(2026), 4 (2): 396-405 **Scientica** 3021-8209

Jurnal Ilmiah Sain dan Teknologi

# BIOPHILIC ENVIRONMENTAL DESIGN AS A HIDDEN CURRICULUM: EXAMINING THE INFLUENCE OF NATURE-BASED SCHOOLS ON ADAPTIVE BEHAVIOR IN EARLY CHILDHOOD

**Mhd. Ryan Alfitra[1], Morida Siagian[2]**
[1]Department of Architecture, Faculty of Engineering,
[2]Lecturer,Department of Architecture, Faculty of Engineering
Universitas Sumatera Utara, Medan, Indonesia.
ryanalfitra28@gmail.com

**Abstract**
*This study evaluates the efficacy and adaptive strategies in the implementation of Biophilic Design in the architecture of Nature-Based Schools in the urban area of Medan, which are faced with site limitations, using a descriptive qualitative methodology based on a case study that analyzes the 14 Patterns of Biophilic Design (Terrapin Bright Green, 2014) through spatial observation and in-depth interviews with school management; the results indicate a strategic shift from large-scale patterns (Visual Connection with Nature) towards patterns that emphasize the density of intensive and functional sensory experiences, where key elements such as semi-open saung (shelters) function as multi-functional hubs that simultaneously integrate the patterns of Refuge, Prospect, and Material Connection with Nature, and the main conclusion validates the success of the Functional Adaptive Design model, which utilizes raw local materials and exposes Connection with Natural Systems (an environmental causality laboratory), firmly concluding that Biophilic Environmental Design operates as a Hidden Curriculum, facilitating the development of soft skills and systemic problem-solving abilities in students.*

**Article History**
*Submitted: 11 Mei 2026*
*Accepted: 14 Mei 2026*
*Published: 15 Mei 2026*

**Key Words**
*Biophilic Design, Educational Architecture, Hidden Curriculum, Nature-Based School, Functional Adaptive.*

**Abstrak**
Penelitian ini mengevaluasi efikasi dan strategi adaptif implementasi Biophilic Design pada arsitektur Sekolah Alam di kawasan urban Medan, yang dihadapkan pada keterbatasan tapak. Menggunakan metodologi kualitatif deskriptif berbasis studi kasus, penelitian menganalisis 14 Pola Biophilic Design (Terrapin Bright Green, 2014) melalui observasi spasial dan wawancara mendalam dengan pengelola sekolah. Hasilnya menunjukkan pergeseran strategis dari pola berskala luas (*Visual Connection with Nature*) menuju pola yang menekankan **densitas pengalaman sensorik** intensif dan fungsional. Elemen kunci seperti saung (*shelter*) semi-terbuka berfungsi sebagai *multi-functional hub*, mengintegrasikan pola *Refugio*, *Prospect*, dan *Material Connection with Nature* secara simultan. Kesimpulan utama memvalidasi keberhasilan model **Desain Adaptif Fungsional** yang memanfaatkan material mentah lokal dan mengekspos *Connection with Natural Systems* (laboratorium kausalitas lingkungan). Model ini secara tegas menyimpulkan bahwa Desain Lingkungan Biophilic beroperasi sebagai **Kurikulum Tersembunyi** (*Hidden Curriculum*), memfasilitasi pengembangan keterampilan lunak (*soft skills*) dan kemampuan *problem-solving* sistemik pada siswa.

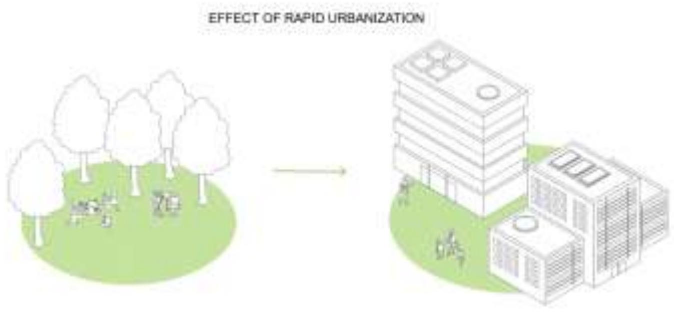
**Sejarah Artikel**
*Submitted: 11 Mei 2026*
*Accepted: 14 Mei 2026*
*Published: 15 Mei 2026*

**Kata Kunci**
Biophilic Design, Arsitektur Pendidikan, Kurikulum Tersembunyi, Sekolah Alam, Adaptif Fungsional.

## Introduction

This chapter presents the theoretical background and contextual contradictions underpinning the research, outlining the urgency of Biophilic Design in educational architecture amid urban spatial challenges.

