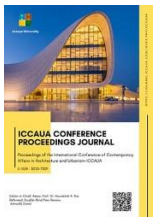

ICCAUA Proceedings Journal
Proceedings of the international conference of contemporary affairs in architecture and urbanism-ICCAUA
Volume 9 (December 2026), 2610157

Journal homepage: https://journal.iccaua.com/

DOI: https://doi.org/10.38027/ICCAUA2026EN0157

Biophilic Learning Environments and Cognitive Performance in Egyptian Primary Schools

* [1] **Yasser Mahgoub** , [2] **Zeinab Tahoun**
[1, & 2] Department of Architecture Design and Digital Architecture, Faculty of Engineering, University of Galala , Suez, Egypt
[1] E-mail: ymahgoub@gu.edu.eg , [2] E-mail: zainab.tahoon@gu.edu.eg,
[1] ORCID: https://orcid.org/0000-0002-6900-0733, [2] ORCID: https://orcid.org/0009-0003-1915-8545

Received: 25.04.2026
Revised: 23.06.2026
Accepted: 01.07.2026
Available online: 10.07.2026

This article has been selected and peer-reviewed for publication in this journal as part of the 9th International Conference of Contemporary Affairs in Architecture and Urbanism, held on 7–8 May 2026 in Istanbul, Türkiye.

Abstract

Despite extensive historical, philosophical, and psychological acknowledgement of nature's positive influence on children's learning, no standardized, empirically validated framework currently exists for measuring how biophilic learning environments affect the creative and cognitive abilities of primary school children — particularly within Egyptian educational architecture. While biophilic design principles are increasingly referenced in contemporary school design discourse, three critical gaps persist in the literature: (1) the absence of quantifiable environmental metrics linking spatial qualities to cognitive outcomes; (2) limited contextual adaptation of biophilic frameworks to developing-country school typologies; and (3) a persistent disconnection between architectural design patterns and measurable cognitive outcomes — including memory consolidation, attention restoration, and problem-solving capacity. This study makes two original contributions to the field. First, it introduces the Biophilic Classroom Assessment Tool (BCAT) the first standardized instrument designed specifically to evaluate the environmental qualities of primary school classrooms in relation to cognitive performance, filling a gap that existing tools have not addressed within non-Western educational contexts. it implements a mixed-method quasi-experimental design that integrates environmental measurements, validated creativity assessments, and systematic behavior mapping — moving beyond the predominantly qualitative or perception-based methodologies that dominate current biophilic design research

Together, these contributions advance the evidence base for environment-behavior research in educational settings and offer a replicable, context-sensitive model applicable to school design policy and practice in Egypt and comparable Global South contexts.

Keywords: Biophilic Design; Egyptian Schools; Cognitive Skills; Creative Ability; Learning Environments; Evidence-Based Design

1. Introduction

The rising ubiquity of digital devices and social media has drastically altered the daily experiences of adolescents, leading to diminished face-to-face interaction and heightened levels of social isolation globally. This behavior became most apparent during the COVID-19 epidemic, which exacerbated physical isolation and restricted opportunities for direct interaction with both social and natural surroundings. As adolescents increasingly spend more indoors and detached from nature, worries about their psychological welfare, social development, and cognitive performance have garnered heightened scientific interest. In this environment, architecture has become a vital element in influencing students' educational experiences and general welfare. Nature-informed design beyond mere compliance with fundamental environmental performance standards, instead addressing the inherent human inclination to establish relationships with living systems and natural surroundings. In educational environments, these links are linked to improved psychological wellbeing, mental rejuvenation, and possibilities for significant social engagement.

The incorporation of nature into school surroundings is especially important when it is integrated into the daily teaching experience rather than regarded as an ancillary element. Exposure to natural surroundings can enhance students' mental health, reinforce their connection to the biosphere, and offer opportunities to monitor ecological processes and environmental transformations. Moreover, including students in activities like gardening, ecosystem observation, and the assessment of sustainable construction systems can foster immersive learning experiences that enhance educational outcomes (Franco et al., 2017). Given that children and adolescents are particularly susceptible to environmental effects during various developmental stages, schools constitute a vital element of the built environment that can significantly impact cognitive development, behavior, and social health. This issue is especially pertinent in developing nations, such as Egypt, where significant sums have been allocated to enhance educational quality via new facilities, technical infrastructure, and pedagogical reforms. The impact of the physical and natural attributes of school surroundings on student cognition remains little investigated in these circumstances.

The connection between nature and cognitive growth has been thoroughly investigated through several theoretical

frameworks, particularly biophilia theory, ecological psychology, and studies on cognitive restoration. The biophilia hypothesis posited by Wilson (1984) asserts that humans have an intrinsic attraction to nature, evolved through processes that enhance psychological well-being and cognitive performance. Research in developmental psychology substantiates this claim, indicating that exposure to natural surroundings enhances attentional ability, memory retention, emotional regulation, and academic engagement. Research indicates that children exposed to green environments demonstrate enhanced concentration, improved problem-solving skills, and increased resilience to stress, while access to natural settings correlates with better executive functioning and psychological well-being (Kuo & Taylor, 2004; Chawla, 2015; Wells & Evans, 2003). These findings have promoted the implementation of biophilic design concepts in educational settings by integrating natural materials, plants, organic shapes, and direct access to outdoor learning areas.

