at GISC.

2.1.2 Furniture Selection

The furniture that is used to furnish classrooms is highly important, as comfort plays a vital role in the learning experience of students. Furniture in most schools in Egypt is made of solid plastic, wood, or particleboard. The normal classroom consists of chairs and desks and some schools incorporate soft seating such as poufs or sofas. The standard selection of furniture in most schools is good for the posture of students as their backs are supported well. Unfortunately, some of the furniture selected nowadays breaks often, as they are not durable enough for the heavy daily use of children. Nonetheless, furniture selections have improved in recent years, pushing for more comfort and flexibility in the classroom, as discussed in the following section, though it has not been applied in Egyptian schools yet.

2. 2 Indoor Spaces Affecting Student Behaviour in Primary Schools

Over many years, studies have proven that designs of built environments influence the behaviour of humans of all ages. It is common to find negative school experiences and results, such as dropped attendance rates and negative behaviour [3]. Aside from social factors that influence the behaviour of students such as the style of teaching and peer relationships, environmental factors play a significant role in influencing the behaviour of children. The classroom environment is comprised of the lighting, colours, and seating layout. Some colours are known to have positive effects, such as green and blue. Blue increases academic performance, especially in creative and difficult tasks [4]. Green was found to be beneficial when there is a requirement for high concentration such as reading [5].

Today, schools are adopting flexible classroom furniture, replacing traditional seating [6]. This decision was made to optimize classroom spaces, promoting a better learning environment. After observing 30 students in 10 different classrooms, Attai et al. [6] found that students were more satisfied and comfortable in school with flexible furniture than students in classrooms with traditional furniture. Furthermore, flexible furniture allows students to use the furniture in many ways and act autonomously around the space. Colours and designs are also important factors to consider when assessing child behaviour and performance in schools. It is highly recommended to adopt natural elements into the classroom, as they have positive effects on students, which is further elaborated on in the coming sections.



Fig. 3: Flexible furniture design by Artcobbell and classroom layout by Huckabee Inc., for elementary classrooms. Adapted from Attai et al. [6]

2. 3 Biophilic Approaches in Primary Schools

The Biophilic approach is a sustainable design technique that aims to connect the students with the outside environment leading to increased academic and behavioural performance [7]. As previously mentioned, biophilic elements reduce stress and improve cognition, mood, physical health, and happiness in spaces [1, 2]. To successfully apply biophilia in spaces, it is suggested to follow the following five principles [8]:

1. Focus on human adaptation to nature which over time, has improved human health and well-being.
2. Encourage connections between people and nature, fostering a sense of responsibility towards both communities.
3. Promote architectural solutions that are interconnected and integrated with nature.
4. Engage frequently and sustainably with nature.
5. Encourage creating emotional bonds with specific settings and locations.

2.3.1 Harmful Influences on Children to be Treated with Biophilic Design

Due to the constant developments in the urban and technological worlds, exposure to natural scenery has been reduced especially in developing countries [9]. Not only has nature been sacrificed for new structures to rise, but the exposure of children to nature has been significantly reduced due to their usage of electronic devices [9,10]. Children have less access to nature at home due to the factors mentioned earlier. A possible solution is to introduce natural elements into schools, as this is the place where children spend most of their time outside of home. It is important to implement biophilic elements to help all students, including those with declining mental health, which is very common in the new generations. Researchers found that students with mental health struggles have a hard time giving sufficient attention or concentration when needed, negatively affecting their learning [11]. Seeing the importance of having nature integrated into the lives of children, schools in the New Capital should strive to support their students through their learning environment.

2.3.2 Biophilic Features to Apply in Primary Schools

Biophilic design elements are an excellent addition to schools because they help reconnect students with the outdoors, enhancing their cognitive abilities and alertness, something schools in the New Capital should aim to achieve. Kellert and Calabrese [8] listed three types of experiences of biophilic designs, as seen in Table 1. It is favourable for designers to incorporate these factors into the classroom to reach the desired improvements in students. Many ways exist to integrate biophilia into learning environments through architecture and interior design, as discussed next.

Table 1: Experiences and Attributes of Biophilic Design.
Adapted from Kellert and Calabrese [8].