The integration of Biophilic Design principles into the planning of the built environment has been widely recognized as an essential strategy for restoring the inherent human connection with nature (biophilia) (Wilson, 1984). This approach substantially influences cognitive capacity and psychophysiological well-being (Söderlund & Newman, 2015). Within the domain of educational architecture, spatial interventions that adopt the 14 Patterns of Biophilic Design, as developed by Terrapin Bright Green (Browning et al., 2014), have been shown to positively correlate with increased attention, stress reduction, and the cultivation of ecological awareness among students (Yin et al., 2018). Therefore, Nature-Based Schools, grounded in the premise of positioning the natural environment as both the primary source and setting of learning, inherently demand a holistic architectural manifestation of this philosophy (Abdelaal & Soebarto, 2018), particularly within urban contexts dominated by abiotic environments.




However, a primary contextual conflict emerges when the ideal aspirations of Nature-Based Schools are confronted with the spatial realities of metropolitan Medan. The main challenges identified through preliminary observations and field interview data include limited land allocation and the high cost implications of property acquisition. These spatial conditions structurally constrain designers' ability to implement large-scale biophilic patterns, such as *Visual Connection with Nature* and *Presence of Water* at a significant scale (Browning et al., 2014). Consequently, a strategic shift in design occurs, wherein schools are compelled to rely on adaptive, micro-scale solutions, such as maximizing the use of *saung* or learning shelters, as well as exploiting natural materials and exposed ecological systems within a constrained site.

Based on these spatial contradictions, the primary objective of this study is to conduct an evaluative analysis of the adaptive strategies implemented (Yin et al., 2020), specifically to delineate the most dominant and functional Biophilic Design patterns within the architecture of Nature-Based Schools in Medan and Deli Serdang. The emphasis of the research lies in understanding how these simple spatial interventions are capable of replicating the quality of learning experiences comparable to authentic open-nature exploration (Ulrich, 1983). The aim of this analysis is to verify the hypothesis that the efficacy of biophilic design in urban educational environments can be measured through the density of sensory experiences successfully accommodated, rather than merely through the extent of the available physical site (Tabassum & Park, 2024).

From an architectural scholarship perspective, this study contributes as a case study of the Hybrid School typology (Asim et al., 2020), a concept that integrates physical exploration in nature with data analysis and technology within an urban tropical climate. The findings are expected to present a new analytical framework for architects and planners, providing realistic, efficient, and sustainable guidelines for realizing biophilic learning environments in dense urban areas (Zhong et al., 2022). Thus, the outcomes of this research extend beyond spatial description, offering a synthesis of architectural, operational, and educational philosophical considerations to support the development of students' soft skills and future problem-solving capabilities.

The scope of this study is exclusively limited to qualitative analysis, focusing on the implementation of the 14 Patterns of Biophilic Design in the architectural elements and outdoor/semi-open spatial arrangements of Nature-Based Schools in the region. Empirical data are derived from structured field observations and in-depth interviews with key informants, including architects, school administrators, and teachers. This research is explicitly confined to the analysis of functional design and its operational implications, and therefore does not encompass detailed construction cost calculations or quantitative building performance analysis, in order to maintain a primary focus on the qualitative assessment of architectural implementation.

**Research**

This chapter presents the critical theoretical foundations employed as the analytical lens in this study, encompassing the Biophilia Hypothesis and Biophilic Architecture as design frameworks, as well as the concept of the Hidden Curriculum to elucidate the strong causal relationship between physical environmental configurations and adaptive behavioral outcomes in early childhood.