In addition to the biophilia approach, ecological psychology underscores the significance of environmental affordances in influencing cognition and behavior. Gibson (1979) contended that cognition arises from the interactions between persons and their environments, wherein physical contexts offer chances for action, exploration, and learning. Heft (2001) illustrated that natural surroundings provide a greater diversity of affordances compared to traditional classroom settings, fostering inquiry, innovation, and active engagement. Studies on nature-based learning environments, outdoor classrooms, and forest schools have demonstrated that exposure to varied and dynamic environmental conditions enhances cognitive flexibility, spatial reasoning, collaborative problem-solving, and motor development (Fjørtoft, 2004; Herrington & Brussoni, 2015). The findings indicate that educational settings that encourage engagement with nature can enhance experiential learning and foster several dimensions of cognitive development.

Recent empirical data has strengthened the correlation between exposure to nature and cognitive function. Systematic reviews and meta-analyses have evidenced beneficial impacts of natural surroundings on attention restoration, executive functioning, and cognitive performance in children (Nguyen & Walters, 2024). Exposure to green settings has been shown to diminish cognitive overload, mitigate stress, and foster conditions conducive to effective learning (Nanda et al., 2024). Longitudinal studies have linked greater environmental greenness to enhanced cognitive functioning in children, whereas experimental research has demonstrated superior attentional performance after exposure to natural settings relative to urban environments (Wells, 2000; Stevenson et al., 2019). These studies collectively demonstrate that nature affects cognition via several mechanisms, including attentional restoration, stress alleviation, environmental stimulation, and chances for experiential learning.

Notwithstanding the expanding corpus of evidence associating natural surroundings with cognitive outcomes, significant gaps persist. Current research predominantly centers on Western contexts and often emphasizes outdoor habitats, but the cognitive effects of indoor biophilic design in educational institutions are inadequately explored. Moreover, while many research indicate favorable correlations between exposure to nature and cognitive performance, the application of these findings within architecture-focused design frameworks is still restricted. At now, there is no empirically verified methodology that systematically assesses the impact of various biophilic design qualities on students' cognitive and creative performance, especially in the Egyptian educational context. As a result, architects and educational planners are devoid of evidence-based instruments to facilitate the integration and assessment of biophilic design solutions within educational settings.

This project aims to create a complete framework connecting biophilic design qualities with quantifiable cognitive results in educational environments. The study integrates theories of biophilia, ecological psychology, and cognitive restoration to delineate the principal characteristics by which nature affects cognition. The framework delineates biophilic educational environments via four interrelated dimensions: exposure to and connection with nature, environmental affordances that promote active learning, restorative aspects of the environment, and the integration of sensory and material elements with nature. These characteristics jointly facilitate cognitive development via attention restoration, executive functioning, cognitive flexibility, problem-solving, creativity, emotional management, and learner engagement.

This study seeks to implement the framework by identifying biophilic design criteria pertinent to Egyptian schools, converting these criteria into quantifiable environmental indicators, evaluating students' cognitive and creative performance, and analyzing the correlations between particular biophilic attributes and cognitive outcomes. A mixed-method quasi-experimental design is utilized, incorporating environmental evaluation, cognitive and creativity assessments, and behavioral observation to offer a thorough knowledge of the impact of educational environments on student performance.

The research enhances the field by promoting an architecture-focused comprehension of the connection between biophilic design and cognition. The suggested approach establishes a basis for evidence-based educational design by converting theoretical notions into quantitative environmental indicators and associating them with quantifiable cognitive results. Moreover, it provides context-specific guidelines for architects, designers, and politicians aiming to improve student wellbeing and cognitive development through nature-integrated educational settings, especially in Egypt and similar Global South contexts.

2. Literature Review

2.1 Egyptian Educational system

The Egyptian Ministry of Education seeks to pay attention to technology and digital transformation and effectively contribute to enhancing the inputs and outputs of innovation, but the reality indicates some of the following opportunities and challenges:

Educational ins tutions suffer from the lack of the technological infrastructure components of digital transformation, the most important of which is the lack of electronic systems to manage the educational process - LMS as a whole, and the

lack of Institutional Digital Repositories that allow providing knowledge and educational resources in a digitally and easilystudents, in addition to the weakness of the Internet The speed varies from place to place.
The Corona pandemic crisis revealed the extent of the fragility of this institutional situation and the inability of educational institutions to continue the educational process in light of the suspension of studies under the imposed ban and social distancing measures, as educational institutions in their traditional image did not use technology in education, and teachers and university professors were not accusviaddition to the existence of a societal digital divide; A study conducted in 2016 indicates that there are 0.9 computers for every 10 students in the second grade of middle school, which prevents some social groups from accessing the Internet, owning computers, and using smart phones.
The Ministry of Education has tended to generalize the use of tablets in education, known as "tablets", which are a means that transforms the student from a mere beneficiary of information to an active and active participant, in obtaining it and in fruitful interaction in the discussion with colleagues and teachers. However, the possibilities are still limited to generalize the experience. There are difficulties in using it because of the weak Internet and the lack of students and teachers accustomed to using it before. The issue of integrating technologies onto schools is still remains that is why the presence of students' present in the school help to improve and monitor the outcomes related to the quality of received education and more importantly the social aspect of being physically present in their school facility1

