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# Biophilic Design Patterns for Primary Schools

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**Abstract:** Existing frameworks for biophilic design have similar strategies and attributes as useful checklists for designers; however, the focus has been on adults rather than children, and there remains the need for more guidance related to school design by extension. The application of biophilia would be a design resolution in schools because of its impact on children's health and well-being, which has been more important since the pandemic started; however, it remains quite unexplored in school design in many countries, including the UK. Biophilic design patterns can be used in school buildings and grounds for greater connectivity between spaces and nature in order to promote children's well-being. This paper focuses on ten biophilic design patterns under two categories of 'nature in the space' and 'natural analogues.' This study presents the findings of case studies in various countries. The analysis focuses on the manifestations of biophilia to inform the application of biophilic design patterns for primary schools. Finally, this paper suggests how primary school children could be involved in a co-design process in order to evaluate biophilic design patterns.

**Keywords:** biophilic design; primary school design; children's well-being; co-design with children; biophilic evaluative tool for children



**Citation:** Ghaziani, R.; Lemon, M.; Atmodiwirjo, P. Biophilic Design Patterns for Primary Schools. *Sustainability* **2021**, *13*, 12207. https://doi.org/10.3390/su132112207

Academic Editor: Abhishek Tiwary

Received: 30 September 2021
Accepted: 2 November 2021
Published: 5 November 2021



## 1. Introduction

Existing frameworks for biophilic design [1–4] have similar strategies and attributes as useful checklists for designers. In addition, the Biophilic Quality Index (BQI) has been devised [5] as a reliable instrument to calculate to what extent a building is biophilic and could also help architects integrate nature in designs; therefore, as the focus of existing frameworks and BQI has been on professionals and design experts rather than building users, particularly children, there remains the need for more guidance related to the biophilic design of schools. The important role that the natural environment plays in maintaining and enhancing mental health and wellbeing has been well established [6,7]. Empirical studies have also highlighted that time in nature, direct and indirect contact with nature, and engaging with nature through simple activities [8,9] are beneficial to wellbeing. The application of biophilia would be a design resolution in schools because of its impact on children's health and well-being; however, it remains quite unexplored in school designs in many countries around the world.

The majority of primary school grounds are made of concrete and grass; however, they can be transformed into varied, ecologically rich places of learning for children. The benefits of outdoor learning have been emphasised by the learning outside the classroom manifesto [10], as school gardens offer significant benefits in terms of learning through experience [11]. In addition, a number of design attributes related to the natural environment have been studied in terms of their educational impacts. A 14.4% improvement in test scores was discovered as a result of natural ventilation [12]. The combination of dynamic lighting and increased ventilation rate indicated boosted positive impact on the speed and

concentration of the children [13]. Furthermore, improved outdoor space and access to nature was correlated with a 7% improvement in test results [14]. Therefore, a connection to nature is important for not only children's well-being but also their education. Beneficial and healing relationships between nature and human functioning are well established. Within an educational setting, experiences with nature promote children's academic learning (by providing a calmer, quieter, and safer context for learning; a warmer and more cooperative context for learning) and seem to promote children's development as persons and as environmental stewards [15].

Biophilic design patterns have the potential to reposition the environmental quality conversation to provide individuals' needs equal consideration alongside the conventional parameters for building performance. Biophilic design patterns [2,16] can be used in school grounds and in indoor spaces for greater connectivity between interior design and nature to promote children's well-being, especially for post-pandemic school design. This paper focuses on ten biophilic design patterns under two categories of 'nature in the space' (direct connection to nature) and 'natural analogues' (indirect experience of nature). The aims of this paper are as follows:

- To address the current lack of systematic analysis of biophilia in schools;
- To identify various biophilic design patterns in different primary schools across the world in selected cases;
- To suggest an evaluative tool for children to assess biophilic design patterns in primary schools in order to engage them in a co-design process.

## 2. Background

In *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*, biophilia is described as 'the inherent human affinity to affiliate with natural systems and processes' [1]. It was in the 1960s, however, when biophilia was first conceived within social psychology. Social psychologist Eric Fromm formed the concept of 'bioiphilious,' meaning 'bio' as in nature and 'philious' as in love. This concept was popularised by Edward Wilson in the 1980s as 'biophilia.' Although the term 'biophilia' is a relatively new concept, it has always been a key component relative to human culture, community, and traditional vernacular architecture.