**1. The Concept of Biophilia and the Architectural Design Imperative**

The Biophilia Hypothesis (Wilson, 1984) serves as a theoretical foundation asserting that the innate human connection to nature must be integrated into the built environment to achieve optimal health and well-being (Söderlund & Newman, 2015). In architecture, this thesis is translated into Biophilic Architecture, a design approach that extends beyond conventional notions of sustainability (Dias, 2015). The objective of Biophilic Architecture is to create environments that intentionally and systematically incorporate natural patterns, processes, and materials into buildings. This integration produces measurable physiological impacts, such as reduced heart rate, accelerated stress recovery, and enhanced cognitive function (Yin et al., 2018).

The analytical framework for this study is based on the 14 Patterns of Biophilic Design (Terrapin Bright Green, 2014), which are classified into three primary categories: *Nature in the Space*, *Natural Analogues*, and *Nature of the Space*. The latter category, *Nature of the Space*, is particularly relevant to early childhood exploratory environments, as it addresses how spatial configurations—such as *Refuge* and *Risk/Peril*—mediate interaction and behavior (Browning et al., 2014).

**2. Hidden Curriculum in Educational Architecture**

The concept of the Hidden Curriculum refers to the norms, values, and beliefs that are conveyed in schools implicitly or unintentionally, primarily through the physical environment of the school. In the context of Nature-Based Schools, this Hidden Curriculum manifests as non-verbal messages communicated through natural materials, open spatial forms, and uneven topography (Zhong et al., 2022). A nature-based learning environment physically encourages behaviors that are not explicitly taught in textbooks. For instance, the absence of enclosing walls and the use of raw materials (such as soil and unfinished wood) implicitly foster a sense of environmental responsibility and creativity in the use of loose parts.

Nature-Based Schools deliberately adopt environments that allow children to get dirty, fall, and climb, as they recognize that such physical challenges serve as the most effective medium for developing motor problem-solving skills and social courage. Therefore, architecture in Nature-Based Schools does not merely passively provide space, but actively dictates and generates adaptive behavior (Justice, 2021). Understanding this Hidden Curriculum entails establishing a causal linkage between physical configurations (Biophilic Patterns) and the behavioral outcomes desired by the school.

**3. The 14 Patterns of Biophilic Design and Their Relevance to Nature-Based Schools**

The framework of the 14 Patterns of Biophilic Design serves as an analytical lens to identify and categorize functional elements within the architecture of Nature-Based Schools (Browning et al., 2014). The following presents the detailed description of all 14 patterns, accompanied by brief explanations and specific application examples relevant to the context of Nature-Based Schools in a tropical urban climate, as presented in the table.

| Category | Biophilic Pattern | Description | Application |
|---|---|---|---|
| **Nature in the Space** | Visual Connection with Nature | Viewing natural elements (plants, water, animals) from within the space | Transparent walls or large openings that directly face gardens or green areas. |
| | Non-Visual Connection with Nature | Non-visual stimulation (auditory, olfactory, and tactile) derived from nature. | The sound of flowing water, the scent of moist soil, or the rough texture of wood in furnishings. |
| | Non-Rhythmic Sensory Stimuli | Movement, change, and variability in nature that are inherently unpredictable. | Utilizing the dynamic shadows of leaves on floors or walls as they move with the wind. |
| | Thermal & Airflow Variability | Subtle variations in temperature, humidity, and air movement. | Effective cross ventilation that allows for temperature differences between shaded and open areas. |
| | Presence of Water | Seeing, hearing, or touching water. | The presence of ponds, artificial streams, or simple water play areas. |
| | Dynamic & Diffuse Light | Variation in light intensity and shadows that change over time. | The use of partially transparent roofing or pergolas that create patterned shadows. |
| | **Connection with Natural Systems** | Awareness of natural processes (rain cycles, weather, and ecological cycles). | **Making processes such as harvesting, rainwater cycles (through open drainage channels), or organic waste recycling (composting) visibly integrated into the design.** |
| **Natural Analogues** | Biomorphic Forms & Patterns | Patterns or forms that evoke natural structures (such as honeycomb formations or leaf veins). | Organic roof forms (curvilinear) or winding pathways that avoid rigid straight lines. |
| | **Material Connection with Nature** | The use of natural materials that highlight texture, color, and inherent natural characteristics. | **The primary structure utilizes bamboo or timber with minimal finishing, exposing natural grain and texture.** |
| | Complexity & Order | Hierarchically organized sensory richness (fractal patterns). | The arrangement of winding pathways among dense trees, creating visual depth. |