2.2 Student Environment

Studies revealed that teenagers learn by interactive experiences with the built environment showed better behavior, and that the natural environment is a catalyst a teenager's communication and connections school awareness in comparison to those isolated or distant from their built environment2. Since the built environment has a major role in influencing the quality of education, attention must be paid to study how school architecture can create the best built environment with standards that are sustainable and friendly.
The 21st century educational buildings, as a direct response to the technology, should revisit the importance of nature to the human wellbeing and create learning environments that motivate students, i.e. spaces that are experienced positively. In this sense, this proposal does not only focus on the physicality of school building in Egypt, but rather it digs deeper into the essence of space as both a product and a catalyst to the human experience and behavior development. In that sense, this research aims to establish a better educational environment that help teenagers have an improved what Nikos Salingaros's called 'living patterns'. Living patterns are an underlying biological structure of design solutions where users of space can respond, both psychologically and physiologically, in a healthy manner (Salingaros, 2017). Such natural response is considered to be the blueprint for psychosocial theory through the works of two psychologists: Alfred Adler and Erik Erikson. This research aim to adopt the concept of living patterns of behavior of teenage students in their micro social environment which is the school, moreover conclude a spatial behavior of individuals as a reflection of the built environment The thesis attempts to build compressive module using the nature as an approach to adjust the characteristic of the building and social responsibility of teenagers behavior. The proposal explores the gap in the literature regarding the impact of the intellectual approaches in the educational system that address students' behavior and morality on the architectural design of schools in Egypt and attempt to resolve one of the main problems that the millennials face and suffer from.
On that note, this thesis aims to investigate the current situation in Egyptian schools and compare them with the schools that have been developed both internationally and locally such as the Japanese school modules in Egypt, Experimental schools, Al=Azhar schools..etc and to set better module for improving the design of school buildings architecture to better suit raising of teenagers' morals and develop their social roles in the community by using natural elements and prepare them for the important future role and character they need. According to UNICEF, 95.4 percent of the population in Egypt aged between six and 18 years old is enrolled in school. Primary and prepatory school is mandatory for all students. These millions of students are distributed across thousands of schools nationwide. But, despite the high enrollment, UNICEF says that "the quality of education remains a major challenge that hinders the capacity of children to develop to their full potential." The quality of schools and tuition value is often related to the quality and number of languages offered in a school. That conception is not immediately evidence by the four types of schools in Egypt: public, private, national institutions, and expat and embassy schools.

3. Theoretical Foundations of Biophilic Design in Educational Environments: From Cognitive Restoration to Contextual Application

The increasing convergence of architecture, environmental psychology, and educational research has underscored the crucial influence of the built environment on human cognition and wellbeing. Modern architectural language increasingly acknowledges that buildings are not mere passive vessels for activities but active entities that affect psychological, behavioral, and cognitive processes. In educational environments, this link is crucial since students dedicate significant time to tasks that necessitate prolonged focus, information processing, memory retention, and innovative problem-solving. Investigating how architectural settings facilitate or obstruct cognitive activities has thus emerged as a vital field of study.
Attention Restoration Theory (ART), introduced by Kaplan and Kaplan in 1989, is a significant theoretical paradigm elucidating the connection between environment and cognition. ART posits that directed attention, essential for learning and academic achievement, is a finite cognitive resource that diminishes with extended mental exertion. When cognitive

1 schools for skills: a new learning agenda for Egypt, OECD 2015
2 James M, Fry R, Mannello M, Anderson W, Brophy S (2020) How does the built environment affect teenagers (aged 13–14) physical and mental fitness

resources are depleted, individuals encounter mental tiredness, impaired concentration, and decreased cognitive function. Natural surroundings, however, have restorative properties that facilitate the recuperation of cognitive resources. Natural environments captivate involuntary attention through attributes including interest, compatibility, extent, and a sense of detachment, thereby permitting directed attention systems to recuperate and rejuvenate. Thus, environments that integrate natural elements can improve students' cognitive performance by alleviating mental tiredness and facilitating attentional restoration.

The significance of cognitive restoration is especially apparent in educational settings. Educational institutions place significant cognitive demands on pupils via ongoing learning tasks, evaluations, and extended durations of focus. Concurrently, educational institutions frequently subject pupils to environmental stressors including congestion, insufficient lighting, suboptimal acoustic conditions, and restricted access to nature. The quality of the physical learning environment is a crucial aspect in students' capacity to sustain attention, absorb information, and engage effectively in educational activities. Educational environments should not only facilitate learning but also promote cognitive rejuvenation and psychological health. The design of educational spaces can either intensify mental tiredness and stress or establish conducive situations that promote concentration, engagement, and creativity.