In the book *Creating Biophilic Buildings* [17], biophilic design was described as '...the deliberate incorporation of elements from nature into the built environment'. Within Terrapin's Bright Greens '14 Patterns of Biophilic Design' [2], biophilic design is divided into three themes: Nature in the Space, Natural Analogues, and Nature of the Space, as Table 1 presents them. Within these three themes, individual patterns are explored, and their benefits expanded upon, taking reference from the work by Kellert and Calabrese [18].

**Table 1.** Fourteen Patterns of Biophilic design—adapted from Terrapin Bright Greens [2].

| Theme | No. | Pattern |
|---|---|---|
| Nature in the Space (Direct Experience) | 1 | Visual Connection with Nature |
| | 2 | Non-Visual Connection with Nature |
| | 3 | Non-Rhythmic Sensory Stimuli |
| | 4 | Thermal and Airflow Variability |
| | 5 | Presence of Water |
| | 6 | Dynamic and Diffuse Light |
| | 7 | Connection with Natural Systems |
| Natural Analogues (Indirect Experience) | 8 | Biomorphic Forms and Patterns |
| | 9 | Material Connection with Nature |
| | 10 | Complexity and Order |
| Nature of the Space (Indirect Experience) | 11 | Prospect |
| | 12 | Refuge |
| | 13 | Mystery |
| | 14 | Risk/Peril |

Interfaces booklet's '14 Patterns of Biophilic Design' [19] incorporates the work of Terrapin Bright Green, describing each pattern and exploring the experience of it. The booklet also highlights practical methods of implementing each pattern. Although the practical examples are somewhat directed at office environments, they do provide a starting point from which to expand and explore the ways in which the integration of biophilic design can be achieved within other built environments, such as schools. However, as part of Nature of Space, pattern 15, 'Awe' was also introduced [4].

Within the 'Practice of Biophilic Design' [18], it is suggested that in order to successfully create a biophilic design, five principles must be followed about 'biophilic design':

1. It requires repeated and sustained engagement with nature;
2. It focuses on human adaptation to the natural world that over evolutionary time has advanced people's health, fitness, and wellbeing;
3. It encourages an emotional attachment to particular settings and places;
4. It promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities;
5. It encourages mutual reinforcing, interconnected, and integrated architectural solutions.

As this study focuses on two categories of biophilic design (Nature in the Space and Natural Analogues) and the associated patterns, Table 2 presents the attributes related to ten biophilic design patterns [2].

**Table 2.** Biophilic design patterns and the associated attributes—adapted from [2].

| Biophilic Categories | Biophilic Design Patterns | Attributes |
|---|---|---|
| Nature in the Space | Visual Connection with nature | View to elements of nature, living systems, and natural processes; |
| | Non-visual connection with nature | auditory, haptic, olfactory, or gustatory stimuli that engender a deliberate and positive reference to nature, living systems, or natural processes. |
| | Non-rhythmic sensory stimuli | Stochastic and ephemeral connections with nature that may be analysed statistically but may not be predicted precisely. |
| | Thermal and airflow variability | Subtle changes in air temperature, relative humidity, airflow across the skin, and surface temperatures that mimic natural environments. |
| | Presence of water | A condition that enhances the experience of a place through seeing, hearing, or touching water. |
| | Connection with natural systems | Awareness of natural processes, especially seasonal and temporal changes characteristic of a healthy ecosystem. |
| | Dynamic and diffuse light | Leverages varying intensities of light and shadow that change over time to create conditions that occur in nature. |
| Natural Analogues | Biomorphic Forms and Patterns | Symbolic references to contoured, patterned, textured, or numerical arrangements that persist in nature. |
| | Material connection with nature | Materials and elements from nature that, through minimal processing, reflect the local ecology or geology and create a distinct sense of place. |
| | Complexity and order | Rich sensory information that adheres to a spatial hierarchy similar to those encountered in nature. |

The benefits to the integration of biophilic design are wide ranging and can positively affect mental wellbeing, physical health, and brain function [20,21]. The benefits of integrating biophilic design into educational environments include improved test scores, optimal health, and increased learning. It also highlights the benefits to including biophilic design strategies with playtime environments such as the playground, providing children with the capacity for improved behaviour, focus, and mental restoration. In an increasingly urban environment, where the opportunity for children to be exposed to nature is continually reduced, it has been found that 96% of children prefer to be outdoors, with studies attributing lower stress levels in children who have nature within their surroundings than those without [20]. Table 3 outlines the attributes, benefits, and practical examples of 10 biophilic design patterns [2,18,19].