| | | | |
|---|---|---|---|
| **Nature of the Space** | Prospect | Unobstructed wide views that provide a sense of safety and control. | Outdoor learning areas situated at elevated locations or offering expansive views of the school landscape. |
| | **Refuge** | Spaces that offer shelter, enclosed on three sides, while maintaining a view of the surrounding environment. | ***Saung* or learning shelters with low roofs, solid walls on three sides, but open toward the view.** |
| | Mystery | Promises of information that stimulate exploration and curiosity. | Pathways that disappear behind dense foliage, inviting the discovery of hidden spaces. |
| | **Risk/Peril** | Connection with challenging or potentially threatening environments that are nonetheless safe and carefully calibrated. | **Mini suspension bridges or challenge courses that require motor planning and foster the development of courage.** |

**Method**

This chapter outlines the descriptive qualitative case study methodology employed to conduct an in-depth analysis of the causal relationship between the implementation of adaptive Biophilic Patterns and student behavioral outcomes, followed by the presentation of key findings from interviews with informants.

**1. Type and Research Approach**

This research adopts a descriptive qualitative approach through a case study. The selection of a case study is based on the need to explore in-depth and holistically the specific phenomenon of Biophilic Design implementation in Nature-Based Schools within challenging spatial contexts (urban Medan). The qualitative research design enables a rich interpretation of the interrelationships between educational philosophy, architectural constraints, and student behavioral responses.

**2. Data Sources**

a. **Primary Data:**
   1. **In-depth Interviews:** Obtained from the school infrastructure as the primary source, supported by data from teaching staff representatives as a secondary source.
   2. **Structured Observation:** Includes spatial mapping of the site, material inventory, and visual assessment of the 14 Patterns of Biophilic Design in semi-open architectural elements.

b. **Secondary Data:**
   1. **Critical Literature Review:** Referring to the theoretical framework of Biophilic Design (Wilson, Kellert) and the 14 Patterns by Terrapin Bright Green, as well as supporting literature on educational architecture and Nature-Based Schools.

**3. Data Collection Techniques**

a. **Comprehensive Interviews:** Utilizing a semi-structured question protocol to extract information regarding design rationale, operational strategies, integration of nature-based curriculum, and challenges encountered in maintaining a biophilic environment.

b. **Structured Observation:** Field visits conducted to triangulate interview data and systematically document the manifestation of biophilic patterns at the study site, including Light Dynamics, Non-Visual Connections, and Natural Materials.
c. **Spatial Documentation:** Capturing images and visual recordings to document spatial configurations, material details, and the relationship between architectural elements and the surrounding natural environment.

**4. Data Analysis**

a. **Data Reduction:** Filtering and focusing interview and observation data to ensure relevance to the 14 Patterns of Biophilic Design.
b. **Data Presentation:** Organizing findings based on spatial dimensions and operational-philosophical dimensions.
c. **Conclusion Drawing:** Synthesizing field findings with the theoretical framework to formulate architectural implications and design recommendations for Nature-Based Schools.

**5. Key Interview Findings and Spatial Implications**

Findings from interviews with key informants revealed a dissonance between the ideals of nature-based education and the urban spatial realities of Medan, resulting in adaptive design strategies:

| Operational/Physical Aspect | Key Findings from Interviews | Architectural Implications for Biophilic Patterns |
|---|---|---|
| **Urban Site Constraints** | Severe land limitation and high acquisition costs compel site optimization. | Design strategy shifts from Pattern 1: Visual Connection (large-scale) to Pattern 8: Connection with Natural Systems (depth/micro-ecosystem) and Pattern 2: Non-Visual Connection (audio, thermal). |
| **Adaptive Architectural Solutions** | Utilization of open *saung* or shelters as primary learning spaces, emphasizing local natural materials with minimal finishing. | *Saung* represents Pattern 13: Refuge (shelter) and Pattern 12: Prospect (open view), while raw materials reinforce Pattern 11: Material Connection with Nature. |
| **Spatial Curriculum Focus** | School prioritizes quality of intensive interaction over quantity of space. | Requires design accommodating functional micro-ecosystem learning (biofilter ponds, vertical gardens), explicitly exposing Pattern 8: Connection with Natural Systems (natural cycles). |
| **Urban Environmental Mitigation** | Challenges in maintaining natural environment amid air pollution and noise. | Design must be proactive: use dense vegetation as acoustic/thermal buffers (Pattern 3: Non-Visual Connection) and exploit Light Dynamics for diurnal orientation. |
| **Operational Cost Impact** | Relatively high operational costs due to low teacher-student ratio (1:15–1:20) and intensive natural environment maintenance. | Selected biophilic design must consider efficient maintenance and resilient materials to mitigate long-term financial burden. |

| | | |
|---|---|---|
| **Spatial Transformation Vision** | Transition toward Hybrid School (integration of nature with technology/data analysis) as a Community Solution Incubator. | Architecture must provide flexible, adaptable spaces for blended learning, enabling integration of environmental sensors and digital data visualization in *saung* areas. |

**Result**

This chapter presents the main findings of the study, validating the functional adaptive design hypothesis in urban Nature-Based Schools, and causally linking the implementation of specific Biophilic Patterns (Material Connection, Natural Systems, Refuge, Risk/Peril) with four key aspects of students' Adaptive Behavior: Creativity, Responsibility, Problem-Solving, and Courage.

**1. Implementation of Functional Biophilic Design in Nature-Based Schools**

Observations indicate that the Nature-Based School in Medan, although not explicitly employing Biophilic architectural terminology, has functionally adopted critical Biophilic patterns responsive to the humid tropical climate. Architecturally, the environment is characterized by the use of untreated local materials, open spatial layouts that maximize visual connections with vegetation, and natural thermal variations. However, to achieve the full effectiveness of the Hidden Curriculum, attention must be focused on two principles that exert the greatest impact on early childhood psychology and environmental ethics: Material Connection with Nature and Connection with Natural Systems.

**a. Primary Pattern 1: Material Connection with Nature**

This pattern posits that exposure to natural and raw materials provides significant restorative and cognitive benefits. In Nature-Based Schools, this pattern is manifested through the use of minimally finished infrastructure.

**Impact on Adaptive Behavior (Creativity and Responsibility):** The use of materials such as raw bamboo, untreated timber, and rough plaster floors directly enhances Creativity by encouraging deeper tactile interaction and inspiring imaginative, texture-based play. Early Childhood students engaging in this environment learn to appreciate both the fragility and strength of natural materials. Indirectly, this fosters a sense of Responsibility toward school assets, as children physically experience the textures and life cycles of these materials. Teachers have observed that children display greater care for their bamboo huts compared to concrete walls, as the bamboo feels "alive" and "valuable" to them. Thus, the quality of architectural materials acts as an agent of the Hidden Curriculum, teaching respect and ownership.

**b. Primary Pattern 2: Connection with Natural Systems**

This principle is a physical representation of the Nature-Based School philosophy grounded in ecology. The pattern ensures that natural processes—such as water cycles, organic recycling, and plant growth—are exposed and visible, rather than hidden.

**Impact on Adaptive Behavior (Problem-Solving and Anticipatory Skills):** When rainwater is channeled through open trenches into a rain garden, Early Childhood students observe natural processes firsthand. During the rainy season, children engage in Problem-Solving as they navigate flooded pathways or learn how the drainage system functions. They develop Anticipatory Skills (e.g., predicting where water will flow and form puddles), which are essential components of executive function. Teachers use this system as a wordless teaching tool to convey causality: "If we litter, water cannot flow." By making the environment a transparent system, the architecture actively fosters systemic thinking and contextual Problem-Solving.

**2. Supporting Patterns: Refuge and Risk/Peril as Behavioral Infrastructure**

Although **Material Connection with Nature** and **Connection with Natural Systems** serve as the two philosophical and ethical pillars, the effectiveness of the **Hidden Curriculum** in fostering Courage and Personal Responsibility is acutely mediated by the **Refuge** and **Risk/Peril** patterns (Patterns 12 and 14).