Direct Experience of Nature	Indirect Experience of Nature	Experience of Space and Place
Light	Images of nature	Prospect and refuge
Air	Natural materials	Organized complexity
Water	Natural colours	Integration of parts to whole
Plants	Stimulating natural light and air	Transitional spaces
Animals	Naturalistic shapes and forms	Mobility and wayfinding
Weather	Evoking nature	Cultural and ecological attachment to place
Natural landscapes and ecosystems	Information richness	
Fire	Age, change, and patina of time	
	Natural geometrics	
	Biomimicry	

As shown by Kellert and Calabrese [8] in Table 1, having an indirect experience of nature is a part of biophilic design. This means that designers can extract design solutions from nature. This experience can be achieved by doing the following:

1. Incorporating natural imagery (ex. pictures, natural materials, organic shapes)
 - a. Emotionally and intellectually satisfying. This form of application must be abundant.
2. Using natural materials in finishing or furniture (ex. Wooden floors, walls, chairs, desks, decorations)
3. Selecting natural colors in the classroom (ex. Earth tones; green, beige, brown, white, blue).
4. Utilizing organic shapes in wall or floor designs, furniture layouts, or furniture shapes.
5. Stimulating natural ventilation and daylight.
6. Using natural geometries (ex. Repeating natural patterns, Fibonacci square, golden ratio).
7. Creatively applying biomimicry (ex. Shading elements taking on the form of leaves)

Kellert and Calabrese [8] added experiencing biophilia through space and place. These are based on human tendencies and how designers can use them to strengthen their designs. Kellert and Calabrese [8] have explained them in the following points:

1. Prospect and refuge refer to the human ability to understand the surrounding areas of dangers, opportunities, safety, and security. This can be accomplished through design strategies such as

providing views to the outside, creating visual connections between interior spaces, and ensuring secure, sheltered environments.

2. Organized complexity refers to people being naturally attracted to complex settings as they are often rich in possibilities and opportunities. This strategy must be implemented in an organized manner.
3. Integration of parts to wholes refers to people appreciating environments where different elements come together as a cohesive whole. This unity can be achieved through a sequential arrangement of spaces and clear boundaries. Additionally, incorporating a central focal point, whether functional or thematic, can enhance the overall integration of space.
4. Transitional spaces are zones that move you from one place to another. This must be done in a manner that is easily understood and links the outside to the inside.
5. Mobility and wayfinding refer to people finding comfort in free movement between different spaces, achieved through easily understood paths and entrances.

First, schools should be designed to allow daylight and natural ventilation to help students be more comfortable and attentive in class, thus increasing their motivation and learning effectiveness [12]. This can be achieved by doing the following:

1. Maximize window sizes.
2. Remove or open anything that may block daylight.
3. Place tables and seats near windows.
4. Place windows on both sides of the indoor spaces or ceiling.
5. Move storage units away from the windows.

Maximising openings in the architectural design is strongly recommended; however, it is recommended that a shading element be used to minimise heat gain and direct sunlight. It is also achievable through implementing the traditional design of schools in Egypt, as seen in Fig. 1 featuring open-air hallways and large windows for natural light and ventilation. It's also important to remove objects that obstruct light access, like shelving or posters [8]. Additionally, using plants enhances student performance and promotes positive feelings [13]. Biophilic design principles allow designers to draw solutions from nature, which can include the following:

1. Incorporating natural imagery (ex. pictures, natural materials, organic shapes)
 - a. Emotionally and intellectually satisfying. This form of application must be abundant.
2. Using natural materials in finishing or furniture (ex. Wooden floors, walls, chairs, desks, decorations)
3. Selecting natural colours in the classroom (ex. Earth tones; green, beige, brown, white, blue).
4. Utilizing organic shapes in wall or floor designs, furniture layouts, or furniture shapes.
5. Stimulating natural ventilation and daylight.
6. Using natural geometries (ex. Repeating natural patterns, Fibonacci square, golden ratio).
7. Creatively applying biomimicry (ex. Shading elements taking on the form of leaves)

2.3.3 Outcomes of Biophilic Design Reflected on Students

Several researchers agreed that biophilic design elements are effective in improving the mood of not only the students but also the teachers. The use of plants aids in improving student performance and evoking

positive feelings [12]. Doxey, Waliczek, and Zajicek [11] have concluded in their research the following, further supported by Daly, Burchett, and Torpy [14]:

1. The presence of plants in a classroom with no other natural elements had the most significant impact on student performance.
2. Plants can be used as an alternative to architectural elements (ex. Windows).
3. Passive encounters with nature can enhance job and home life satisfaction and influence mood and cognition.
4. Plants decrease symptoms of illnesses.
5. Potted plants can reduce absences among primary school children.
6. Student behaviour and grades improved when greenery was introduced into the classroom.
7. Lecturers who had plants in their classrooms were more organized and enthusiastic than lecturers without plants.