**Table 3.** Attributes, benefits, and examples of the 10 patterns of biophilic design.

| No. | Pattern | Experiences and Attributes [18] | Benefits to Wellbeing [2] | | | Design Examples [19] |
|---|---|---|---|---|---|---|
| | | | Stress Reduction | Cognitive Performance | Emotion, Mood, and Preference | |
| 1 | Visual Connection with Nature | -Plants<br>-Animals<br>-Natural landscapes and ecosystems | Lowered blood pressure and heart rate | Improved mental engagement/attentiveness | Positively impacted attitude and overall happiness | 1. Work spaces next to windows with a view to nature<br>2. Plants, flowers, and green walls |
| 2 | Non-Visual Connection with Nature | Weather | Reduced systolic blood pressure and stress hormones | Positively impacted on cognitive performance | Perceived improvements in mental health and tranquility | 1. Sound (animals, conversation, music, and water)<br>2. Smell (perfume and fragrant plants)<br>3. Touch (hand rails and water for cooling) |
| 3 | Non-Rhythmic Sensory Stimuli | Water | Positively impacted on heart rate and systolic blood pressure and sympathetic nervous system activity | Observed and quantified behavioural measures of attention and exploration | | 1. Indoor kinetic facades<br>2. Interactive design displays<br>3. Swaying grasses<br>4. Falling water<br>5. The sound of insects |
| 4 | Thermal and Airflow Variability | Air | Positively impacted comfort, well-being and productivity | Positively impacted concentration | Improved perception of temporal and spatial pleasure | 1. Openable windows, manually or individually<br>2. Work areas with external balconies<br>3. Visible mechanical ventilation |
| 5 | Presence of Water | Weather | Reduced stress, increased feeling of tranquillity, lower heart rate and blood pressure | Improved concentration and memory restoration<br>Enhanced perception and psychological responsiveness | Observed preferences and positive emotional responses | 1. Water walls<br>2. Fountains<br>3. Aquariums<br>4. Paintings of ocean/water life<br>5. The colour blue |
| 6 | Dynamic and Diffuse Light | Fire | Positively impacted circadian system functioning | | | 1. Daylight from multiple angles<br>2. Firelight<br>3. Light distribution<br>4. Ambient diffuse lighting on walls/ceiling<br>5. Personal dimmer controls |
| 7 | Connection with Natural Systems | -Cultural and ecological attachment to place<br>-Transitional spaces | | | Enhanced positive health responses; shifted perception of environment | 1. Work spaces with patios or roof gardens<br>2. Native planting that grows and dies with the seasons |
| 8 | Biomorphic Forms and Patterns | -Images of nature<br>-Natural Colours<br>-Naturalistic forms and shapes<br>-Evoking nature<br>-Natural geometries<br>-Biomimicry | | | Observed view preference | 1. Organic shapes<br>2. Natural colours<br>3. Spirals<br>4. Fractals<br>5. Curves<br>6. Geometric forms |
| 9 | Material Connection with Nature | -Natural Materials<br>-Age, changes, and the patina of time | | Decreased diastolic blood pressure improved creative performance | Improved comfort | 1. Materials that reflect native ecology such as specific woods, clay, stones, and other fabrics |
| 10 | Complexity and Order | -Evoking nature<br>-Organised complexity<br>-Integration of parts to wholes | Positively impacted perceptual and physiological stress responses | | Observed view preference | 1. Repetitive and symmetrical shapes<br>2. Pattern order in wallpaper and flooring design<br>3. Exposed structure and mechanical systems facades<br>4. Spandrel and window hierarchy<br>5. Floor plan |

## 3. Case Studies

A review of the literature shows that there are not many examples of systematic case studies related to biophilic design in schools. There are few case studies of schools that present biophilic design [4,17]; however, they are presented more as descriptive examples than analytical cases alongside other types of buildings without comparison. For this study, the selected cases (in two climates) represent different models of school design and approaches as follows.

- School design with full integration of nature;
- School design that integrates some natural elements;
- School design that integrates the imitation of nature.

The case studies have been analysed to identify (1) the main design considerations in integrating nature (directly and indirectly) and (2) the main biophilic patterns and elements applied in the design of schools (indoors and outdoors). Table 4 shows the presence of different biophilic design patterns in the selected schools (case studies in tropical and temperate climate) that would be discussed individually to highlight how the patterns were applied in each school.

