

Biophilic Toolbox for Promoting Physical and Mental Performance in Early Childhood Educational Spaces

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Abstract

Based on many empirical studies, nature play a crucial role in improving every aspect of children's development—from the physical to the social, cognitive and even emotional. Unfortunately, today's children are much less connected to the natural world. They spend in average 90% of their time indoors in artificial built environments away from nature; the natural connection has been replaced with more virtual technological interactions and less unstructured outdoor play. The negative outcomes for children of this disconnection include very high rates of childhood obesity, social disorder and increased psychological stress. This paper investigates a biophilic architectural approach that focuses on creating an interconnection between life, nature and the built environment to enriches children's daily lives in educational spaces. The research method consists of a wide range of literature review to explore the concept of nature connection, biophilia, biophilic design principles, and their impact on creating educational spaces for children. The findings took the form of biophilic toolbox that could help in promoting physical and mental performance of children in educational spaces.

Keywords: Biophilia; Biophilic Design; children; educational spaces; nature; physical performance; mental performance.

1. Introduction

In the last decades, humanity has been facing entirely new health hazards resulting from being disconnected from the natural world. According to United States Environmental Protection Agency, children spend 90% of their time indoors and much of that time is spent in school [1].

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In addition to technological revolution, video games, and television children stay for a long time indoors in educational spaces (i.e., daycare, nursery, or school), which resulted in a whole new generation diagnosed by attention disorders and physiological depression [2]. In this sense, the German social psychologist Erich Fromm coined the term "biophilia", which appeared as a solution to this problem, through pointing out to the importance of direct connection with the natural world. He explained that biophilic environment could support the physical and mental components, unburden the cognitive system, foster the sensorial system, and support the children's immune system [3].

As a result, architects participating in the design of educational settings for children must gain a deeper grasp of how to increase children's tendency for biophilia. Hence, this research aims at exploring principles of biophilic design, and the impact of integrating them into the design of educational spaces. This research put together the latest scientific information on the biophilic design features that are known for its positive impacts on performance and productivity of educational building occupants and provide a creative, natural learning environment. Further, it provides a simple theoretical toolbox for early childhood educational buildings that promote their physical and mental performance.

2. Materials and Methods

For accomplishing the intended objectives of this research, several methods were implemented:

Firstly, A literature review was conducted to investigate the research problem which is the 'Children's disconnection with Nature', and gathering evidence for this disconnection, reasons and how does it badly effect on them.

- An in-depth literature review that investigates the importance of 'Children's connection with Nature' and its benefits for promoting their physical and mental performance in general.
- An exploration for Biophilia and 'Biophilic design' factors and attributes that has an impact on human's physical and mental performance.

Secondly, Investigation of many worldwide biophilic educational trends was performed. The objective was to explore the application of some attributes of biophilia and how it had affected children's performance.

Finally, the research proposes a theoretical toolbox for designing early childhood educational building that promote their physical and mental performance.

3. Literature Review

Much of the built environment, nowadays, has created psychological and physical divisions between human inhabitants and the natural world [2]. Reduced direct contact with the natural world has been labeled the 'extinction of experience' by the ecology professor Robert Michael Pyle [4]. Modern world human spends in average 90% of their time in artificial built environments that failed to provide a positive and satisfying connection to nature [2]. Many traditional design strategies that ignore nature can lead to negative impacts on

human health, children mental development and worker satisfaction [5]. Children -in particular- are facing entirely new health hazard resulting from the widening gap between humans and nature in the modern world [6]. Obesity, attention-deficit disorder, impaired social skills and what can be characterized as a “culture of depression” are adding to the stress levels and severely impacting children nowadays. [7,8,9]

“*Nature deficit disorder*” refers to the phrase coined by the American author ‘Richard Louv’ in his book “*Last Child in the Woods*” that human beings -especially children- are spending less time outdoors resulting in a wide range of behavioral problems [10]. Moreover, in an interview with the Guardian newspaper, psychologist Michael Shayer reported the findings of a study sponsored by the Economic and Social Research Council (ESRC) of more than 10,000 11 to 12-year-old British children. The principal finding was that UK children have fallen two or three years behind in cognitive and conceptual development from where they were 15 years ago. Shayer explained this due to the lack of experiential play and the growth of video games, TV culture [11].

