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Reimagining Cities: Designing Biophilic Urban Spaces with AR for STEM Learners (14–18)

BIOS4YOU
AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

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General topic of the learning path	Biophilic Cities: Nature-Based Design for Urban Spaces
Specific name of the learning unit	Reimagining Cities: Designing Biophilic Urban Spaces with AR
Target user age	14-18 years
Learner prerequisites	Basic knowledge of Environmental Science, Biology, and Geometry
Description of the learning unit	This unit invites students to explore how nature can inspire sustainable and healthier urban environments. Using AR tools, learners will visualize and interact with biophilic elements such as green roofs, natural lighting systems, and ventilation inspired by ecosystems. The activity encourages system thinking, creativity, and problem-solving through immersive STEM-based learning.
Subject involved	Environmental Science, Biology, Physics, Mathematics, Technology
Keywords	Biophilic Design, Urban Planning, AR, Sustainability, Biomimicry, Interactive Learning, Nature-Inspired Innovation
Key-skills, abilities, knowledge that can be acquired	Understand biophilic principles and their applications in urban contexts; apply STEM concepts to design sustainable spaces; develop AR-based visualization and prototyping skills; enhance problem-solving and critical thinking
Resources and didactic tools used	AR tools (e.g., CoSpaces Edu, Assemblr EDU, Merge Cube, JigSpace), maps and urban plans, scientific databases, visual resources, online platforms, case studies of biophilic cities
Evaluation criteria and assessment	Assessment will be based on students' ability to apply biophilic design concepts, integrate AR tools to communicate their ideas, and demonstrate understanding of environmental and scientific principles through presentations, digital prototypes, and reflective feedback

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Introduction:

As global cities expand and become more densely populated, people are increasingly disconnected from the natural environments in which human beings evolved. Urban populations now face pressing challenges such as air pollution, mental fatigue, social isolation, and the intensification of climate change. Biophilic design is one of the most promising and research-supported responses to these issues, an interdisciplinary approach that seeks to reintegrate nature into the built environment.

This training unit aims to introduce learners to biophilic design and its relevance to urban spaces, sustainability, and human well-being. It presents scientific foundations, case studies, and design-oriented thinking to demonstrate how nature-inspired solutions can reshape cities in healthier, more sustainable ways.

Biophilic design builds on *biophilia*, which describes the innate human tendency to connect with nature and other living systems (Wilson, 1984). Rather than merely incorporating decorative plants into buildings, biophilic design involves the thoughtful integration of natural light, ventilation, water, materials, spatial forms, and ecological systems into the architecture and planning of urban spaces. Studies have demonstrated that exposure to natural elements in built environments contributes to better health outcomes, reduced stress, greater creativity, and enhanced cognitive function (Kellert et al., 2008; Browning et al., 2014).

This connection is frequently lacking in contemporary cities, often dominated by concrete surfaces, artificial lighting, and enclosed structures. Research has shown that limited access to natural elements, such as daylight or green views, can significantly improve recovery rates, mood, and attention span. Ulrich (1984) found that patients recovering from surgery in hospital rooms with views of trees healed faster and required less pain medication. Similar findings by Li and Sullivan (2016) demonstrated that students recovering from mental fatigue performed better on tasks when they had access to green outdoor views from the classroom.

Biophilic design also plays a crucial role in promoting urban sustainability. It enhances stormwater management through permeable landscapes and green infrastructure, mitigates urban heat through vegetation and shading, supports biodiversity by reintroducing habitat niches, and lowers energy use through passive lighting and ventilation strategies. Jamei et al. (2016) highlight how urban geometry and natural elements can significantly improve outdoor thermal comfort, while Beatley (2016) emphasizes the broader urban planning benefits of biophilic interventions in creating resilient, livable communities.

This unit explores the application of biophilic principles through the lens of STEM, Science, Technology, Engineering, and Mathematics. It addresses how biological systems support urban

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biodiversity, how light and air movement influence comfort and energy efficiency, how geometrical patterns from nature inspire structural design, and how sustainable materials and digital tools like Augmented Reality (AR) can support innovative and environmentally conscious construction. This approach's cross-disciplinary nature encourages technical knowledge, critical thinking, and problem-solving in the context of real-world urban challenges.

Recent literature confirms that incorporating biophilic patterns into the design of buildings and public spaces leads to measurable psychological and physiological benefits. Browning, Ryan, and Clancy (2014) identified 14 biophilic design patterns, such as dynamic light, natural shapes, and material connection to nature, that positively affect health and productivity in both work and learning environments.

By familiarizing themselves with biophilic concepts, learners are empowered to reimagine and prototype urban spaces that foster deeper relationships between people and their environment. Whether applied to schools, parks, housing, or public infrastructure, biophilic design provides a framework for more sustainable and restorative cities, cities that prioritize ecological integrity and human well-being.

1. EXPLORE – Understanding the Context and Key Concepts

What is Biophilic Design?