### *3.1. Vo Trong Nghia's Farming Kindergarten*

This kindergarten in Vietnam is a two-storey school with a knot-shaped roof and a vegetable garden on top with three protected courtyard playgrounds. The surface of the roof is covered in grass and plants to create an extra garden. It slopes down to the ground at two ends to allow easy access, then rises up over two levels of classrooms. With facilities for up to 500 pupils, it was designed by Vo Trong Nghia Architects. Despite a tight budget, the architects wanted the building to become a prototype for sustainable school design, where children can learn how to grow their own food. The outer walls are shaded behind concrete louvres that encourage the growth of climbing plants, while the green roof above serves as a form of insulation. Windows on both external and courtyard-facing walls offer natural lighting and cross ventilation throughout the building; therefore, the kindergarten operates without air conditioners in the classrooms despite being located in a harsh tropical climate. Other sustainability initiative includes the use of solar power to heat water and the recycling of waste water from the factory to irrigate greenery and flush toilets [22].

### *3.2. The Green School*

The Green School, opened in Bali in 2008, is committed to education that promotes sustainability and shapes future green leaders. It currently serves more than 800 students aged 3–18 [23]. The Green School, a giant laboratory built by PT Bambu, is located on a sustainable campus straddling both sides of the Ayung River in Sibang Kaja, Bali, within a lush jungle with native plants and trees growing alongside sustainable organic gardens. The campus is powered by a number of alternative energy sources, including a bamboo sawdust hot water and cooking system, a hydro-powered vortex generator, and solar panels. Campus buildings include classrooms, gym, assembly spaces, faculty housing, offices, cafes, and bathrooms. A range of architecturally significant spaces from large multi-storey communal gathering places to much smaller classrooms comprises features of the campus. Local bamboo, grown using sustainable methods, is used in innovative and experimental methods that demonstrate its architectural possibilities. The result is a holistic green community with a strong educational mandate that seeks to inspire students to be more curious, more engaged, and more passionate about the environment and the planet [24].

### *3.3. Barn Klong Bon School and Art Spaces*

With this project, Vin Varavarn Architects aimed to design a new building for Barn Klong Bon School situated on Koh Yao Yai Island of Phang-Nga province, Thailand, replacing the old structure that had deteriorated over time. The design team ended up rearranging the floor plan of the classrooms on the second floor to deviate 90 degrees from the original position, consequentially separating the classrooms and reconnecting them using the corridor at the back of the building. The new configuration not only creates a space between each classroom but also keeps the upper floor spacious, unobstructed, and well-ventilated, interestingly facilitating a spatial connection between the upper floor and the ground floor where the art classroom is located. The difference of the floor levels causes the ground floor of the building to be situated at different levels, which results in the different ceiling heights. The design accentuates the spaciousness and openness of the

area where the ceiling is higher. One of the interesting details of the building is its use of translucent corrugated panels with the steel frames of the windows and doors. The design brings in natural light while protecting the interior spaces from the rain. The walls on the second floor are cladded with bamboo wood, generating a friendly vibe in the space while resonating with the natural surrounding outside [25]. Openable opaque facades allow the occupants to experience the natural environment from the internal space. Curtains are used to divide spaces and also enable the occupants to connect to nature through non-rhythmic sensory stimuli, as the air movement through the building gently move the curtains. Natural materials, open facades, and indoor plants connect the occupants to nature.

### *3.4. Eureka Centre in Anglo Colombiano School*

This school building contains two half-moons slightly separated from each other, defining a longitudinal axis which generates access points to the building. Moreover, the two clay half-moons embrace a central forest-like courtyard with an 'oval' configuration in the form of a leaf. The kinetic form of the patio is in contrast to the static cubic blocks of the rest of the school. The shape of the building and its functional principle perform as an exhibit itself, where the classrooms and events happening around are visible due to the transparency provided from the materials; this enhances the possibilities of seeing and being seen. The central space is the main building articulator connecting the different floor plans via a 'helical' system of circulations ending at the student lounge at the top floor plan and, afterward, connecting onto the building terrace that performs as an additional academic area. On the other hand, the classrooms foreseen in the perimeter of the 'oval' patio become interconnected via the 'helical' system of circulations. Plants at the ground floor can be seen from the circulation space around the atrium [26]. Natural materials and colour palettes are used alongside planting relative to the internal spaces, creating a material connection with nature. Tables 5 and 6 present the application of patterns in these four schools.