Daly, Burchett, and Torpy [14] conducted a study with over 360 students aged 12 to 13, finding that adding plants to classrooms improved grades in mathematics, science, and spelling by 10-14% in two of three schools. The third school, which already had a gardening program, showed no improvement. The researchers also noted that plants enhance air quality, reducing carbon dioxide (CO_2) and volatile organic compounds (VOCs), even in schools with open windows. This underscores the importance of plants in environments lacking proper ventilation.

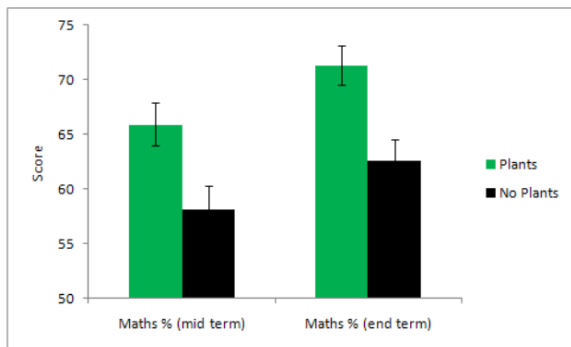


Fig. 4: Mid-term and end-of-term mathematics results of classrooms with and without plants in School A.
Adapted from Daly, Burchett, and Torpy [14]

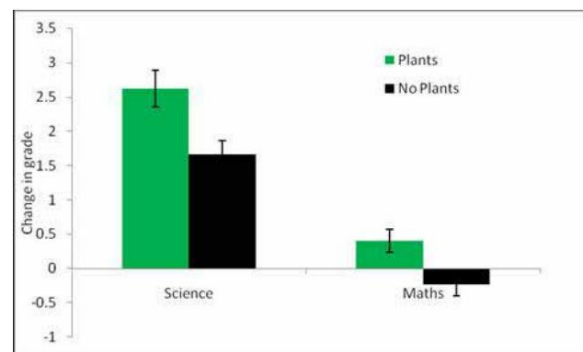


Fig. 5: End-of-term math and science grades change in comparison with and without plants in School B
Adapted from Daly, Burchett, and Torpy [14]

3. Comparative analysis

To identify the shortcomings in school interior design in Egypt, primary school students and teachers were surveyed about their experiences with school and classroom designs. A questionnaire was distributed among 6 teachers and 27 students between the ages of 7 and 15 in typical schools to gather data on design flaws in their classrooms. They were given a digitalised questionnaire that included photos of biophilic design to understand the aspects inquired about. The goal is to theoretically compare these issues using descriptive analysis with biophilic design principles, creating a reference for future research and serving as a practical guide for interior designers, especially those who are designing schools for the New Capital. The findings are summarised in Table 2 where each design element is analysed starting with how it is implemented, how biophilia addresses it, and then analytically comparing the two.

In the first section of the questionnaire, respondents rated their overall comfort in the classroom, with 36.4% giving a score of 3 out of 5, and 54.6% rating it as 4 or 5. Only 9.1% rated it as 2. When asked about

biophilic elements in their schools, most reported either no implementation or only recent initiatives, with common features being the use of green colours and large windows for natural lighting. In the second section, students rated natural lighting exposure mostly between 3 and 5, with 33.3% at 3, 33.3% at 4, and 27.3% at 5. Additionally, 81.9% preferred natural lighting and 66.7% felt more energized in those environments, while 78.8% noted a significant mood improvement in naturally lit classrooms.