- Definition and origin:

Biophilia can be defined as a love of life or living systems. It is theorized that humans have an inherent need to affiliate with the world around us and are naturally inclined to do so. This inclination is inborn, and as much as we gravitate toward it, we can also be averse to it. For instance, we might naturally want to be outside in the sunlight and warmth of a summer day, but we also do not want to find ourselves near a poisonous snake. Biophilic design helps us discover how the built environment could and should, be radically re-conceptualized around the fundamental workings of the human mind (Vagal, 2020).

- How Does Biophilic Design Benefit Humans?

Over the past 5,000 years, the rise of large-scale agriculture, manufacturing, technology, industrial production, engineering, and modern urban life represents only a brief chapter in human history. Despite these advancements, they have not replaced the benefits of living in harmony with the natural environment. Much of our emotional well-being, problem-solving, critical thinking, and creative abilities still stem from skills and instincts developed through deep connections with natural systems. These connections continue to play a vital role in our health, development, and productivity (Kellert, 2015).

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Biophilic design offers measurable benefits by reconnecting humans with the natural patterns and sensory experiences that shaped our evolution over millennia. Rooted in our biological affinity for nature, a concept known as biophilia (Wilson, 1984), this design approach recognizes that our cognitive, emotional, and physiological systems are best attuned to environments resembling those in which humans evolved, such as forests, savannahs, and other natural settings (Kellert et al., 2008).

Scientific studies have shown that even minimal exposure to natural elements, such as access to daylight, views of greenery, fresh air, or tactile interaction with organic materials, can significantly enhance psychological well-being. These benefits include reduced stress levels, improved mood, greater creativity, and heightened cognitive performance (Ulrich et al., 1991; Kaplan & Kaplan, 1989). Contact with nature has also been associated with faster recovery rates in healthcare settings, improved concentration in educational environments, and increased workplace job satisfaction (Terrapin Bright Green, 2012).

From a physical health perspective, biophilic environments promote better air quality through natural ventilation, reduce noise pollution by integrating plants and natural materials, and encourage physical movement through well-designed green spaces. Exposure to natural light, particularly when aligned with circadian rhythms, improves sleep quality and overall vitality (Van den Berg et al., 2010).

In addition to individual benefits, biophilic design supports social health by fostering a sense of belonging and community. Spaces with natural elements like courtyards, promenades, and public gardens are more inviting and inclusive, encouraging interaction, collaboration, and shared experiences (Beatley, 2011). These environments can nurture stronger community bonds and contribute to more resilient, socially cohesive urban settings.

- Six Elements of Biophilic Design

Biophilic design is an evidence-based approach integrating natural elements into built environments to enhance human well-being. Rooted in the concept of biophilia, the innate human affinity for nature, this design philosophy has evolved to encompass various frameworks that guide its application in architecture and urban planning.

One of the foundational frameworks, developed by Stephen R. Kellert, outlines six core elements of biophilic design:

1. Environmental Features: Incorporation of natural elements like light, air, water, plants, and natural materials.
2. Natural Shapes and Forms: Using biomorphic forms, fractals, and natural patterns.
3. Natural Patterns and Processes: Integration of features that reflect nature’s rhythms, changes, and sensory variability.
4. Light and Space: Designing with natural light, dynamic illumination, and spatial variability to evoke natural experiences.
5. Place-Based Relationships: Creating spaces that reflect local ecology, culture, and a sense of belonging.

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6. Evolved Human-Nature Relationships: Acknowledgment of psychological connections to prospect-refuge theory, fear and awe, and the restorative benefits of nature.

Recent studies have expanded upon these elements, emphasizing their relevance in contemporary design practices. For instance, a 2023 review by Wijesooriya et al. highlights the integration of biophilic design frameworks with sustainable design criteria, underscoring the importance of aligning biophilic principles with environmental performance standards.

Furthermore, Al Sayyed and Al-Azhari (2025) research demonstrates the physiological benefits of biophilic design elements, such as natural light and ventilation, in reducing stress and enhancing comfort in residential settings. These findings reinforce the significance of incorporating biophilic elements to promote health and well-being in built environments.

By understanding and applying these six elements, designers and educators can create spaces that foster human-nature connections and support cognitive function, emotional well-being, and overall health.

- Biophilic and well-being:

The affiliation with nature as an inherited human inclination is the theory of biophilia; Wilson popularized this term in (1984). Kellert and Calabrese (2015) advocated the practice of biophilic design. They defined it as a process that offers a sustainable design strategy that seeks to interconnect people and nature based on three experiences and twenty-four design attributes. Strengthening this connection with nature reduces stress and improves health and well-being.

Since people usually spend more time inside buildings than in exterior environments, implementing a biophilic interior design approach is particularly important. However, this subject is still being researched, and the related literature is somewhat limited. Admittedly, principles and design processes are open to multiple interpretations that lead to ambiguity. “While the goal of the biophilic design is clear, understanding it and its application is less so” (Vagal, 2020).