### *3.5. Hazelwood School*

Hazelwood School in Glasgow was designed for children and young people with sensory impairment and complex learning needs. It aims to create a bespoke building that avoids long dark corridors with maximised levels of natural light and incorporated visual sound and tactile clues. The school caters for 60 students aged from two to 19 with multiple disabilities and a combination of two or more of the following impairments: sight, hearing, mobility, or cognition. The design focused on creating a safe and stimulating environment for pupils and staff and incorporated cork-clad walls and weaving walkways to help students find their way around. Various sensory lighting has been used to engage children with vision-related disabilities. Facilities including a hydrotherapy pool place the sensory stimulation aspect at the heart of the school [27]. The architect eliminated any institutional feel by creating a bespoke building that maximised levels of natural light and incorporated visual, auditory, and tactile clues. The school steps and curves around the existing beech trees create a sequence of safe, landscaped teaching gardens. High level clerestory glazing forms a substantial part of the façade of the north-facing classrooms, allowing maximum daylight to penetrate deep into the spaces and ensuring an even distribution of light [28]. This school presents the use of biophilic design for children and young people with special needs, including autism and particularly designing to encourage free movement.

**Table 4.** Presence of ten biophilic design patterns in seven schools.

| Theme | No. | Pattern | Farming Kindergarten | Green School | Barn Klong Bon School | El Colegio Anglo Colombiano | Hazelwood School | The Garden School | Paul Chevallier School |
|---|---|---|---|---|---|---|---|---|---|
| Nature in the Space (Direct Experience) | 1 | Visual Connection with Nature | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 2 | Non-Visual Connection with Nature | Not evident | Yes | Yes | Not evident | Yes | Yes | Yes |
| | 3 | Non-Rhythmic Sensory Stimuli | Not evident | Yes | Yes | Not evident | Not evident | Not evident | Not evident |
| | 4 | Thermal and Airflow Variability | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 5 | Presence of Water | Not evident | Yes | Yes | Not evident | Yes | Not evident | Not evident |
| | 6 | Dynamic and Diffuse Light | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 7 | Connection with Natural Systems | Yes | Yes | Yes | Not evident | Not evident | Yes | Yes |
| Natural Analogues (Indirect Experience) | 8 | Biomorphic Forms and Patterns | Yes | Yes | Yes | Yes | Not evident | Yes | Yes |
| | 9 | Material Connection with Nature | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 10 | Complexity and Order | Not evident | Yes | Yes | Yes | Yes | Not evident | Yes |

**Table 5.** Use of patterns in case studies located in tropical climate related to Nature in the Space (Direct Experience).

| No. | Pattern | How the Patterns Were Applied | | | |
|---|---|---|---|---|---|
| | | **Farming Kindergarten** | **Green School** | **Barn Klong Bon School** | **Eureka Centre in Anglo Colombiano School** |
| 1 | Visual Connection with Nature | Three sheltered courtyards with visible tree planting | Vast openings to nature | Indoor plants | Plants in the courtyard |
| 2 | Non-Visual Connection with Nature | Not evident | Openings allow sound and smell of nature (jungle) inside | Open facades allow light, air, smell, and tough inside | Not evident |
| 3 | Non-Rhythmic Sensory Stimuli | Not evident | -Open facades allow seeing natural movement within nature<br>-Openness of the building allows air to create movement within the space | Open façades allow air movement within interior (plants and curtains that divide spaces) | Not evident |
| 4 | Thermal and Airflow Variability | Designed for cross ventilation (naturally ventilated interior) | Air movement creates cooling effect for users and changes in humidity level | Open façades allow air flow, changes in temperature, movement, and humidity | Air circulation is created by opening windows and to the courtyard |
| 5 | Presence of Water | Not evident | The open facade connects the occupants to water through rainfall (seen and heard from inside) | Not evident | Not evident |
| 6 | Dynamic and Diffuse Light | -Natural lighting through windows to courtyard facing and outer walls<br>-Louvres filter the direct light | Open façade and roof form to provide natural light throughout the day | -Large openable facades and opaque glass panels diffuse the natural light<br>-Internal courtyard allows light to the centre | Varying intensities of light and shadow creates conditions that occur in nature |
| 7 | Connection with Natural Systems | -Green roof as an edible garden<br>-Experiencing growth cycle of plants | Open structure enables occupants to connect to the changes in nature | Openable facades allow the occupants to experience the changes of weather conditions | Not evident |

**Table 6.** Use of patterns in case studies located in tropical climate related to Natural Analogues (Indirect Experience).

| No. | Pattern | How the Patterns Were Applied | | | |
|---|---|---|---|---|---|
| | | **Farming Kindergarten** | **Green School** | **Barn Klong Bon School** | **Eureka Centre in Anglo Colombiano School** |
| 8 | Biomorphic Forms and Patterns | Curved building with green roof (natural hill shape with access from the ground | Curves and natural shapes (ranging from the furniture, incorporating the natural features and strength of bamboo) | Images of animals and trees on the walls | -Symbolic references to nature (patterns, textures, and numerical arrangements)<br>-Curved walkways and seating |
| 9 | Material Connection with Nature | Bricks and tiles are used within the buildings | Natural materials are used throughout the school | Natural, native materials (bamboo) are used within the building | -Minimal processing materials reflect local ecology or geology<br>-Earth tones to create the look of clay have been used as well as brick |
| 10 | Complexity and Order | Not evident | Sustainable features (solar panels, mini hydro vortex, and water filtration) are visible to users | Structural elements indoors | Ventilation and power systems are visible to the users |