Parents illustrated many reasons why their children spend less time in nature than they themselves did, including safety concerns [12], disappearing access to natural areas, competition from television and computers, dangerous traffic, and more homework [13] and other pressures [14].

a)3.1 Children's Connection with Nature

Many studies had shown that engaging with nature on many different levels (from simply viewing nature, to incidental exposure, through to active interaction with nature) can enhance physical and mental performance. Natural environments are often perceived as places to relax, escape, and unwind from the daily stresses of modern life, thus having a positive effect on our emotional wellbeing [15]. Much empirical evidence has also demonstrated that nature experiences have a positive influence on children -in particular-, helping them to develop positive values about nature and their physical and psychological wellbeing, inter- and intrapersonal skills, and cognitive functioning. The following Table 2. summarizes and illustrates -through research-based evidence- how contact with nature yields surprisingly broad physical and mental benefits:

Table 1: Summary of research-based evidence on the effect of nature on physical and mental performance
 [Done by the authors, 2022]

| Physical performance | Mental performance |
|---|---|
| Includes the aural, musculoskeletal, respiratory, circadian systems and overall physical system. | Includes mental agility and memory, as well as the ability to think, learn and perform either logically or creatively. |
| <ul style="list-style-type: none"> - Natural views through a glass window reduced blood pressure faster than a view of artificial nature via a digital window or no window at all [16]. - Access to natural outdoor spaces can enhance social wellbeing. [17]. - Moderate ambient noise (like water features or moving leaves sound) induce higher processing disfluency, enhances both the originality and the appropriateness dimensions of creativity. [18]. - Green plants were associated to lower stress level among highly stressed children in rural areas [19]. - Children and adults who participate in wilderness excursions like hiking and camping trips had “an increased sense of aliveness, well-being, and energy,” [20]. | <ul style="list-style-type: none"> - Perceptual pleasure (strong dopamine) is focused primarily on the ‘visual system’ [21]. - Experiences of natural environments enhance restorative experiences with less levels of tension, anxiety, anger, or confusion [22, 23]. - Unstructured, imaginative, exploratory outdoor play has long been recognized as an essential component of wholesome child development [24]. - Children who experience school grounds with both green areas and manufactured play areas are more physically active, more aware of nutrition and more civil to one another [25]. - Attention span increases when children are surrounded by more natural, greener settings [26]. - The attention deficit disorder symptoms are significantly decreased by introducing more natural surrounding [27]. |

3.2 Understanding Biophilia

Although the term Biophilia is quite uncommon, however, upon breaking down the word, it becomes clearer. **Bio** means “relating to life,” and **philia** means “love, especially an abnormal love for a specified thing” [28]. Thus, the basic definition for ‘Biophilia’ is the love of life. In the next section, the concept of Biophilia and its application in architectural context will be discussed in detail.

b) The Emergence of Biophilia

The idea of biophilia has originated since the beginning of human history; where early humans evolved and lived in intimate connection with the natural world. Table 2. summarizes the development of the term “Biophilia” and its conception in the last century.

Table 2: Timeline for the contribution to the emergence of “Biophilia”

| Year/Author | Contribution to the emergence of Biophilia |
|---|--|
| 1945 Erich Fromm | <ul style="list-style-type: none"> • The social psychologist coined the term “Biophilia” to describe the innate bond that humans share with other living species. • In his book “The Anatomy of Human Destructiveness” he redefines it as ‘the passionate love of life and of all that is alive.’ |
| 1979 Edward O. Wilson | <ul style="list-style-type: none"> • The evolutionary biologist first used the term biophilia in the field of biology in an article titled “Biophilia” [29] |
| 1984 Edward O. Wilson | <ul style="list-style-type: none"> • He developed the concept in an entire book once again titled “Biophilia”, describing how positive feelings towards nature are inborn in human beings. |
| 1993 Edward O. Wilson & Stephen R. Kellert | <ul style="list-style-type: none"> • Wilson teams up with the Social Ecologist <i>Stephen Kellert</i> to edit a book, entitled “The Biophilia Hypothesis” [30], stating that biophilia became biologically encoded in our DNA because it helped enhance our existence and survival through physical, emotional, and intellectual fitness. |

[Done by the authors, 2021]

In the last decades, many researchers and designers have been studying how do we move from research to application in a manner that effectively enhances health and wellbeing through the built environment. The next part puts biophilia as a concept in context with architectural design through what is called 'biophilic design'.