Biophilic design considers other life forms (Beatley, 2017) and works efficiently in different contexts (Orman, 2017). It consists of direct, indirect, and symbolic experiences that aid human-nature connections (Bewza, 2012). Characteristics include access to diverse space types with different spatial qualities (Mangone et al., 2017), varied surface textures, glass, natural view, natural materials, warm colors (Spivack and Rogelberg, 2010), plants, natural sunlight, ventilation, open spaces and windows (Gray and Birrell, 2014).

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- Biophilic design example:

1- Apple Park, California, USA

Apple's new campus is widely regarded as one of the leading examples of biophilic design. The doughnut-shaped structure copies the natural curves found in nature and brings light into the offices from every angle. A new, 9,000-tree woodland also surrounds the campus.

2- Bosco Verticale, Milan, Italy

Finding nature in a high-rise apartment seems quixotic, but it may be just the biophilic injection dense cities need. After centuries of practice distinguishing the urbane from wilderness, a pair of residential high rises in Milan, Italy, has flipped the paradigm by proposing a new social ecology within its building façade and is providing an option for ultra-urban access to nature.

Bosco Verticale, designed by architect Stefano Boeri, opened in 2014 to provide residents with an alternative to suburban single-family neighborhoods. Boeri envisioned public exchange with neighbors through a terrace-scape on the building's exterior façade. In this space, residents would have views of nature, direct access to vegetation, and the opportunity for neighborly exchange about the pleasantries of gardening, plants, and wildlife. Relying on a compact intimacy of the gardening tradition, Bosco Verticale expands Milan's cultural habits of terrace gardening into a community-level asset that occurs as a forest on a building within the city.

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3- Kampung Admiralty

Kampung Admiralty offers a case study on how nature can be a primary element of these residential buildings. It, too, provides residents with rooftop agriculture and gardens throughout. The multitiered levels of the building progressively treat stormwater that flows through the site. The building has flourished within the three years since it opened to residents.

Figure … source: Jana Soderlund

STEM Concepts Involved:

Biophilic design is inherently multidisciplinary, drawing from nature's processes and forms to enhance the built environment in ways that support human health, ecological balance, and aesthetic richness. Integrating STEM education, science, Technology, Engineering, and Mathematics into biophilic design allows students to explore and apply real-world skills while engaging with sustainability challenges and environmental awareness.

Each STEM discipline offers a unique perspective for understanding and applying nature-inspired solutions:

- Biology deepens our understanding of natural systems, ecosystems, and biodiversity, which is essential for designing environments that interact harmoniously with living organisms.
- Physics helps us explore the behavior of natural forces like light, airflow, and energy transfer, all of which influence environmental comfort and efficiency.
- Mathematics provides the tools to recognize and apply natural patterns, such as symmetry, fractals, and the Fibonacci sequence, that often guide form and proportion in nature-based design.
- Technology empowers learners to experiment with innovative materials and digital tools, such as augmented reality (AR), to prototype and visualize sustainable, nature-integrated spaces.

Students gain practical experience in scientific observation, critical thinking, spatial reasoning, and ecological literacy through this approach. These connections support technical skill

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development and a deeper appreciation of nature's role in solving human-centered design challenges, bridging education, innovation, and sustainability.

Recent studies emphasize the power of nature-based STEM learning to foster creativity, well-being, and environmental responsibility among young learners (e.g., Wijesooriya et al., 2023; Al Sayyed & Al-Azhari, 2025). These experiences become even more immersive and impactful when supported by interactive technologies like AR.

- Natural systems and ecosystems (Biology)

Biophilic design integrates natural systems and ecosystems into urban environments to enhance human well-being and ecological balance. Urban spaces can mimic natural habitats by incorporating green roofs, vertical gardens, and biodiversity corridors, promoting environmental balance and psychological benefits.

Recent research highlights the importance of biodiversity in urban settings. For instance, the study "Biophilic Design Integration: Enhancing Sustainability and Human Well-Being in Modern Architecture" discusses how integrating natural elements into architectural design can improve mental health and environmental sustainability.

Moreover, urban areas can host a surprising level of biodiversity and provide unique ecosystems at various scales. Urban nature offers the potential to create needed ecological connectivity across fragmented landscapes, lessen per capita environmental footprints, and nurture climate-resilient ecosystems (https://www.nlc.org/article/2025/04/09/catalyzing-biodiversity-on-buildings/?utm_source=chatgpt.com).

Implementing biophilic design, especially in urbanized areas, can sometimes lead to unintended negative consequences for natural ecosystems. Therefore, careful planning and consideration are essential to ensure that integrating natural elements into urban design supports and enhances existing ecosystems rather than disrupting them (Szewrańskiet al., 2024).

Incorporating natural systems into urban design benefits the environment and supports human health. Studies have shown that exposure to natural environments can reduce stress, improve cognitive functioning, and increase workplace productivity (Senthil & Jayalakshmi, 2025).

Students can appreciate the interconnectedness of human and ecological health by understanding and applying the principles of natural systems and ecosystems in urban design. This knowledge empowers them to create urban spaces that are not only sustainable but also conducive to the well-being of all inhabitants.