### *3.6. The Garden School*

The Garden School is a school for four to sixteen years old with special educational needs (especially autism) in Hackney, England. The design includes varied seating, including a window seat that offers views onto the playground as well as playful built-in hexagonal seating for children to relax and restore their energy. The hexagonal plinths vary in height and are made from natural wood, creating a material connection with nature. Textured carpets with varying pile heights and wallpaper with images of woodland provide tactile and visual connections to nature, which is mainly important for children with special educational needs. At one end of the space, there is a multi-sensory feature that children can interact with and control artificial lighting. When each of the natural surfaces touched, the colours of the LED lighting discs will change softly, and natural sounds will be triggered. Touching two surfaces will cause overlapping sounds, and two sets of lights to be illuminated. There are colour changing LED lighting disks on the ceiling, and their colours change softly when the interactive feature is touched. The colours represent the natural tones that we experience throughout the day, i.e., dawn, midday, or dusk (yellows, oranges, reds, blues, and purples) [29].

### *3.7. Paul Chevallier School*

This wooden nursery and elementary school complex in Lyon by French architects, Tectoniques, is located on a sloping site. One of the major characteristics of the project is the relationship between architecture and nature. It has hilly rooftops carpeted with plants and walkways for children to explore. There is also a vegetable garden. Therefore, the project harmonises vegetation on the upper and lower levels. The volumes in wood are separated by the broad, planted-out roofs, with their waves of colour. The two-storey and three-storey buildings were designed with V-shaped plans. The nursery school frames a garden, while the elementary school wraps around a narrow courtyard. The two schools operate independently but share some facilities. Timber cladding covers most of the building's interior and exterior, but is interspersed with a few yellow-painted panels on the walls and ceilings. Spacious corridors run between classrooms and feature floor-to-ceiling windows in order to increase natural light. From the inside, nature is framed by the large windows of the classrooms, and its close proximity makes it an element of the children's educational needs. Wood is of pre-eminent presence—there are wood panels throughout for the walls, façades, and floors. They are left exposed on the inside surfaces, giving solidity and depth to the walls and partitions. The tactile exposed wooden cladding stimulates the sense of touch [30]. Tables 7 and 8 present the application of biophilic design patterns in these three schools.

The case studies of these seven schools have presented application of various biophilic design patterns; however, based on the location and climate, there have been differences in the application of these patterns indoors and outdoors. The analysis is useful for the designers; however, it cannot be discussed with primary school children to gather their views about these patterns and their applications. Therefore, an age appropriate evaluative tool needs to be designed in order to involve children in the biophilic design process of their schools.

**Table 7.** Use of patterns in case studies located in temperate climate related to Nature in the Space (Direct Experience).

| No. | Pattern | How the Patterns Were Applied | | |
|---|---|---|---|---|
| | | **Hazelwood School** | **The Garden School** | **Paul Chevallier School** |
| 1 | Visual Connection with Nature | Mature trees around site. Are visible and accessible to students | Window seats allow occupants a view to nature outside | -Vegetable garden<br>-Accessible rooftop with plants |
| 2 | Non-Visual Connection with Nature | Touching natural materials | Nature sounds are played within the space | Use of natural materials with texture |
| 3 | Non-Rhythmic Sensory Stimuli | Not evident | Not evident | Not evident |
| 4 | Thermal and Airflow Variability | Natural ventilation | Natural ventilation | Natural ventilation |
| 5 | Presence of Water | Indoor pool | Not evident | Not evident |
| 6 | Dynamic and Diffuse Light | -High level and height glazing<br>-Louvers to filter sun<br>-Light, shadow varied: replicates nature | -Natural lighting inside controlled with blinds | -Natural light in corridors<br>-Floor to ceiling windows<br>-Façade with holes and wood frame |
| 7 | Connection with Natural Systems | Not evident | Visible view from seats | Nature is framed by the large windows |

**Table 8.** Use of patterns in case studies located in tropical climate related to Natural Analogues (Indirect Experience).

