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Biophilic Design in Theory and Practice: Human Well-Being and Sustainable Development Across Building Typologies

Maha A. Alsarhan[1], Khawola F. Mahmoud[2]

Abstract

This study reviews how biophilic design strategies, rooted in the human affinity for nature, enhance well-being and support sustainable development through improved spatial quality and user comfort. Through a systematic review of interdisciplinary literature in architecture, environmental psychology, and urban planning, it examines five major building typologies: educational, healthcare, residential, hospitality, and commercial. The findings show consistent psychological and physiological benefits across all contexts, with natural light, vegetation, water, and ventilation linked to stress reduction, mood improvement, and better environmental perception. Each typology demonstrates distinct outcomes, including cognitive and attentional gains in educational settings, faster recovery in healthcare, and experiential or economic benefits in commercial and hospitality environments, while residential buildings show greater comfort and emotional well-being. Cultural, climatic, and economic factors, along with varied research methods, influence both effectiveness and comparability. The study emphasizes the need for standardized evaluation, integration of physiological and environmental metrics, and context-sensitive strategies. Overall, it presents biophilic design as a practical and evidence-based approach for creating healthy, resilient, and sustainable built environments.

Keywords: *Biophilic Design, Human Well-Being, Sustainable Architecture, Building Typologies, Environmental Psychology.*

Introduction

Biophilia, originally rooted in philosophy and psychology, has increasingly influenced the design of man-made environments in recent decades. Biophilic architecture represents an innovative approach that benefits people and the environment by promoting health, enhancing well-being, and improving quality of life [1]. Numerous studies have demonstrated that direct or indirect experiences with nature offer significant benefits for human health and well-being, including stress reduction, increased productivity, and improved mood [2].

This innate human affinity for the natural world is referred to as “biophilia”. Biophilia is strongly linked to human health and well-being are influenced by the quality of interior environments where people live, work, and interact [3, 4]. However, the modern lifestyle has created a noticeable gap between humans and nature, resulting in negative impacts on health, performance, and overall quality of life. Integrating biophilic principles into interior design is considered an effective strategy to bridge this gap and restore human–nature connections. Furthermore, the level of biophilic elements incorporated into built environments can be adapted according to specific health and well-being needs [5].

Biophilic design has a wide range of applications across different architectural domains, including residential, commercial, and institutional buildings. It is associated with multiple health benefits that can address various environmental and social challenges specific to a given region or territory [6]. As an essential component of contemporary architecture, biophilic design is closely connected to human health, ecology, and sustainability [7]. In modern societies, the growing physical and psychological need to reconnect with nature has been recognized as part of cultural heritage and human identity. One of

[1] Department of Architectural Engineering, College of Engineering, University of Mosul, Mosul 41002, Iraq, Email: maha.23enp97@student.uomosul.edu.iq, (Corresponding Author)
[2] Department of Architectural Engineering, College of Engineering, University of Mosul, Mosul 41002, Iraq

the central objectives of biophilic architecture is to restore the human–nature relationship by addressing the disconnection caused by urbanization and modern lifestyles [3]. Biophilic design seeks not only to create physical connections with nature but also to foster mental and emotional bonds between humans and their natural environment. Ultimately, this design philosophy aims to bridge the gap between modern architectural practices and the fundamental human need to engage with the natural world [8].

Contemporary cities face high stress, mental health issues, crime, and illness, while the built environment suffers from urban heat island effects and pollution. Biophilic design is a key approach in sustainable architecture, integrating natural systems into buildings to enhance human well-being and ecological sustainability. By embedding natural elements in urban structures, it creates spaces that are ecologically responsible and psychologically supportive [9].

Biophilic design applies to residential, commercial, and institutional buildings and is recognized as a culturally responsive, health-oriented strategy. It combines environmental and regional aspects, offering physical, psychological, social, ecological, and economic benefits. However, research remains fragmented, with few systematic reviews on its use in different building types. This study aims to review biophilic design strategies and examine their role in enhancing human well-being and promoting sustainable development through improved spatial quality and user comfort in the built environment.

Biophilic Design: Concepts, Dimensions, and Impacts

Concept and Foundations of Biophilic Design

Biophilia was first described by Erich Fromm (1973) as a human psychological orientation attracted to all that is alive and vital [10, 11, 12]. It is defined as the love of life and living systems. Wilson and Kellert later introduced the Biophilia Hypothesis, which proposes that human dependence on nature goes beyond physical needs to include aesthetic, intellectual, cognitive, and spiritual satisfaction [13]. Stephen R. Kellert and colleagues expanded this concept by coining the term “biophilic design,” emphasizing the connection between humans and nature within the built environment [14].