c) Biophilic Design

Biophilic design is presented as an innovative approach to design that fosters the positive connection with the natural world through incorporating nature into the built environment to create a healthy human life and enhance wellbeing. At the building scale, biophilic design can inspire architects to build connection with nature. At the human scale, following biophilia can enhance physical fitness and improve health. Mental and behavioral benefits range from increased wellbeing and motivation, less stress and anxiety, improved problem solving and creativity, enhanced concentration and improved social skills [2]. Biophilic design can be directly, indirectly, or symbolically revealed and can sometimes occur unconsciously, without deliberate creation or even sometimes explicit recognition [31]. To aid designers in the architectural practice, biophilic design can be divided into three main categories, as shown in Table 3. providing a framework for understanding and enabling thoughtful incorporation of a diverse range of strategies into the built environment [32]. It can be used in different combinations to achieve successful biophilic designs for various targeted users.

Table 3: 14 Patterns of biophilic design according to [based on Browning and his colleagues 2014]

| Biophilic design Categories (14 patterns) | | |
|--|---|---|
| Nature in the Space | Nature Analogues | Nature of the Space |
| <p>1. Visual connection with Nature</p> <p>A visual view of nature, natural systems and processes.</p> | <p>8. Biomorphic Forms & Patterns</p> <p>Symbolic references to arrangements that persist in nature.</p> | <p>11. Prospect</p> <p>The ability to see and perceive both opportunities and dangers.</p> |
| <p>2. Non-visual connection with Nature</p> <p>Stimuli that trigger a positive reference to nature, natural systems or processes.</p> | <p>9. Material Connection with Nature</p> <p>Nature-inspired materials and components that reflect the local environment or geology and provide a particular sense of place.</p> | <p>12. Refuge</p> <p>The sense of enclosure or shelter that provides safety and security</p> |
| <p>2. Non-Rhythmic Sensory Stimuli</p> <p>Stochastic and ephemeral connections with nature that aren't predictable.</p> | <p>10. Complexity & Order</p> <p>Rich sensory information that adheres to a spatial hierarchy like in nature.</p> | <p>13. Mystery</p> <p>Partially obscured views or other sensory devices.</p> |
| <p>3. Thermal & Airflow Variability</p> <p>Subtle changes in temperature, humidity, airflow that mimic natural environments.</p> | | <p>14. Risk/Peril</p> <p>An identifiable threat coupled with a reliable safeguard.</p> |
| <p>4. Presence of Water</p> <p>viewing, hearing, or touching water to have a sense of a place.</p> | | |
| <p>5. Dynamic & Diffuse Light</p> <p>Light and shadow intensities that change throughout time.</p> | | |
| <p>6. Connection with Natural Systems</p> <p>Awareness of natural processes through architectural spaces.</p> | | |

4. Children and Biophilic Educational Trends

Children learn in a very different way than adults. Adults typically consider environment as a background for their activities, whereas children see nature as a stimulant and experiential factor of their activities. Children evaluate nature based on their interactions and sensory experiences with it rather than its aesthetics [33]. However, the problem with children’s environmental education programs is that they approach education from an adult’s perspective. Davis Sobel mentioned, in his book “Children and Nature: Design principles for educators”, the three basic stages for children’s development of their environmental education [34]. These stages are explained in Figure 1.