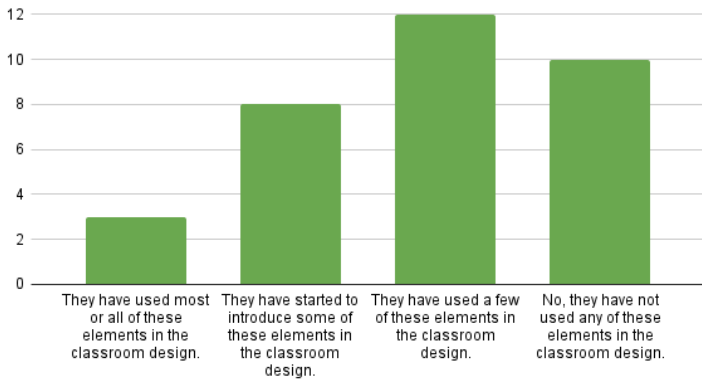


Fig. 6: Frequency of biophilic element application in typical Egyptian schools.

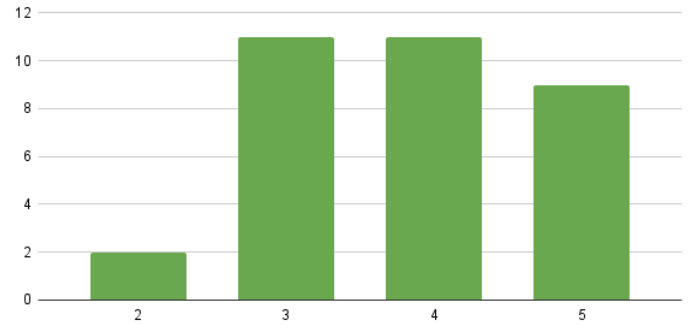


Fig. 7: Rating of natural light exposure inside classrooms rated 1-5.

Students and teachers were surveyed about ventilation methods and efficiency in their schools. Only 45.5% reported that the ventilation was adequate, while 54.5% reported bad odours and stuffiness. They were then asked about the frequency with which they open the windows in class, to which most gave a 3 out of 5. Following, respondents were asked about which ventilation method their schools relied on most. Many indicated that HVAC systems are more commonly used than natural ventilation, with 48.5% agreeing that windows provide sufficient ventilation, though 18.2% disagreed. Finally, they were asked whether their schools encouraged opening windows rather than relying on the HVAC systems (see Fig. 9). Unfortunately, schools have not encouraged opening windows, preferring to rely on AC.

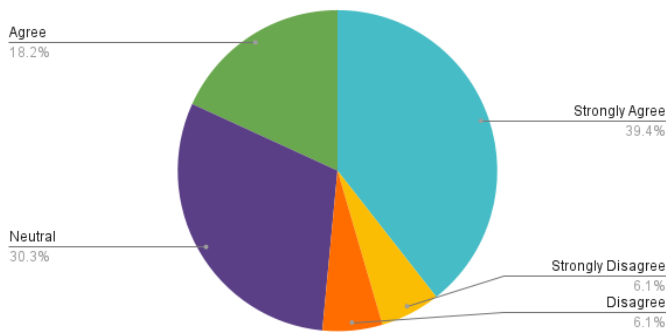


Fig. 8: Rate of Egyptian schools' reliance on HVAC systems more than natural ventilation

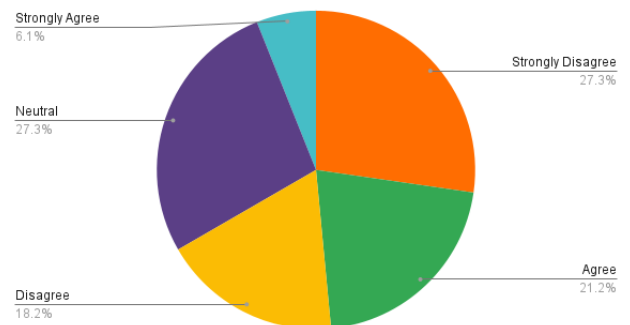


Fig. 9: Rate of Egyptian schools' encouragement of utilising natural ventilation instead of HVAC systems.

The last section of the questionnaire inquired about natural elements to analyse how people perceived them and whether they would respond to them well or not in their schools. An impressive 90.9% of respondents reported mental well-being and relaxation, and 84.8% reported physical well-being when they are surrounded by nature. Furthermore, 75.8% stated that natural settings help them focus on their tasks, while the remaining 24.2% felt neutral. Respondents were then asked to rate their connection to nature inside the classroom (see. Fig. 10). 21.2% rated their connection as 1 out of 5, 33.3% rated as 2, 21.2% rated as 3,

12.1% rated as 4, and 12.1% rated as 5. 78.8% of respondents then expressed their desire to connect with nature more during school hours. Moreover, 90.9% of respondents also emphasised the importance of nature to them in their classroom (Fig.11). Finally, 87.9% of respondents said they are pleased with the idea of having natural imagery surrounding them and would like its implementation in their classes.