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- Light and ventilation (Physics)

Light and ventilation are fundamental physical elements in biophilic design, directly influencing human comfort, health, and productivity. Understanding the physics behind natural light and airflow enables the creation of built environments that harmonize with natural processes, enhancing occupant well-being and environmental sustainability.

Natural Light

Natural light, or daylighting, plays a crucial role in regulating human circadian rhythms, which are essential for maintaining sleep patterns, hormonal balance, and overall health. The strategic use of daylight in architecture involves considering building orientation, window placement, and reflective surfaces to maximize light penetration while minimizing glare and heat gain.

Recent research highlights the benefits of incorporating natural light into building design. For instance, a study published in Frontiers in Virtual Reality demonstrated that environments with biophilic elements, including natural light, significantly reduced physiological stress indicators compared to non-biophilic environments (Al Sayyed & Al-Azhari, 2025).

Moreover, daylight-responsive lighting control systems can reduce reliance on artificial lighting, saving energy and reducing greenhouse gas emissions. Integrating such systems requires understanding the physics of light, including its intensity, direction, and spectral qualities. For STEM learners aged 14–18, exploring the physics of natural light offers hands-on opportunities to understand concepts like light reflection, refraction, and energy efficiency.

- Geometry and patterns in nature (Mathematics)

Geometry and mathematical patterns are fundamental to understanding the natural world and play a crucial role in biophilic design. By studying these patterns, students can gain insights into the underlying principles that govern natural forms and apply this knowledge to create harmonious and sustainable urban spaces.

- Fractals and Self-Similarity

Fractals are complex geometric shapes that exhibit self-similarity, meaning they look similar at different scales. These patterns are prevalent in snowflakes, coastlines, and tree branches. Fractal analysis has been used to understand the complexity of natural systems and has applications in fields ranging from ecology to medicine.

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- Fibonacci Sequence and the Golden Ratio

The Fibonacci sequence and the associated golden ratio are mathematical concepts frequently occurring in nature. They can be observed in the arrangement of leaves on a stem, the pattern of seeds in a sunflower, and the spiral shells of mollusks. Understanding these patterns helps students appreciate the mathematical order underlying natural forms.

- Symmetry and Tessellations

Symmetry is a common feature in natural organisms, contributing to their structural stability and aesthetic appeal. Tessellations, or tiling patterns, are also found in nature, such as in the honeycomb structures of beehives. Studying these patterns allows students to explore concepts of balance and repetition in design.

- Applications in Biophilic Design

Incorporating natural geometric patterns into urban design can enhance inhabitants' aesthetic and psychological well-being. For example, fractal patterns in architectural elements can reduce stress and improve cognitive function. Understanding and applying these mathematical principles enable students to create designs that resonate with natural forms and promote sustainability.

- Sustainable materials and design thinking (Technology)

What Are Sustainable Materials?

Sustainable materials are eco-friendly. They either grow back quickly, are recyclable, or use less energy to produce. When used in biophilic design, these materials also support health and well-being.

Here are some exciting examples being explored and used today:

- Bamboo, cork, and hempcrete are plant-based materials that grow quickly and naturally absorb carbon dioxide. They require less processing than traditional materials like concrete or plastic. These bio-based materials can reduce the carbon footprint of buildings significantly (Mnasri et al., 2021).
- Mycelium is the root structure of mushrooms. It can be grown into building blocks or panels. This material is lightweight, fully compostable, and doesn't need chemical processing. It's often used in green architecture (Alaneme & Anaele, 2023).
- Bioconcrete is a special kind of concrete that heals its cracks using bacteria. These bacteria produce a natural substance that seals the crack when moisture enters. This

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innovation reduces maintenance needs and extends the life of buildings (Aytekin et al., 2024).
- Low-emissivity (Low-E) glass reflects heat but lets in natural light. This glass helps reduce energy use for heating and cooling while still providing access to daylight, which is vital in biophilic spaces (Elverici, 2024).

Using these materials makes cities more sustainable and supports biophilic design's biggest goal: improving our connection to nature while protecting the environment.

What Is Design Thinking?

Design thinking is a creative process that helps people devise solutions to complex problems. It's not just about making things look good; it's about meeting real needs in smart, effective ways.

It includes five steps:

1. Empathize – Understand what people need.
2. Define – Identify the core problem.
3. Ideate – Brainstorm creative solutions.
4. Prototype – Build a model or test version.
5. Test – Try it out and improve based on feedback.

In biophilic design, you might use design thinking to create:

- A park bench made from local wood and mycelium foam.
- A school courtyard with natural light, trees, and seating shaped like leaves.
- A small rooftop greenhouse that collects rainwater.

Research shows that using design thinking in sustainability projects helps people collaborate better and create real-world solutions. It's already being used to tackle significant challenges like climate change, green transportation, and eco-friendly housing (Leal Filho et al., 2024).

2. Execute — Applying Biophilic Design in Practice and Prototyping with AR

Introduction:

To move from understanding biophilic design to applying it, learners must explore how nature-based strategies can be translated into real-world urban spaces. Biophilic design is not just a set of ideas; it is a design approach that requires thoughtful integration of environmental systems, materials, and technologies into the urban fabric.