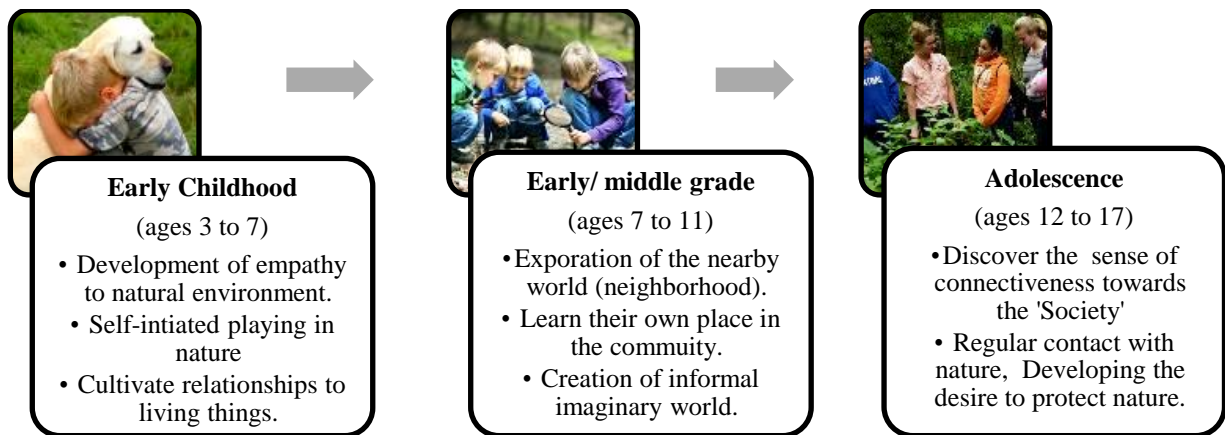


Figure 1: Illustration for the main tips to strengthen the child-nature relationship

[based on Davis Sobel,2008]

This research targets the early childhood stage, where recent research strongly suggests that the opportunity for children younger than age 7 to explore in natural environments is very important for developing their biophilic tendencies.

Recently, different educational models that adopt to increase children’s contact with nature to support healthy lifestyles for children are started to emerge. The following examples represent a progressive education philosophy and alternative models for nature-based biophilic educational spaces for children, that challenged the traditional educational practice.

4.1 Green Education

Green spaces are good settings for outdoor learning, as interaction with nature can lead to increased connectedness to nature and ecological literacy [35]. One of the best green education models that target these age group early are the “outdoors-in-all-weather nursery schools” and “forest kindergartens” that as a way of teaching children of all ages about the natural world. Since the 1990s, parents and educators in Germany have established 700 Wald kindergartens where children ages 3 to 6 spend their entire day in the outdoors in all weather conditions. In the UK, the Forest Education Initiative (FEI) has been working for the last 20 years to

enhance the children experience in the wildlife by setting up several Forest Schools (FS). Forest Schools are essentially a specialized approach of nature-based learning than school can adopt to compliment other education programs, rather than a specific type of school such as Free Schools, Academies etc. In some models, the kindergarten consists of a small, one- or two-room, building housing an administrative office, storage for accoutrements and supplies for forest adventures. Children meet there at the beginning of the day to collectively decide on a plan for the day, assemble the gear needed, load it into a cart and backpacks, and take off into the forest to discover whatever befalls the group as shown in Figure 2.



Figure 2: A group of children playing with leaves and stones, experience their sensory properties [source: <http://www.safbaby.com/forest-kindergarten-a-better-way-to-teach-our-young-children/>]

In the United States, the nearest equivalent to the forest kindergarten is the growth of preschools located in nature centers. The Nature preschool at the Schlitz Audubon Nature Center near Milwaukee, Wisconsin, is one of a small but growing number of nature-based preschools in the nation committed to both environmental education and active learning. Playing and learning adventure occurs throughout the center's prairie, forests, ponds, and marshes. The stated goal is to develop the child's ability to work independently and cooperatively, to act in a caring and responsible way towards the environment to foster a love of nature. In Egypt, the SEKEM Kindergarten was founded under the umbrella of the SEKEM Development Foundation. It is open to all children of SEKEM employees as well as children from the surrounding neighborhoods. It provides a rich world of imagination, play and discovery through the surrounding sensory experiences in the farms. The outdoor was adopted through taking children in tours around the childcare building to explore surrounding natural elements, see the concept of change through observation of plant growth, and mimicking the sounds produced by insects and animals. The children's days are filled with practical and artistic work, imaginative play and fairy tales, puppetry and music, and healthy outdoor pursuits, as shown in Figure 3.



Figure 3: Flexible sensory skill through multi culture interaction

[Source: ISCDC Project report and SEKEM Development

community website: <http://www.sekem.com/kindergarten.html>]

4.2 Environmental education

Although there is undoubtedly much overlap between green education and environmental education, and indeed the terms are often used interchangeably both in the literature and by practitioners, formal environmental education appears to differ from ‘green education’ in many ways. “Environmental education” is a learning process that increases people's awareness about the environment and fosters attitudes, motivations, and commitments to make informed decisions towards nature [36]. On the other hand, “green education” is a more holistic concept and can include learning about either a) nature or b) other subjects; but the key element is being outside or outdoors whereas environmental education seems to be more specific in that the aim is to primarily to change attitudes and to encourage sustainable behaviors and stewardship of the natural world; but this does not necessarily need to happen outdoors in nature [37].