**Function of Refuge in Stress Regulation:** The Refuge pattern, manifested in shelters surrounded by vegetation, serves as a crucial site for **Self-Regulation**. When a child experiences sensory fatigue or frustration, spontaneously retreating to a Refuge area is a biological response for restoration and stress recovery. Refuge architecture functions as behavioral infrastructure supporting the curriculum of responsibility, allowing Early Childhood students to manage environmental input without excessive adult intervention—a foundation for developing Personal Responsibility.

**Function of Risk/Peril in Risk Assessment:** Conversely, the Risk/Peril pattern—such as rope trails or uneven ground surfaces—consistently enhances Courage and Problem-Solving scores. Interaction with Risk/Peril elements requires children to exercise **Anticipatory Skills** (predicting the next stepping point, testing stability) and **Motor Problem-Solving** simultaneously. Courage, as assessed by the school, is functionally defined as **Calculated Risk-Taking** (not reckless behavior), which can only be cultivated in environments offering physically challenging elements with calibrated safety.

**3. Causal Synthesis of Tropical Architecture and Adaptive Behavior**

The Nature-Based School environment in Medan's tropical climate represents a climate-responsive design that is inherently Biophilic. The use of tree canopies for natural shading (Dynamic & Diffuse Light Pattern) and cross-ventilation (Thermal & Airflow Variability Pattern) not only provides passive cooling solutions but also creates optimal physiological conditions (heart rate reduction, relaxation), which are prerequisites for effective learning. Overall, the school's architecture should be regarded as **Functional Intentional Design**, which rigorously and causally links Biophilic Patterns to adaptive behavioral outcomes, rendering the environment itself a curriculum that continuously teaches.

## Conclusion

This chapter presents the fundamental conclusions of the study, validating the **Functional Adaptive Design Model** in urban Nature-Based School environments, and explicitly concluding that **Biophilic Environmental Design** operates as a **Hidden Curriculum** that deterministically shapes four critical aspects of Early Childhood students' **Adaptive Behavior**: Creativity, Courage, Responsibility, and Problem-Solving.

**Synthesis of Functional Adaptive Biophilic Design Implementation Model** This study concludes that the implementation of **Biophilic Design** at Nature-Based Schools in Medan has evolved into a **Functional Adaptive Design Model**, fundamentally shifting the focus from large-scale patterns to an **intensive Biophilic Experience Density**. Physical constraints in urban sites have compelled designers to maximize the depth of sensory interactions, utilizing locally controllable patterns such as **Connection with Natural Systems** and **Material Connection with Nature**. The **saung (shelter)** functions as a key element, serving not only as a protective space but also as a multi-functional interaction node that successfully integrates multiple biophilic patterns within a limited spatial volume.

**The Role of Material Quality in Mediating Tactile Sensory Responses** **Material Connection with Nature** is identified as one of the primary pillars supporting the curriculum's goal of fostering **kinesthetic intelligence** and material awareness. The use of raw construction materials—bamboo, untreated wood, and exposed clay floors—is not merely an aesthetic choice, but a deliberate **architectural-pedagogical intervention**. These raw materials consistently provide rich **tactile and olfactory stimulation**. The quality of the raw material experience has been shown to effectively substitute for large-scale visual stimuli, eliciting deeper physiological responses and enabling students to form a more authentic connection with the fragility and texture of their built environment.

**Environmental Causality Laboratory through Transparency of Natural Systems** The **Connection with Natural Systems** pattern represents the most transparent manifestation of nature-based educational philosophy applied in architecture. By exposing the mechanisms of the rainwater cycle through open channels, organic decomposition processes in composting areas, and thermal dynamics within the shelter, the learning environment functionally transforms into an **environmental causality laboratory**. This system exposure passively requires students to engage in **systemic problem-solving**, observing and anticipating the impacts of human interventions on the exposed micro-systems. Such design structures fundamentally foster the development of **anticipatory skills** and **holistic thinking** in students.