This part of the training unit takes a hands-on, creative, and digital turn. Learners are encouraged to think like planners, architects, and urban ecologists by proposing new ideas that embody biophilic principles. At the same time, digital tools such as Augmented Reality (AR) are introduced as supportive platforms that allow learners to visualize and prototype their designs.

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AR provides an interactive layer to the learning experience, bridging conceptual thinking and spatial planning while encouraging experimentation in a virtual environment. Recent studies confirm that AR tools enhance learners' spatial awareness and design thinking when engaging in sustainability and STEM projects (Wu et al., 2020; Bower et al., 2017).

This section fosters technical and creative growth by combining case-based analysis, design prototyping, and AR-driven modeling. It helps bridge the gap between theoretical knowledge and practical application, a crucial step in empowering young learners to envision cities that are greener, healthier, and more human-centered.

Design Thinking Challenge: Rethinking Urban Spaces with Biophilic Principles

The creative application of biophilic principles begins with the ability to observe, critique, and improve spaces through a problem-solving lens. Design thinking, a structured, human-centered methodology, offers a robust framework for this task. Widely used in education, engineering, and architecture, design thinking fosters innovation through empathy, ideation, prototyping, and iteration. Sustainability and built environments encourage learners to address complex challenges by combining ecological knowledge with creative exploration (Leal Filho et al., 2024).

This activity guides learners through a design thinking cycle as they reimagine an existing urban space, whether in their local environment or a fictional context. The process begins with a critical assessment of the site's current limitations. These may include heat exposure, poor ventilation, lack of vegetation, impermeable surfaces, or low biodiversity. Drawing from this assessment, learners define a set of needs or design challenges that reflect environmental and human priorities.

The ideation phase introduces biophilic solutions: strategies that draw inspiration from nature to solve problems such as overheating, poor air quality, or social isolation. Drawing on principles outlined in *14 Patterns of Biophilic Design*(Browning et al., 2014), learners are encouraged to consider direct and indirect connections to nature, including greenery, water features, material selection, and spatial configurations promoting a sense of refuge or prospect. Solutions may involve introducing shaded gathering spaces with tree canopies, integrating green walls to improve air quality and thermal comfort, or incorporating water channels to absorb and manage rainwater.

As part of their creative output, learners develop a conceptual plan for the redesigned space, focusing on daylight access, natural airflow, biodiversity corridors, and sensory interaction with organic materials. These ideas are informed by biophilic principles and STEM-related analysis, for example, applying geometry to optimize layout, biology to select appropriate plant species, and physics to plan passive ventilation strategies.

To further guide this process, the Global Wellness Institute (2018) provides a practical framework on how biophilic design can improve community well-being through access to nature, enhanced mobility, and sensory diversity. These guidelines encourage designers to think

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holistically, seeing urban spaces not just as physical infrastructure but as places for health, emotional connection, and environmental resilience.

Ultimately, this challenge cultivates an understanding of biophilic design as a scientific and human-centered endeavor, one that requires technical reasoning, empathy, and creativity to solve real-world urban issues.

AR Prototyping: Visualizing Nature-Inspired Urban Futures

After developing a redesign concept through the design thinking process, learners move on to prototyping their ideas using Augmented Reality. AR offers an exciting opportunity to bring biophilic visions to life, enabling learners to place natural features within a digital replica of the selected urban space. This stage reinforces spatial reasoning and allows deeper engagement with previously conceptualized design elements.

Using platforms such as CoSpaces Edu or Assemblr EDU, learners create interactive 3D visualizations that include key biophilic components. These might consist of tree-lined promenades, rooftop gardens, reflective water basins, naturally ventilated corridors, or leaf-patterned canopies inspired by fractal geometry. The goal is to model the redesigned space with precise attention to environmental performance and user experience.

Recent studies show that AR can significantly support environmental education and creativity, especially when learners design with sustainability goals (Wu et al., 2020). In this exercise, learners are encouraged to annotate their designs, describing the function of each biophilic feature, the STEM principle it reflects, and the expected benefit for human and ecological health.

Beyond digital modeling, the AR prototypes can be used for presentation and peer review, where learners explain and defend their design decisions. This reflective phase adds a layer of critical thinking and communication skills, reinforcing design literacy and environmental awareness.

School-Based Projects in Biophilic Design: Learning Through Experience in Secondary Education

Introducing biophilic design to secondary school learners presents a powerful educational opportunity to connect theoretical knowledge with real-world ecological challenges. In recent years, several high schools across Europe have implemented biophilic-oriented projects that engage students in reimagining built environments through nature-based thinking. These initiatives foster ecological awareness, promote well-being, and support interdisciplinary learning that spans biology, environmental science, design, and architecture.

Although not always labeled under *biophilic design*, many of these projects explicitly address core biophilic principles, such as enhancing sensory contact with natural elements, improving air

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quality, and designing outdoor learning environments. Through such activities, students aged 14–18 gain hands-on experience in rethinking urban and educational spaces, often producing models, drawings, or sustainability proposals grounded in their observations of and interactions with nature.