5. Results and Discussion: The Biophilic Toolbox

Creating a healthy educational environment for children, always started with identifying, synthesizing, and collecting the evidence about the benefits to children from having a connection to nature. But unfortunately, most of these studies is limited to field of psychology and human science, and that has been conducted in the last few decades. In this sense, it was essential for architects to understand performance priorities of the users (early childhood), to identify design strategies and interventions that enhance physical and mental performances in their educational environment.

This study purposes a simple toolbox, as shown in Table. 4, for designing educational spaces for early childhood based on the collected literature review and the biophilic design principles addressed by Kellert in 2015 [38]; in which designer could add or modify strategies based on the required user's physical and mental benefits.

Table 4: The Biophilic toolbox for enhancing children's physical and mental performance [Done by authors]

| The Biophilic patterns | | Physical & Mental Benefits | The Biophilic Toolbox |
|------------------------|-------------------------------|--|--|
| Nature in the Space | Visual Connection with Nature | <ul style="list-style-type: none"> • Reduce stress. • Improve thinking & cognitive performance. • Less stress and anxiety. • Improve responsibility towards animals and living things. • Less hostility and aggression. • Increase social interaction. | <ul style="list-style-type: none"> ➤ Varied vegetation indoors and out (long trees, vegetation, flowers) ➤ The presence of non-human animal life (can be achieved as feeders, green roofs, farms, aquaria, ...etc) ➤ Responding to outer weather (i.e., simulating weather-like qualities through manipulating airflow, temperature, and humidity...etc). |

| | | | |
|-------------------------|---|---|--|
| | Non-Visual Connection with Nature | <ul style="list-style-type: none"> • Reduce stress, lower heart rate and blood pressure and stress hormones. • Improve thinking & cognitive performance. • Improve tranquility. | <ul style="list-style-type: none"> ➤ The representation of natural features using photographs, paintings, sculpture, murals, video, simulations, and modern technologies such as web cameras, video, and spotting scopes. |
| | Non-Rhythmic Sensory Stimuli | <ul style="list-style-type: none"> • Reduce stress, lower heart rate and blood pressure and sympathetic nervous system activity • Arouse attention, exploration, and curiosity. | <ul style="list-style-type: none"> ➤ Experiences at a subconscious level through momentary exposure that is not typically sought out or anticipated (i.e., multiple interventions that overlap with seasons, the repeating rhythmic motion of a pendulum in peripheral view vs. straight view pathways...etc) |
| | Thermal & Airflow Variability | <ul style="list-style-type: none"> • Improve comfort feeling and wellbeing. • Improve concentration and children's learning skills. | <ul style="list-style-type: none"> ➤ Changes and variability in environmental air flow, temperature, humidity and pressure over time and spaces. |
| | Presence of Water | <ul style="list-style-type: none"> • Reduce stress, lower heart rate and blood pressure. • Improve concentration. • Positively impact on children's perceptual and physiological stress responses. | <ul style="list-style-type: none"> ➤ Indoor or outdoor reflective surface like clean or moving water. ➤ Views of water ponds, fountains, man-made aquaria, and other structures. |
| | Dynamic & Diffuse Light | <ul style="list-style-type: none"> • Natural light facilitate movement and contribute to the children's comfort and satisfaction. • Positively impact on the circadian system functioning. | <ul style="list-style-type: none"> ➤ Glass walls and clerestories ➤ Reflecting bright colours and materials ➤ The contrast between lighter and darker areas, as well as changes in daylight throughout time. |
| | Connection with Natural Systems (Biodiversity) | <ul style="list-style-type: none"> • Improve health with less illness symptoms. • Less hostility and aggression. • Less stress and anxiety. • Improve comfort feeling. | <ul style="list-style-type: none"> ➤ Including wetlands, forest glades, and grasslands; green roofs; simulated aquatic environments; and other approaches to create a sustaining natural system in the built environment. |
| Nature Analogues | Biomorphic Forms & Patterns | <ul style="list-style-type: none"> • Observed view preference • Dynamic and ambient qualities of the space increase children satisfaction and motivation. • Improve imagination and creativity | <ul style="list-style-type: none"> ➤ Use of natural patterns, geometries, textures, or bio-inspired solutions (i.e., fractals, leaf-like patterns, animal facsimiles woven into fabrics) ➤ Scale levels with random variation in important aspects as opposed to strict repetition |
| | Material Connection with Nature | <ul style="list-style-type: none"> • Prevent diastolic blood pressure and stress level. • Less hostility and aggression. • Less stress and anxiety. • Improve comfort feeling. | <ul style="list-style-type: none"> ➤ Natural materials such as timber, rock, cotton, or leather are used in a wide range of decorations items, interior and exterior designs. ➤ Colors should embrace neutral tones found in sand, rock, and vegetation. |