| No. | Pattern | How the Patterns Were Applied | | |
|---|---|---|---|---|
| | | **Hazelwood School** | **The Garden School** | **Paul Chevallier School** |
| 8 | Biomorphic Forms and Patterns | Not evident | -Honeycomb-like seating<br>-Wallpaper (woodlands) | Panels with circular holes that allow lights to the classrooms |
| 9 | Material Connection with Nature | Materials and elements from nature, such as cork and wood | -Materials to evoke nature<br>-Natural colours | Use of wood internally and externally for walls, façades, and floors |
| 10 | Complexity and Order | Wooden structural elements | Not evident | Visible wooden structures (frames) |

## 4. Outcome: An Evaluative Tool

As the biophilic design patterns have been introduced mainly to designers, its complexity makes it difficult to be used directly for gathering views of children as the main users of schools. Therefore, in order to bridge this gap and present children's views todesigners, this study aims to create a tool to gather these voices in primary schools (Key Stage 2—ages 7–11). The suggested tool is based on literature review and analysis of case studies to include the features related to various biophilic design patterns.

The collection of ordinal data seems appropriate for this evaluative tool because according to Bryman [31], ordinal data are based on counts of items assigned to specific categories which stand in some clear, ordered, and ranked relationship. Therefore, it could help to find the importance of the identified items through the use of rating scales. However, it is important to find the appropriate ranking scale for children to evaluate different features. In the context of school design and researching children, there have been reports that suggest gathering children's opinions by means of a 'rating scale.' The 'School Building Assessment Methods' describes the different forms of pupil participation, including the School Building Rating Scale as a comprehensive assessment tool [32]. This qualitative assessment tool has been organised into categories that include the essential components necessary for meeting the demands of an optimum learning environment. The questionnaire includes 'fifty-five statements' pertaining to the school building to be

rated by building users such as students and school staff. The rating scale is a 7-point numeric scale based on a continuum from very unsatisfactory (VU) to very satisfactory (VS). This study shows the possibility of using rating scales for children; however, it could be argued that it seems complicated to apply for all age groups of children. Therefore, making rating scales age-appropriate is important to consider. In another relevant report titled 'Evaluation of Building Schools for the Future' [33], the pupils' questionnaire is based on a rating scale to gather their opinions about their 'school and its facilities, views on school, about their teachers and themselves' (in four main sections). The type of scale varies from 3-point (Agree, Not sure, and Disagree) to 5-point (Very Good, Good, Neither/nor, Poor, and Very Poor). However, changing the type of scale might confuse children; therefore, consistency seems important. Therefore, for this age group of children, a simple ranking scale that is linguistically familiar to children is suggested. Thus, a 4-point scoring scale, which has been tested previously to assess the satisfaction of children (11–12 years) related to various items in their schools [34], has been selected. This scoring scale indicates four as the best score and one as the poorest score. In order to express a level of agreement with a statement, the scores are defined as follows.

1. Sad;
2. I do not mind;
3. Happy;
4. Very happy.

The suggested features are related to the biophilic design patterns extracted from the literature review (visual analysis and evidence-based studies and case studies (to select the common patterns—eight out of ten). In particular, regarding the direct connection to nature and different senses, the outcome of a few studies [35–37] with children regarding their school ground was considered for selecting the features related to patterns as well as the summary of literature review presented in Table 2. For example, 'the school I'd like' 2001 competition emphasised children's ideas for their school yards—which included a lot of spaces to be filled with ponds and gardens. With younger children, there was a further theme expressed, which was the need for more natural features, including water, wildlife, and animals [35]. Similarly, an analysis of previous studies presents children's interest in accessing the landscape (e.g., trees, garden, mazes, grass, wild garden, and ponds) and inclusion of a pet corner or bird boxes in the school ground [35,36], as also highlighted by children in a recent study [37]. Table 9 presents the first format of this evaluative tool; however, because the majority of children (participated in this study) expressed their happiness with most of the features, the tool was developed to allow children to express various feelings related to each feature by choosing one or more feelings or even expression of 'no feeling'; therefore, the tool was developed to include different feelings associated with the features (as Table 10 presents) in connection with Table 11, which shows the extracted features related to the patterns.