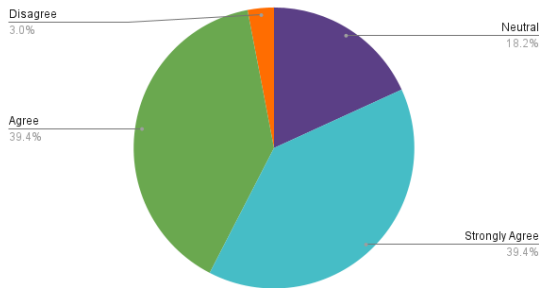


Fig. 10: The measured importance of natural connection in school to users.

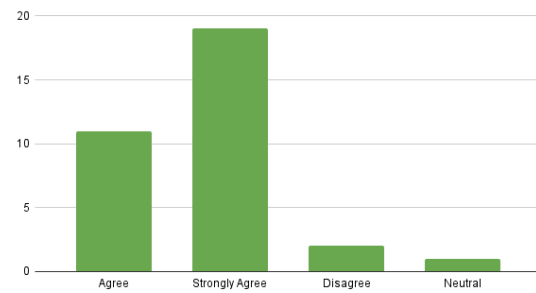


Fig. 11: The measured importance of natural elements in surroundings to users.

Table 2: Comparison of typical Egyptian school elements and how these elements are addressed in biophilia.

Elements	Existing	Biophilic approach	Researcher analysis
Natural lighting	Large windows are used on building facades, and on both sides of the classrooms if the hallways are open air.	Maximising window sizes and skylights.	Most schools have enough daylight access coming into the classroom through large windows. Some schools have windows on two sides of the classrooms depending on the architectural style, maximising daylight entry.
Natural ventilation	Large windows along with AC and fans are installed.	Utilising natural air ventilation rather than depending on HVAC systems.	The large windows are not opened often, leaving the students and teachers feeling uncomfortable by the odours and stuffiness of the classrooms. The schools do not encourage opening windows and opt to use ventilation systems instead.
Natural elements and textures	Natural textures are rarely used but can be found in flooring. Natural colours can be found as some schools use green and beige in their colour palettes.	Use of natural materials and textures in furniture, flooring, and walls.	Natural textures and elements are crucial in design because they are the key to tying the outside environment with the inside of a building. It is highly important for the well-being of students and, therefore must be implemented.
Biomimicry	Biomimicry can be found in patterns; however, it is not common.	Biomimicry is present in naturally formed furniture shapes, and furniture layouts. This also includes wall and floor designs, and even ceiling designs.	Older schools typically have students seated in rows, lacking dynamic group seating. Newer schools are experimenting with innovative furniture arrangements and organic wall elements, though these changes are not yet seen in classrooms above kindergarten.
Furniture Design	Traditional furniture is equipped. They are made of solid plastic or metal coloured white, dark green, or dark blue.	Furniture is made of natural materials and sometimes takes on an organic form.	School furniture is often uncomfortable, inflexible, and lacks natural textures. These aspects should be considered for their positive impact on concentration and health.

Conclusion

As the world shifts towards sustainability and prioritizing human well-being, especially in the wake of the COVID-19 pandemic, it is crucial to incorporate sustainable designs into built environments. One effective approach to sustainable design is biophilia, which has demonstrated positive effects on well-being, cognition, behaviour, mood, and academic performance. Research has shown that when biophilic elements are introduced into classrooms, they significantly benefit both teachers and students. Therefore, it is important to continue implementing these elements to help individuals feel more comfortable in their environments. This, in turn, can lead to stronger relationships with peers, improved mood, and enhanced academic outcomes.

Recommendations

It is recommended that both private and public sectors adopt biophilic design when opening new schools to improve outcomes for students and teachers. This design approach leads to reduced stress, improved concentration, and enhanced mood. In classrooms, features like natural light, wood textures, and plants can boost focus, creativity, and engagement. Additionally, using sustainable materials fosters environmental awareness and teaches students the importance of sustainability. By integrating biophilic principles, schools can create spaces that support student growth and resilience while promoting a lifelong connection to nature and fostering positive environmental values for future generations.

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