This challenge is especially pertinent within the Egyptian educational framework. Egyptian schools have elevated occupancy rates, congested classroom demographics, and a significant reliance on artificial indoor climatic conditions. Educational institutions often emphasize functional needs, capability, and cost-effectiveness, neglecting environmental attributes that enhance cognitive health. Consequently, a disparity frequently arises between the architectural features of educational facilities and the physiological and psychological requirements of students. Moreover, climate conditions, urban congestion, and restricted access to green infrastructure pose further obstacles to the incorporation of nature in educational settings. These difficulties underscore the necessity for architectural strategies that might improve educational outcomes and environmental quality.

In this regard, biophilia theory offers a significant conceptual framework. Biophilia, introduced by Wilson (1984), refers to the inherent human inclination to establish links with nature and other living organisms. The biophilia hypothesis posits that human evolutionary growth has fostered a biological inclination towards natural surroundings, rendering interaction with nature vital for psychological health and well-being. Extensive research indicates that individuals continuously favor natural areas over urbanized settings, associating greenery, water, and natural landscapes with comfort, contentment, and positive emotional experiences. These choices indicate that the human-nature link transcends mere aesthetic enjoyment and embodies essential psychological and cognitive requirements.

Biophilic design, rooted in the biophilia concept, is an architectural strategy that aims to incorporate natural materials, patterns, and processes into the constructed environment. Biophilic design seeks to establish environments that fulfill humans' inherent desire for a connection with nature, while also enhancing health, wellness, and performance. Biophilic design transcends superficial imitation of nature by integrating authentic experiences with flora, natural light, water, and outdoor settings, alongside indirect interactions via natural materials, organic shapes, and biomorphic patterns. The fundamental assertion is that exposure to natural elements in constructed environments might yield beneficial psychological and cognitive effects akin to those encountered in natural settings.

The theoretical basis for biophilic design is supported by Attention Restoration Theory and Stress Recovery Theory. While ART focuses on the rehabilitation of cognitive resources, Stress Recovery Theory posits that natural surroundings facilitate physiological and psychological recuperation from stress. Collectively, these hypotheses elucidate why surroundings with natural attributes are frequently regarded as therapeutic. Such circumstances foster favorable emotional reactions, diminish cognitive strain, and aid in recuperation from mental exhaustion. Conversely, numerous metropolitan settings possess overstimulating, taxing, or repetitive traits that elevate stress and impair cognitive function. Biophilic design aims to convert constructed surroundings into restorative spaces that enhance psychological well-being and cognitive performance.

Researchers have delineated many experiences, dimensions, and contextual characteristics that enable human-nature linkages to implement biophilic design. These experiences are typically classified as direct encounters with nature, indirect encounters with nature, and experiences of space and place. Direct experiences encompass physical interaction with natural elements including flora, sunlight, water, and ambient air circulation. Indirect experiences encompass natural materials, hues, textures, and depictions of nature incorporated into architectural environments. Experiences of space and place involve spatial arrangements that elicit traits typically associated with natural surroundings, like prospect, refuge, intricacy, mystery, and transitions between indoor and outdoor areas.

While these categories offer a valuable foundation for comprehending biophilic design, research demonstrates significant overlap among individual qualities. Environmental features seldom operate in isolation; instead, various natural aspects concurrently interact to affect users' psychological and cognitive reactions. Water features can facilitate both direct and indirect encounters with nature, while concurrently promoting environmental restoration and sensory involvement. Daylight frequently interacts with perceptions of nature, vegetation, and spatial openness to yield cumulative benefits on wellbeing and cognition. The interconnectedness of biophilic qualities indicates that the efficacy of biophilic design should be perceived as the result of cohesive environmental experiences rather than discrete design interventions.

Thus, implementing biophilic design in educational settings necessitates a thorough comprehension of how various natural elements collectively enhance cognitive repair, alleviate stress, recover attention, and improve learning outcomes. Nonetheless, most current biophilic design frameworks have been formulated within Western contexts and may not adequately represent the environmental, cultural, and climatic attributes of Egyptian schools. Differences in spatial utilization, solar exposure, vegetation kinds, and teaching methodologies require the contextual modification of biophilic design concepts. Consequently, creating a paradigm that converts biophilic theory into quantifiable architectural metrics appropriate for Egyptian educational settings is essential for comprehending and improving the connection between school architecture and student cognition.

Table 1: Experiences and attributes of Biophilic design By Kellert and Calabrese.

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

3.1. Direct Experience of Nature

The direct experience of nature means having a direct contact with nature and natural processes. The eight Biophilic design attributes that are used in this experience are listed in Table.1. The most researched attributes in this experience category in psychological literature are the use of plants in the built environment and natural landscapes and ecosystems.

3.1.1 Natural Light

Natural Light has been promoted by various disciplines as being beneficial for wellness of building occupants, including psychology. From a Biophilic view, humans evolved under natural, diurnal light conditions and therefore natural light and natural light processes should be preferred and most beneficial.

3.1.2 Water

Water has also been found to be restorative, both through views of water [8] and sounds of water. Kaplan and Kaplan note how preferred environments often have a view of water and this was also found in various other studies. In fact, images of the urban environment that contained water were found to be even more preferred than nature images containing no water.