- Selected Project Example from Secondary Schools

Putney High School, part of the Girls' Day School Trust in London, launched an innovative biophilic classroom pilot project in 2021 to study how natural elements in learning environments affect student well-being, focus, and cognitive engagement. The project was tailored for older students in Key Stages 4 and 5 (ages 14–18) and developed in partnership with researchers from Oxford Brookes University and Studio P Architects.

The redesigned classroom incorporated multiple elements derived from the *14 Patterns of Biophilic Design* (Browning et al., 2014), including:

- Natural materials and textures: Timber panels, wool textiles, and raw finishes reduced sensory fatigue and created a calming visual aesthetic.
- Plants and greenery: Indoor plants were integrated not only to create a visual connection to nature but also to improve air quality and offer micro-restorative effects.
- Dynamic lighting: LED systems were tuned to mimic circadian rhythms, supporting attention and mood regulation during various parts of the school day.
- Acoustic design: Sound-absorbing materials and quiet zones were included to limit overstimulation and create areas of cognitive refuge.

Teachers and students who used the classroom reported improved concentration, reduced stress, and a more enjoyable learning atmosphere. In addition to passive exposure to natural elements, students evaluated the classroom's impact, learning to reflect critically on how environmental design affects health and performance.

"The feedback we received from students using the space was overwhelmingly positive," said Suzie Longstaff, Head of Putney High. "They felt more relaxed, engaged, and connected to their learning."

- Reflections and Opportunities for AR Integration

While the Putney project is a leading example of biophilic learning environments at the secondary level, it remains focused on physical environmental design. Future iterations of such projects could greatly benefit from incorporating Augmented Reality (AR) to enhance imagination and interactivity.

AR could allow students to:

- Visualize different biophilic layouts before physically redesigning a space.
- Overlay data such as sunlight direction, airflow, or sound levels in real time.
- Prototype new features like green walls, water elements, or eco-furniture virtually.

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- Participate in collaborative urban design projects by simulating biophilic zones in schoolyards, rooftops, or public areas.

This kind of integration would empower students to not only experience biophilic environments but also create and share them digitally, using STEM skills in meaningful, applied ways.

The Biophilic Classroom Project at Putney High School is a successful example of how secondary learners can benefit from immersive, nature-connected environments. As awareness grows about the relationship between environment, learning, and well-being, this model offers a valuable reference for other schools seeking to incorporate biophilic thinking.

By combining such initiatives with digital design and AR prototyping tools, future school-based projects could become even more engaging, personalized, and reflective of 21st-century learning goals, where sustainability, creativity, and technology come together.

3. ENHANCE – Mastering Tools and Concepts

While the earlier sections introduced the foundations of biophilic design and gave learners the opportunity to explore and create nature-integrated spaces, this final section focuses on how Augmented Reality (AR) can enhance learning, deepen spatial understanding, and communicate biophilic ideas more effectively.

In secondary education, particularly in STEM-based learning, AR has emerged as a powerful tool to bridge abstract environmental concepts with concrete spatial experience. As research by Wu et al. (2020) and Tang et al. (2022) shows, AR increases engagement, supports complex spatial reasoning, and enhances students' ability to design and analyze 3D environments. These qualities make it particularly well-suited for visualizing biophilic elements in urban contexts, where layout, environmental flow, and materiality play key roles.

Through AR, digital devices allow learners to place nature-inspired features such as trees, shade structures, or water elements into real-world surroundings. This helps them imagine greener cities and simulate and evaluate their own ideas, reinforcing the connection between environmental thinking and digital creativity.

Below is a curated list of AR tools that support the exploration and communication of biophilic principles by students aged 14–18. Each tool offers different affordances—from simple drag-and-drop interfaces to more complex, simulation-based design platforms.

Recommended AR Tools for Biophilic Design and STEM Learning

1. CoSpaces Edu

Platform: Browser-based, with apps for iOS and Android
Best for: Creating interactive AR/VR 3D scenes, coding integration, design storytelling

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Why it's useful:
CoSpaces Edu allows students to build immersive environments and bring them into the real world via AR. It supports logic-based coding and physics simulations, making it a rich tool for STEM integration. Students can model biophilic features like green corridors, shade-providing structures, or open-air classrooms, and then walk through their designs in mixed reality.

Educational impact:
Bower et al. (2017) highlighted CoSpaces Edu as one of the leading tools for enhancing creative and spatial competencies in middle and secondary school learners. It supports engagement with sustainability topics through exploration and presentation.

Website: https://cospaces.io

2. Assemblr EDU

Platform: Web-based, iOS, Android
Best for: Quick prototyping, visual design presentations, collaborative learning
Why it's useful:
Assemblr EDU allows students to create 3D content using a library of pre-built models or their own uploads. It's intuitive and user-friendly, even for learners new to AR. Students can create and position biophilic elements in school courtyards, local parks, or urban streetscapes.