**Table 9.** Evaluative tool format for assessing children's happiness.

| No. | Feature | Image | Very Happy | Happy | I Do Not Mind | Sad |
|---|---|---|---|---|---|---|
| | | | | | | |

**Table 10.** Evaluative tool format for assessing children's feelings.

| No. | Feature | Image | Calm | Happy | Excited | Anxious | Angry | No Feeling |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

**Table 11.** Features associated with selected biophilic design patterns.

| Theme | No. | Patterns | Features |
|---|---|---|---|
| Nature in the Space (Direct Experience) | 1 | Visual Connection with Nature | - Animals (e.g., birds and pets)<br>- Landscape in school ground<br>- Plants inside the classrooms |
| | 2 | Non-Visual Connection with Nature | - Sound of water<br>- Sound of birds' song<br>- Smell of flowers<br>- Natural materials to touch (bamboo, wood, and stone) |
| | 3 | Non-Rhythmic Sensory Stimuli | None |
| | 4 | Thermal and Airflow Variability | - A lot of fresh air from the windows |
| | 5 | Presence of Water | - A pond in school ground<br>- An aquarium in the building |
| | 6 | Dynamic and Diffuse Light | - Lots of natural light from the windows<br>- Skylight/roof window (in classrooms and school hall) |
| | 7 | Connection with Natural Systems | - View to outside to see plants and trees<br>- Plants to grow and look after |
| Natural Analogues (Indirect Experience) | 8 | Biomorphic Forms and Patterns | - Natural form for seats and spaces<br>- Circular or oval windows<br>- Patterns of plants on walls (flowers and leaves)<br>- Patterns on creatures on walls and floors (butterflies and shells)<br>- Curved forms and spaces<br>- Images of landscape on walls<br>- Images of seaside on walls |
| | 9 | Material Connection with Nature | -Natural materials (bamboo and wood) inside the building to see and touch<br>- Natural materials in school ground (bamboo, wood, and stone)<br>- Colourful walls and ceiling<br>- Colourful glasses on the windows and doors |
| | 10 | Complexity and Order | None |

This evaluative tool (to assess children's happiness) was tested in a few primary schools in four countries, including England, Indonesia, Malaysia, and Thailand, with 291 children. In order to obtain permission for this research study, there were two stages: (1) gaining authorisation from the Faculty of Art, Design and Architecture at De-Montfort University and (2) obtaining permission from the individuals under the schools' authority, including headteachers, children, and parents. Almost all children participated in this study could respond to all the items. The suggested tool for assessing children's feelings related to different features was also tested in one primary school in England, where 134 children participated and could respond well by expressing their feelings associated with various features.

## 5. Recommendation for Further Research

There is a growing body of research and examples of involvement of children with architects [37,38] as well as UK's Government-led Building Schools for the Future Programme (BSF) of 2005–2010, which helped mainstream school-based co-design projects between practitioners and stakeholders [39], including Joined up Design for Schools [40]

and Young Design Programme [41]. There is also an ongoing GCRF Networking project with respect to the implication of biophilic design in post-disaster primary schools. As co-designers, the idea is to view children as equal stakeholders throughout the entire experience, contributing to the process as experts of their own lives. It is important to acknowledge their competence and provide them with methods of self-expression that encourages comfort and creativity. User participation should be a part of the foundation for a design proposal, which results in a design that is highly relevant in terms of use and an increased sense of belonging [38]. Co-designing with users indicates collective creativity applied across the span of a design process [42]. In order to extract children's views, codesign methods need to be adapted to the child's expressive needs. This study analysed case studies of schools in two climates—tropical and temperate to present the application of biophilic design patterns. It also suggested an evaluative tool in which children could become involved in designing primary schools (indoor and outdoor spaces) in order to identify spatial design trends that promote direct and indirect connections to nature. However, regarding the biophilic design of schools, gathering views of children and other stakeholders, including teachers in different climatic and cultural environments, is recommended. In addition, similar evaluations could be carried out in secondary schools with children, young people, and teachers. The outcome could inform designers, architects, educators, and policy makers about the biophilic design of schools during the pandemic and post-pandemic period to promote children's and teachers' well-being.

**Author Contributions:** R.G. has been the lead author and the Co-PI of the project Healing by Nature with P.A., who contributed to the selection and analysis of case studies in Southeast Asia. M.L. contributed to the analysis of case studies, original draft preparation, and development of evaluative tool. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by The Academy of Medical Sciences, grant number GCRFNGR5\1121.

**Institutional Review Board Statement:** This study was approved on 07/12/2020 by Ethics Committee, Faculty of Art, Design and Hu-manities at De Montfort University. The ethics application was amended, reviewed and approved again on 18/06/2021 (reference code: G1).

**Informed Consent Statement:** Informed consent was obtained from the Headteachers and parents/guardians of children participated in this study.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We thank the Academy of Medical Sciences (AoMS) for funding this GCRF Networking research project (Healing by Nature—GCRFNGR5\1121).

**Conflicts of Interest:** The authors declare no conflict of interest.

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