3.1.3 Natural Landscapes and Ecosystems.

The view of greenery from a window, which is listed under the natural landscapes and ecosystems attribute, has been shown in several studies as having beneficial effects on the wellbeing of building occupants.

3.2 Indirect Experience of Nature

As direct contact with nature may not be possible in every design situation, such as in certain medical environments, and looks at representation of nature in the built environment. This experience has ten attributes, which can be found in Table

3.2.1 Images of Nature

Images of Nature can even be more restorative than the view of real nature, depending on the content of the image and the view of nature. Therefore, images of nature may have a large role in environments where exterior views with lush nature may not be possible, due to seasons, adjacent buildings, or external environment.

3.2.2 Natural Materials

Natural Materials The amount and type of material is important for perceived restorative quality and preference. In a study that was made by Nyrud and colleagues the amount of wood in a patient room that was most preferred was an intermediate amount, with the floor, one wall and furniture being made of wood. An entire wood surfaced room and a room with no wood were the least preferred amongst respondents.

3.2.3 Natural Geometries

Natural Geometries refer to mathematical properties commonly encountered in nature. These include hierarchically organized scales, sinuous rather than rigid artificial geometries, self-repeating but varying patterns, and more. For example, fractals are a geometric form often encountered in the natural world, where a basic shape occurs in repeated but varied and predictable ways that contribute both variety and similarity to a setting. Other prominent natural geometries include hierarchically ordered scales such as the “Golden Ratio” and “Fibonacci Sequence.”

3.2.4 Occupational stress, anxiety and depression among Egyptian teachers

Occupational stress (OS) among teachers predispose to depression and anxiety. No study was done to assess these problems among Egyptian teachers. This study aimed to assess the prevalence of OS, depression and anxiety among Egyptian teachers. A cross sectional study was done on 568 Egyptian teachers. The respondents filled a questionnaire on personal data, and the Arabic version of the Occupational Stress Index (OSI), the Arabic validated versions of Taylor manifest anxiety scale and the Beck Depression Inventory (BDI) were used to assess OS, anxiety and depression respectively. The prevalence of OS, anxiety and depression among teachers was (100%, 67.5% and 23.2%) respectively. OS, anxiety and depression scores were significantly higher among teachers with an age more than 40 years, female

teachers, primary school teachers, those with inadequate salary, higher teaching experience, higher qualifications and higher workload. A significant weak positive correlation was found between OS scores and anxiety and depression scores. This study indicated the need for future researches to address risk factors of OS and mental disorders among Egyptian teachers, and the need of periodical medical evaluation of teachers and medical and psychological support for the identified cases.

4. Identification of Biophilic Design Elements for Educational Environments

The classification proposed by Kellert and Calabrese provides a comprehensive framework for understanding biophilic design through three categories: direct experience of nature, indirect experience of nature, and experience of space and place (Table 1). These categories encompass a broad range of environmental attributes that facilitate human-nature connections within the built environment.

However, not all biophilic attributes are equally relevant to educational settings or demonstrate the same influence on cognitive performance. Therefore, a literature synthesis was conducted to identify the attributes most frequently associated with attention restoration, memory, creativity, learning performance, and psychological wellbeing in children. The review revealed that attributes related to natural light, vegetation, views of nature, natural materials, and natural geometries consistently showed positive effects on cognitive functioning and learning outcomes.

The selection of these attributes was further guided by their applicability to the Egyptian educational context, where schools are often characterized by high occupancy rates, prolonged indoor exposure, and limited access to nature. Consequently, five biophilic design elements were identified as the most relevant and evidence-based components for educational environments: **natural light, vegetation and greenery, views of nature, natural materials, and natural geometries and forms**.

These five elements form the basis of the proposed framework and provide the foundation for examining the relationship between biophilic design and students' cognitive skills, including attention, memory, executive functioning, creativity, and learning engagement.

5. Methodology: Establishing the Relationship Between Biophilic Design Elements and Cognitive Skills

This study adopted a literature-based analytical methodology to establish a conceptual framework linking biophilic design elements in educational environments with children's cognitive performance. Following the identification of five biophilic design elements through the literature review, the methodology focused on examining the cognitive outcomes associated with each element and synthesizing these relationships into an integrated framework.

The methodological process began with a comprehensive review of studies in the fields of biophilic design, environmental psychology, cognitive development, and educational architecture. Particular attention was given to empirical research investigating the effects of nature-based environmental characteristics on children's cognitive functioning. The review included both foundational theoretical studies and contemporary empirical investigations addressing the relationship between environmental qualities and cognitive outcomes in educational settings.

The five selected biophilic design elements served as the analytical categories of the study. For each element, relevant literature was examined to identify reported effects on cognition. The analysis focused on cognitive domains that repeatedly appeared across the reviewed studies, including attention, memory, executive functioning, problem-solving, creativity, cognitive flexibility, information processing, and learning engagement. Studies were reviewed to determine whether specific biophilic characteristics demonstrated a positive, negative, or neutral influence on these cognitive domains.