Educational impact:
Studies like Tang et al. (2022) show how AR-based design activities help learners translate environmental theory into visually and spatially rich expressions, fostering environmental awareness through immersive digital engagement.

Website: https://www.assemblrworld.com

3. Reality Composer (Apple)

Platform: iOS and macOS
Best for: High-precision spatial design, layering AR objects in real environments
Why it's useful:
Reality Composer is part of Apple's developer suite and allows learners to anchor AR objects into real environments, manipulate them using sensors, and simulate their interaction with space and light. It's best suited for advanced secondary learners interested in architectural detail.

Educational impact:
This tool supports understanding of form, proportion, and interaction between elements—critical skills in both architectural design and environmental simulation (Wu et al., 2020).

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Website: https://developer.apple.com/reality-composer/

4. SketchAR

Platform: iOS, Android
Best for: Concept sketching in AR, freeform visual experimentation
Why it's useful:
SketchAR blends drawing and AR, making it ideal for students who want to hand-sketch their ideas directly into physical space. This tool supports organic exploration of biomorphic forms such as curved walls, tree-inspired structures, or landscape features.

Website: https://sketchar.io

Conclusion and Learning Integration

Integrating AR into biophilic design education enables learners to become active agents in imagining healthier urban environments. It aligns with the goals of STEM by combining observation, experimentation, and technical design, while also engaging creativity, collaboration, and sustainability literacy.

By the end of this section, learners should be able to:

- Identify and compare key AR tools for design purposes.
- Use at least one AR app to visualize a biophilic urban element.
- Reflect on how the use of AR deepens their understanding of space, nature, and human interaction with the built environment.

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• Phase	Description
Explore	- Introduction to Biophilic Concepts: Introduce learners to the science and purpose of biophilic design in urban environments. - STEM Contextualization: Identify biological, physical, mathematical, and technological principles relevant to nature-based urban design. - Environmental Observation: Guide learners in observing and documenting natural patterns in local or school-based urban settings. - Conceptual Research: Explore global examples of biophilic cities and urban nature integration (e.g., Singapore's green corridors, Milan's vertical forests). - Needs Analysis: Determine gaps in existing learning spaces and students' understanding of sustainable urban systems.
Execute	- Design Thinking in Practice: Facilitate student-led urban space redesign challenges using biophilic strategies aligned with STEM principles. - Interactive Prototyping: Engage students in developing site-specific or conceptual biophilic urban interventions (e.g., green roofs, rain gardens, nature corridors). - AR Prototyping: Students visualize their redesigned spaces using AR tools such as CoSpaces Edu or Assemblr EDU, simulating natural light, airflow, and organic forms. - Collaborative Projects: Encourage teamwork in creating digital biophilic environments that reflect ecosystem services and human well-being. - Feedback and Peer Reflection: Students present their projects, receive peer review, and reflect on how nature and technology can shape healthier cities.
Enhance	- AR Skill Building: Deepen understanding of AR tools and spatial visualization for urban design. - Application to Biophilic Concepts: Use AR to explore how design elements like green facades, light corridors, or tree canopies function in real spaces. - AR-Based Storytelling: Students narrate their biophilic projects using AR annotations, demonstrating the STEM logic behind their design choices. - Gamified Learning Experiences: • Earn points and badges by identifying or placing biophilic elements (e.g., native trees, natural materials). • Progress through design "quests" simulating urban challenges (e.g., managing shade or water runoff). • Work in teams on "green city" simulations and compete to design the most sustainable space. - AR-Based Assessment: Assess design comprehension through AR interactions (e.g., place-based challenges or scenario responses), measuring both spatial reasoning and application of STEM knowledge.

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Resources:

Absolutely Education. (2022). Biophilic Classroom Pilot – Putney High School. https://absolutely-education.co.uk/biophilic-design-in-schools/

Alaneme, K. K., & Anaele, J. U. (2023). Mycelium based composites: A review of their bio-fabrication procedures, material properties and potential for green building and construction applications. Alexandria Engineering Journal, 83(2), 234–250. https://doi.org/10.1016/j.aej.2023.10.012

Al Sayyed, H., & Al-Azhari, W. (2025). Investigating the role of biophilic design to enhance comfort in residential spaces: human physiological response in immersive virtual environment. Frontiers in Virtual Reality, 6, 1411425

Aytekin, A., et al. (2024). Advances in microbial self-healing concrete: A critical review of mechanisms, developments, and future directions. Science of The Total Environment, 905, 167504. https://doi.org/10.1016/j.scitotenv.2023.167504

Beatley, T. (2011). Biophilic Cities: Integrating Nature into Urban Design and Planning. Island Press.

Beatley, T. (2017). 'Handbook of biophilic city planning and design'. Washington, DC: Island Press/Center for Resource Economics. doi: 10.5822/978-1-61091-621-9.

Bewza, A. (2012). 'Linking boundaries: the adaptable notion of home, ProQuest Dissertations and Theses.' University of Manitoba (Canada). Available at: http://libresources.sait.ab.ca/login?url=https://search.proquest.com/docview/1314574108?accountid=13652 .