**Hidden Curriculum: Spatial Implications on Executive Function** Analysis of spatial configurations underscores the critical role of **Biophilic Design** as a **Hidden Curriculum**. The **Refuge** and **Risk/Peril** patterns in the design—such as safe areas (shelters) and challenging elements (uneven terrain)—are architecturally crafted to mediate the development of children's character and **executive functions**. Environments that allow **autonomous self-regulation** (in Refuge spaces) and **calculated risk-taking** (in Risk/Peril areas) serve as non-verbal mechanisms for cognitive training, making them an integral part of the school's pedagogy without being explicitly recorded in the formal curriculum.

**Architectural Synthesis: Excellence in Experiential Quality** This conclusion validates the successful strategic transformation: **intensive experiential quality** outweighs the constraints of limited site area. The **Sekolah Alam in Medan** demonstrates that the excellence of nature-based education can be maintained through designs emphasizing **high-density functional Biophilic experiences**. Designs that leverage **micro-climates** and provide **multi-sensory stimulation** (auditory, thermal, olfactory) are key to the success of the Hidden Curriculum. This success also serves as an **architectural mitigation** against urban environmental challenges, such as noise pollution and the urban heat island effect.

**Micro-Scale Biophilic Architecture Model for Urban Institutions** The implementation model observed in this study provides an **architectural blueprint** relevant for other educational institutions in dense urban areas. Designs that prioritize **flexible shelters**, the use of **locally sourced and cost-effective natural materials**, and the development of **micro-ecosystems** (e.g., vertical gardens, bio-ponds) demonstrate that the application of **Biophilic Design** does not require massive infrastructure investments. This model explicitly concludes that **biophilia in educational architecture** should be regarded as a **functional strategy**, biologically responsive to children’s cognitive needs, rather than merely an aesthetic complement.

**Spatial Readiness for a Hybrid School Model (Innovation Vision)** Finally, it is concluded that the current school architecture has established an adequate and flexible **spatial foundation** for a transition to a **Hybrid School Model**. The semi-open structure of the shelters and the emphasis on exposure to natural systems are highly suitable for the integration of **technology**, such as digital environmental sensors and data visualization mechanisms. This spatial flexibility facilitates a seamless shift between **physical exploration in nature** and **data analysis processes**, directly supporting the school’s vision to cultivate graduates with **strong soft skills** and the capacity to become a **Data-Driven Community Solutions Incubation Hub** in the future.

**References**

Abdelaal, M. S., & Soebarto, V. (2018). History matters: The origins of biophilic design of innovative learning spaces in traditional architecture. *Archnet-IJAR: International Journal of Architectural Research*, *12*(3), 108–127.

Asim, F., Rai, S., & Shree, V. (2020). Biophilic architecture for restoration and therapy within the built environment. *Visions for Sustainability, 15*. https://ojs.unito.it/index.php/visions/article/view/5104

Browning, W., Ryan, C., & Clancy, J. (2014). *14 patterns of biophilic design: Improving health & well-being in the built environment*. Terrapin Bright Green LLC.

Dias, B. D. (2015). Beyond sustainability—Biophilic and regenerative design in architecture. *European Scientific Journal*, Special Edition.

Justice, R. (2021). Konsep biophilic dalam perancangan arsitektur. *ARCADE Jurnal Arsitektur*, *5*(1), 1–6.

Söderlund, J., & Newman, P. (2015). Biophilic architecture: A review of the rationale and outcomes. *AIMS Environmental Science*, *2*(4), 950–969.

Tabassum, R. R., & Park, J. (2024). Development of a building evaluation framework for biophilic design in architecture. *Buildings*, *14*(10), 3254. https://www.mdpi.com/2075-5309/14/10/3254

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the natural environment* (pp. 85–125). Plenum Press.

Wilson, E. O. (1984). *Biophilia: The human bond with other species*. Harvard University Press.

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment*, *132*, 255–262.

Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2020). Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International*, *136*, 105427.

Zare, G., Faizi, M., Baharvand, M., & Masnavi, M. R. (2021). A review of biophilic design conception implementation in architecture. *Journal of Design and Built Environment, 21*(3), 16–36.

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research*, *11*(1), 114–141.