A thematic synthesis approach was employed to categorize and compare the findings. Reported cognitive outcomes were coded according to the biophilic design element being investigated and subsequently grouped into broader cognitive skill categories. This process enabled the identification of recurring patterns and relationships across multiple studies. Rather than examining individual environmental variables in isolation, the analysis sought to understand how each biophilic design element contributes to cognitive performance through mechanisms such as attention restoration, stress reduction, sensory stimulation, and environmental affordances.

The resulting matrix established the theoretical relationship between the five biophilic design elements and the targeted cognitive skills. This matrix constituted the basis for the development of the conceptual framework, where each biophilic element was linked to specific cognitive outcomes supported by evidence from the literature. The framework therefore represents a synthesis of existing knowledge regarding the pathways through which biophilic educational environments may influence students' cognitive performance.

The final outcome of this methodological stage was the construction of a biophilic-cognition framework that organizes the identified relationships between the five biophilic design elements and cognitive skills. This framework subsequently informed the empirical phase of the study and provided the theoretical foundation for assessing the cognitive implications of biophilic design in educational environments.

For a scientific paper, this section should be transformed from a theoretical review into **synthesized results that identify the dimensions of a biophilic design framework and explain their cognitive impacts**. The findings can be presented as follows:

6. Results: Development of a Biophilic Design Framework for Educational Environments and Its Cognitive Impacts

The synthesis of the literature revealed a strong relationship between biophilic design principles and children's cognitive development. Three interconnected theoretical domains emerged as the foundation for constructing a biophilic design framework for educational environments: **Biophilia and Cognitive Development**, **Ecological Psychology and**

Environmental Affordances, and **Nature-Based Cognitive Restoration**. Together, these domains identify the environmental attributes through which nature influences cognitive performance and learning outcomes.

6.1 Nature Exposure as a Cognitive Enhancement Mechanism

The reviewed studies consistently demonstrated that direct and indirect exposure to nature positively influences children's cognitive functioning. Rooted in Wilson's Biophilia Hypothesis (1984), the findings indicate that human beings possess an innate tendency to connect with natural environments, resulting in enhanced attention, emotional regulation, and learning performance. Empirical evidence showed that access to natural settings improves concentration, particularly among children experiencing attention difficulties, while also enhancing memory retention, problem-solving abilities, and academic engagement.

These findings suggest that **visual and physical connections with nature** constitute a primary framework dimension. This dimension includes access to green spaces, outdoor learning environments, natural views, and opportunities for direct interaction with vegetation and natural ecosystems. The cognitive outcomes associated with this dimension include:

- Improved attention restoration.
- Enhanced executive functioning.
- Better memory retention.
- Increased problem-solving capacity.
- Reduced cognitive fatigue and stress.
- Higher levels of academic engagement.

6.2 Environmental Affordances and Active Learning

The ecological psychology literature highlighted the importance of environmental affordances in supporting cognition. Findings indicate that natural environments provide a wider range of opportunities for exploration, movement, manipulation, and discovery than conventional classroom settings. These affordances stimulate active engagement with the environment and support embodied learning processes.

Natural learning environments were found to promote cognitive flexibility, spatial reasoning, collaborative problem-solving, and exploratory behaviors. Studies of nature-based playgrounds and outdoor educational settings demonstrated superior cognitive and motor development compared with traditional school environments.

Consequently, **environmental affordances and experiential learning opportunities** emerged as a second framework dimension. This dimension encompasses varied topographies, interactive outdoor spaces, flexible learning landscapes, and environments that encourage exploration and movement. Associated cognitive benefits include:

- Enhanced creativity and divergent thinking.
- Improved cognitive flexibility.
- Better spatial cognition.
- Increased collaborative learning behaviors.
- Stronger problem-solving skills.
- Greater learner engagement.

6.3 Nature-Based Cognitive Restoration

A third theme emerging from the literature concerns the restorative capacity of nature. Research consistently demonstrated that natural environments reduce mental fatigue, cognitive overload, and stress while supporting psychological well-being. Exposure to greenery was associated with higher cognitive functioning, greater resilience to environmental stressors, and improved attentional performance.

Studies examining both passive exposure (views of nature) and active exposure (walking or learning in natural settings) reported measurable improvements in attention and executive functioning. These findings support the integration of restorative environmental qualities within educational settings.

Accordingly, **restorative environmental design** forms a third framework dimension, including green infrastructure, quiet natural spaces, sensory engagement with nature, and opportunities for refuge and contemplation. Cognitive outcomes associated with this dimension include:

- Attention restoration.
- Reduced stress and mental fatigue.
- Improved emotional regulation.
- Enhanced executive functioning.
- Increased cognitive resilience.

6.4 Sensory and Material Connections with Nature

The literature on biophilic educational design further emphasized the importance of incorporating natural materials, textures, organic forms, and multisensory experiences. Schools designed according to biophilic principles reported higher levels of student engagement and improved cognitive performance. Natural materials and sensory richness contribute to environmental stimulation without causing cognitive overload.