Browning, W. D., Ryan, C. O., & Clancy, J. O. (2014). 14 Patterns of Biophilic Design: Improving Health and Well-being in the Built Environment. Terrapin Bright Green. https://www.terrapinbrightgreen.com/reports/14-patterns

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2017). Augmented Reality in education – cases, places and potentials. Educational Media International, 54(1), 1–15. https://doi.org/10.1080/09523987.2017.1404355

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Elverici, G. (2024). Low-emissivity glass is revolutionizing building efficiency. Here's how. World Economic Forum. https://www.weforum.org/stories/2024/06/low-emissivity-glass-revolutionizing-building-efficiency/

Global Wellness Institute. (2018). Build Well to Live Well: Biophilic Design Guidelines. https://globalwellnessinstitute.org/wp-content/uploads/2018/12/biophilicdesignguide-en.pdf

Gray, T. and Birrell, C. (2014). 'Are biophilic-designed site office buildings linked to health benefits and high performing occupants?', International Journal of Environmental Research and Public Health, 11(12), pp. 12204–12222. doi: 10.3390/ijerph111212204.

Jamei, E., Rajagopalan, P., Seyedmahmoudian, M., & Jamei, Y. (2016). Review on the impact of urban geometry and greenery on outdoor thermal comfort. Renewable and Sustainable Energy Reviews, 54, 1002–1017. https://doi.org/10.1016/j.rser.2015.10.104

Kaplan, R., & Kaplan, S. (1989). The Experience of Nature: A Psychological Perspective. Cambridge University Press.

Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (2008). Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. Wiley.

Kellert, S. R. and Calabrese, E. F. (2015). 'The practice of biophilic design', Biophilic-Design.Com, pp. 1–20. doi: 10.1063/1.1387590.

Leal Filho, W., Salvia, A. L., Lazzarini, B., & Will, M. (2024). Design thinking for sustainable development: A bibliometric analysis and case study research. Journal of Cleaner Production, 455, 142285. https://doi.org/10.1016/j.jclepro.2024.142285.

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. Landscape and Urban Planning, 148, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015

Mangone, G. et al. (2017). 'Bringing nature to work: Preferences and perceptions of constructed indoor and natural outdoor workspaces', Urban Forestry & Urban Greening, 23, pp. 1–12. doi: 10.1016/j.ufug.2017.02.009

Mnasri, S., et al. (2021). Biobased building materials for sustainable future: An overview. Case Studies in Construction Materials, 15, e00679. https://doi.org/10.1016/j.cscm.2021.e00679

Orman, P. (2017). 'Understanding the biophilia hypothesis through a comparative analysis of residential typologies in Phoenix, São Paulo, and Tokyo', ProQuest Dissertations and Theses. Arizona State University. Available at:

Project Number: KA220-BW-23-30-126516

http://libresources.sait.ab.ca/login?url=https://search.proquest.com/docview/1965514378?accountid=13652

Senthil. M, Jayalakshmi. S. (2025). Biophilic Architecture: Integrating Nature into Architecture for Sustainable Living and Enhanced Well-Being. IJRPR, DOI: https://doi.org/10.55248/gengpi.6.0325.1237.

Spivack, A. J., Askay, D. A. and Rogelberg, S. G. (2010). 'Contemporary physical workspaces: A review of current research, trends, and implications for future environmental psychology inquiry', in Environmental Psychology: New Developments, pp. 37–62. Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84895332762&partnerID=40&md5=fac398af48d1741786ee330bdf164ca6 .

Szewrański S, Mrówczyńska MM, Hoof J van. Biophilia in contemporary design: Navigating future opportunities and challenges. Indoor and Built Environment. 2024;34(1):3-6. doi:10.1177/1420326X241262626.

Tang, J., Fan, X., & Deng, Y. (2022). Augmented reality and environmental awareness: Exploring immersive approaches in sustainability education. International Journal of Environmental and Science Education, 17(4), 55–72.

Terrapin Bright Green. (2012). The Economics of Biophilia.

UCEM – University College of Estate Management. (2022). Biophilia: Examples in the Built Environment. https://www.ucem.ac.uk/whats-happening/articles/biophilia-examples-built-environment/

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. Science, 224(4647), 420–421. https://doi.org/10.1126/science.6143402

Ulrich, R. S. (1991). Effects of interior design on wellness: Theory and recent scientific research. Journal of Health Care Interior Design.

Vagal. R. (2020), Theory of Biophilic Design, Mohawk Group.

Van den Berg, A. E., Koole, S. L., & Van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? Journal of Environmental Psychology, 23(2), 135–146.

Wilson, E. O. (1984). Biophilia. Harvard University Press.

Wijesooriya, M., et al. (2023). Biophilic design frameworks: A review of structure, development techniques, and their compatibility with LEED sustainable design criteria. Journal of Green Building, 18(1), 45-60.

Project Number: KA220-BW-23-30-126516

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2020). Current status, opportunities and challenges of augmented reality in education. Computers & Education, 62, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024

Project Number: KA220-BW-23-30-126516

Co-funded by
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BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
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