| | | | |
|----------------------------|--|--|--|
| | Complexity & Order | <ul style="list-style-type: none"> • Positively impact on children's perceptual and physiological stress responses. • Encourage exploration and information analysis skills. • Enhance children's creativity. | <ul style="list-style-type: none"> ➤ Information richness in design through variability and diversity (i.e., curvilinear surfaces that gradually open information to view) ➤ Integration of space by a key focal point, which might be functional or thematic. |
| Nature of the space | Prospect (The ability to see and perceive both opportunities and dangers) | <ul style="list-style-type: none"> • Reduce stress and improve concentration. • Prevent the children's boredom or irritation. • Improve comfort feeling and perception of safety. | <ul style="list-style-type: none"> ➤ Brightness in the field of view (operable windows, porches, decks, balconies, colonnades, pavilions, gardens...etc) ➤ Horizon/sky imagery (sun, mountains, clouds...etc) ➤ View corridors and visual connections between interior spaces. |
| | Refuge (The sense of enclosure or shelter that provides safety and security) | <ul style="list-style-type: none"> • Improve concentration and perception of safety. • Less stress and anxiety. • Better understanding skills. | <ul style="list-style-type: none"> ➤ Clearly understood pathways critical to fostering feelings of security ➤ Canopy effect (such as lowered ceilings, screening, branchlike forms overhead) |
| | Mystery | <ul style="list-style-type: none"> • Strong dopamine or pleasure responses to children. • Arouse attention and curiosity. • Increase children satisfaction and prevent boredom. | <ul style="list-style-type: none"> ➤ Incorporation of decor, natural materials, artifacts, objects, and spaces whose primary purpose is to delight, surprise, and amuse (i.e., Curving edges that slowly reveal are more effective than sharp corners in drawing people through a space, etc) |
| | Risk/Peril | <ul style="list-style-type: none"> • Enhance physical fitness • Strong dopamine or pleasure responses to children. • Arouse attention and curiosity. • Improve children's critical thinking skills | <ul style="list-style-type: none"> ➤ There are many examples for different degrees of risk depending on the intended user or the space available (i.e., a cantilevered walkway over a sheer cliff; viewing a predator may provide a greater sense of control, whereas rock-hopping through a water feature presents the risk of getting one's feet wet) |

This Biophilic toolbox is a theoretical guidelines limited to and based on a large number of literature reviews to offer some design consideration that might enhance children's performance through connection with nature. In this sense, further researches for a practical implementation of these guidelines shall be discussed in next studies.

➤ **Research gaps and limitations**

However some of the other gaps that was explored during the study are:

- the absence of research model that links theory with application to enhance children's performance and wellbeing through architectural design. In addition to that, an assessment tool that allows quantifiable measures

of functional and psychological performance of all ages and abilities among users.

- Architectural solutions cannot be imposed but must evolve through community-based processes to engage stakeholders (mode of learning) and users (children and parents) in creating these design solutions.

6. Conclusions

Much of the built environment, nowadays, has created psychological and physical divisions between human and the natural world. Children, in particular, are facing entirely new health hazard resulting from this widening division in the modern world, they spend the majority of their daily time indoors and much of that time is spent in educational spaces. This can affect children's health, attendance, concentration and performance. This study investigates an alternative approach based on biophilic design. It focuses on creating an interconnection between life, nature and the built environment to create architecture that enhances children's physical and mental performance in educational spaces. In order to achieve that, the research methodology was consisting of a wide range of literature review study was investigated to explore the children disconnection and connection to nature to understand "why nature really matters?", followed by concept of biophilia and exploring its application in educational trends. The findings took the form of biophilic toolbox that could help in promoting children's physical and mental performances in educational spaces.

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