This finding identifies **sensory and material integration of nature** as a fourth framework dimension. Key design variables include natural materials, organic geometries, daylight, natural ventilation, and multisensory environmental experiences. The resulting cognitive impacts include:

- Increased environmental engagement.
- Enhanced concentration.

- Improved sensory processing.
- Greater emotional comfort and well-being.
- Support for creative thinking.

Synthesized Framework

The findings collectively suggest that a biophilic educational environment influences cognition through four primary design dimensions:

Table 2: Final Fram work.

Biophilic Design Dimension	Design Indicators	Cognitive Outcomes
Nature Exposure and Connection	Green spaces, vegetation, outdoor learning, natural views	Attention restoration, memory improvement, academic engagement
Environmental Affordances	Exploration spaces, varied topography, flexible learning environments	Creativity, cognitive flexibility, problem-solving, spatial cognition
Restorative Environments	Green infrastructure, refuge spaces, sensory contact with nature	Reduced stress, improved executive functioning, emotional regulation
Sensory and Material Integration	Natural materials, daylight, ventilation, organic forms	Concentration, engagement, sensory stimulation, creative thinking

Overall, the results demonstrate that biophilic educational environments support cognition through mechanisms of **attention restoration, cognitive stimulation, experiential learning, stress reduction, and sensory engagement**. These mechanisms provide the conceptual basis for the proposed framework linking biophilic design attributes to cognitive development outcomes in children.

7. Conclusion

This study investigated the correlation between biophilic design and cognitive performance in educational settings by conducting an extensive literature review on biophilia, environmental psychology, cognitive development, and educational architecture. The results indicate that nature-integrated learning environments can beneficially affect students' cognitive abilities by promoting attention restoration, alleviating stress, providing environmental stimulation, and increasing engagement in the learning process. Utilizing the theoretical frameworks of the Biophilia Hypothesis, Attention Restoration Theory, Stress Recovery Theory, and Ecological Psychology, the study formulated a conceptual comprehension of the ways in which architectural surroundings can enhance cognitive development.

Analysis of established biophilic design frameworks, notably the classification by Kellert and Calabrese, revealed five biophilic design elements that are most pertinent and consistently endorsed in educational environments: natural light, vegetation and greenery, views of nature, natural materials, and natural geometries and forms. The literature indicates that these characteristics correlate with enhancements in essential cognitive domains, such as attention, memory, executive functioning, creativity, problem-solving, and learning engagement. The study established a paradigm that connects particular biophilic design components to quantifiable cognitive results in educational settings.

The study fills a significant gap in the literature by converting general biophilic design principles into a specific framework relevant to educational architecture. Although prior studies have thoroughly examined the advantages of nature exposure, there has been little focus on determining which specific biophilic characteristics are most pertinent to learning environments and their correlation with distinct cognitive abilities. Moreover, much current research has been performed in Western contexts, resulting in a deficiency of contextually relevant frameworks appropriate for educational settings in emerging nations, such as Egypt.

This paper's primary contribution is the creation of an architecture-centered paradigm that systematically links biophilic design aspects to cognitive performance measures. The framework offers a theoretical and methodological basis for forthcoming empirical studies aimed at assessing the influence of school surroundings on student cognition. Furthermore, it provides architects, designers, and educational policymakers with a systematic framework for integrating evidence-based biophilic techniques into the design and evaluation of educational buildings.

The findings indicate that biophilic design should be regarded not merely as an environmental or aesthetic intervention, but as a cognitive design technique that can enhance learning outcomes and student well-being. Educational institutions are encountering escalating challenges associated with mental fatigue, diminished attention spans, and restricted connections to nature; thus, incorporating biophilic principles in school design may foster healthier, more restorative, and cognitively supportive learning environments.

Subsequent study ought to empirically evaluate the suggested framework across diverse educational contexts and age demographics to substantiate the linkages delineated in the literature. These investigations would aid in establishing quantifiable design standards and enhance the evidentiary foundation for incorporating biophilic ideas into educational policy and architectural practice

Acknowledgements

The authors would like to acknowledge the participating primary schools in Egypt for granting access to their facilities and classrooms to perform environmental measurements and systematic behavioral mapping. We also thank the technical assistants and language editors who provided invaluable non-authorial support during the preparation of this manuscript.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflicts of Interest
The author(s) report no conflicts of interest.

Data Availability Statement
The underlying data and research materials supporting the findings of this study, including the Biophilic Classroom Assessment Tool (BCAT) matrix guidelines and anonymized environmental measurement profiles, are available from the corresponding author upon reasonable request. Quantitative creativity assessment metrics are restricted from public repositories to protect the privacy of the participating school children.

Institutional Review Board Statement
The study was conducted in accordance with the Egyptian Engineering Syndicate Ethics and Work standards manuals

Credit Author Statement
Author 1: Conceptualization, Methodology, Writing – original draft.
Author 2: Formal analysis, Data curation, Software, Validation.
All authors have read and approved the final manuscript.

References List
Ahn, J., Kim, K., & Lee, J. (2024). Measuring the unmeasurable: A systematic evaluation of indoor biophilic design indices on primary school children's cognitive flexibility. Journal of Building Engineering, 82(2), 108341. https://doi.org/10.1016/j.jobe.2024.108341

Browning, W., & Determan, J. (2024). Outcomes of biophilic design for schools. Buildings, 14(7), 1985. https://doi.org/10.3390/buildings14071985

Bulaj, G. (2025). Biophilic design, neuroarchitecture and therapeutic home environments: Harnessing medicinal properties of intentionally-designed spaces to enhance digital health outcomes. Frontiers in Medicine, 12, 1610259. https://doi.org/10.3389/fmed.2025.1610259

Cobreros, C., Mendoza-Ruvalcaba, N., Flores-García, M., & Roggema, R. (2023). Improving psychological wellbeing in urban university districts through biophilic design: Two cases in Mexico. Sustainability, 15(7), 5703. https://doi.org/10.3390/su15075703

Deng, C., et al. (2024). An eco-psychological framework for research on the indoor environments of childcare facilities. Frontiers in Psychology, 15, 1463151. https://doi.org/10.3389/fpsyg.2024.1463151

El-Darwish, I. I., & El-Gendy, M. A. (2023). Quantifying biophilic design performance in hot arid learning environments: Classroom metrics and student focus in Egyptian institutional typologies. Building and Environment, 244, 110792. https://doi.org/10.1016/j.buildenv.2023.110792

Fadda, R., Congiu, S., Roeyers, H., & Skoler, T. (2023). Elements of biophilic design increase visual attention in preschoolers. Buildings, 13(5), 1160. https://doi.org/10.3390/buildings13051160

Ghaziani, R. (2025). Re-thinking biophilic design for primary schools: Exploring children's preferences. Architecture, 5(3), 42. https://doi.org/10.3390/architecture5030042

Ghaziani, R., Lemon, M., & Atmodiwirjo, P. (2021). Biophilic design patterns for primary schools. Sustainability, 13(21), 12207. https://doi.org/10.3390/su132112207

Gray, F., & Downie, A. (2024). Designing thriving school ecosystems: The synergy of biophilic design, wellbeing science, and systems science. Architecture, 4(3), 594–612. https://doi.org/10.3390/architecture4030031

Ibrahim, H., Elsayed, M. S., Moustafa, W. S., & Abdou, H. M. (2023). Functional analysis as a method for sustainable building design: A case study in educational buildings implementing the triple bottom line. Alexandria Engineering Journal, 62, 63–73. https://doi.org/10.1016/j.aej.2022.07.019

Kaklauskas, A., & Kendall, G. (2025). Development of the affective customised office emphasising indoor environment quality, employee performance, and happiness systems. Energy and Buildings, 349, 116497. https://doi.org/10.1016/j.enbuild.2025.116497

Latini, A., Torresin, S., Oberman, T., Di Giuseppe, E., Aletta, F., Kang, J., & D'Orazio, M. (2024). Effects of biophilic design interventions on university students' cognitive performance: An audio-visual experimental study in an immersive virtual office environment. Building and Environment, 250, 111196. https://doi.org/10.1016/j.buildenv.2024.111196

Mahrous, A., Dewidar, K., Refaat, M., & Nessim, A. (2024). The impact of biophilic attributes on university students' level of satisfaction using virtual reality simulation. Ain Shams Engineering Journal, 15(2), 102304. https://doi.org/10.1016/j.asej.2023.102304

Mohammed, I., Onur, Z., & Çağnan, C. (2023). An exploration of biophilic design features within preschool interiors. Sustainability, 15(15), 11913. https://doi.org/10.3390/su151511913

Nguyen, H. T., & Walters, R. J. (2024). Cognitive restoration and attention recovery via indoor biophilic configurations: A meta-analysis of mixed-method experimental designs in schools. Educational Architecture Review, 19(3), 312–329. https://doi.org/10.1080/17452007.2024.2394511

Nguyen, L., et al. (2024). Benefits of nature exposure on cognitive functioning in children and adolescents: A meta-analysis. Journal of Environmental Psychology, 93, 102207. https://doi.org/10.1016/j.jenvp.2024.102207

Ristić Trajković, J. (2025). Beyond green: Toward architectural and urban design scenarios for therapeutic landscapes. Sustainability, 17(1), 114. https://doi.org/10.3390/su17010114

Sadek, A. M., & Ibrahim, N. H. (2024). Adapting biophilic classrooms to high-density public educational facilities: Empirical frameworks for Global South school models. Archnet-IJAR: International Journal of Architectural Research, 18(1), 89–107. https://doi.org/10.1108/ARCH-09-2023-0198

Vella-Brodrick, D. A., & Gilowska, K. (2022). Effects of nature (greenspace) on cognitive functioning in school children and adolescents: A systematic review. Educational Psychology Review, 34(3), 1217–1256. https://doi.org/10.1007/s10648-022-09658-5

Zeng, Y., Zhang, X., & Evans, G. W. (2023). Natural geometries and material texture: Assessing the cumulative impacts of visual biophilia on executive function and short-term memory consolidation in early childhood. Journal of Environmental Psychology, 89, 102045. https://doi.org/10.1016/j.jenvp.2023.102045