Biophilic design represents the practical application of the biophilia hypothesis, integrating natural elements into architecture to support human physiological and psychological health, well-being, and sustainability. Its key principles include: (1) ongoing engagement with nature, (2) adaptations that enhance health and well-being, (3) emotional attachment to place, (4) positive human–nature interactions that foster environmental responsibility, and (5) integrated and reinforcing architectural solutions [3, 5, 15]. These principles integrate nature into architecture to enhance physical health, mental well-being, and community resilience. Rooted in the concept of “biophilia,” or the innate human affinity for nature, biophilic design applies these principles intentionally in the built environment, fostering human–nature connections and creating sustainable, healthy, and emotionally fulfilling spaces.

Overall, “Biophilia” refers to the innate human response to enjoy and respond well to nature and benefit from natural elements, which can be shown using Physiological Responses, Psychological Outcomes, and Behavioral Tendencies. Indicators. Building on this intrinsic human affinity for the natural world, “Biophilic design” is an intentional, evidence-driven methodology in architecture and interior design that incorporates elements of nature into built environments that help humans bond with nature, which leads to enhancing overall health, well-being, and sustainability.

Dimensions and Typologies of Biophilic Design

Biophilic design connects people to nature by integrating theoretical dimensions with tangible design elements. This section categorizes these dimensions into two main types: organic (naturalistic) and place-based (vernacular), and identifies six core typologies, each defined by measurable attributes. This framework supports the planning and evaluation of spaces that foster human–nature connections while promoting well-being and sustainability.

Complementing these are the experiential dimensions of Direct and Indirect Experience. Direct Experience includes environmental features present in the built environment, while Indirect Experience involves symbolic representations of nature [16]. In addition, the Space and Place dimension focuses on designing environments that reflect cultural, historical, or environmental contexts, supporting human health and well-being [17]. The framework identifies three experiential domains comprising 24 specific attributes, as shown in Figure 1.

The organic or naturalistic dimension includes forms and shapes in the built environment that directly, indirectly, or symbolically reflect humans’ innate attraction to nature. In contrast, the vernacular

dimension refers to design that reflects the culture and ecology of a specific locality or geographic region [18, 19]. These dimensions manifest through six core elements, each supporting direct, indirect, or spatial experiences of nature, as shown in Table 1.

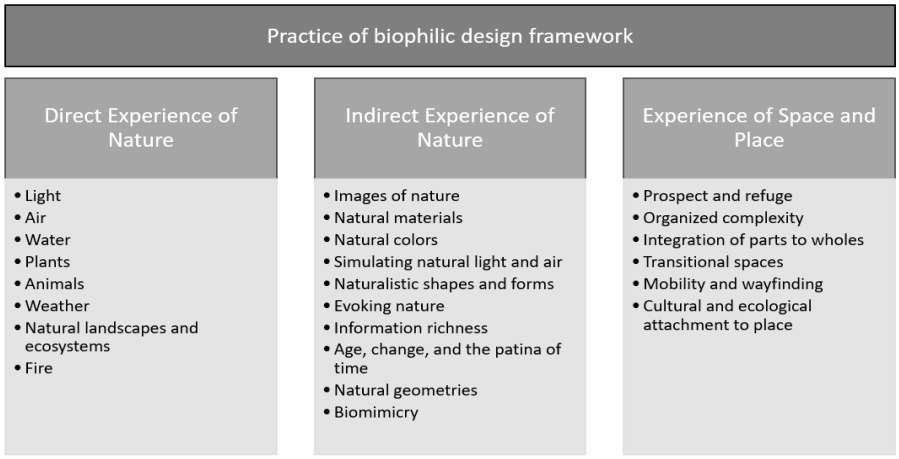

Fig. 1. Practice of the biophilic design framework based on Kellert and Calabrese (2015) [7].

Table 1. Integrated Framework of Biophilic Dimensions and Experiential Elements based on [1, 16, 20] (by author).

Dimensions	Biophilic Element	Description	Key Attributes	Biophilic Experience
Organic / Naturalistic	**1. Environmental Features**	Incorporating tangible natural components into the built environment.	Color-Water-Air, Sunlight-Plants-animal-Natural material-Views and Vistas-Façade Greening-Geology and Landscape-Habitats and ecosystems	**Direct Experience**
	2. Natural Forms and Shapes	Use of biomorphic and organic shapes and patterns.	Botanical Motifs-Tree and columnar supports Animal (mainly vertebrate) Motifs-Shells and Spirals-Egg, oval, and tubular forms Arches, vaults, domes-Shapes resisting straight lines and right angles-Simulation of natural features-Biomorphy-Geomorphology-Biomimicry	**Indirect Experience**
	3. Natural Patterns and Processes	Emulating natural rhythms, growth patterns, and textures.	Sensory Variability-Information Richness Age, change, and the patina of Time-Growth and Efflorescence-Central Focal Point-	**Indirect Experience**

			Patterned Wholes- Bounded Spaces- Transitional Spaces- Linked series and chains- Integration of parts to wholes- Complementary Contrasts- Dynamic balance & tension- Fractals- Hierarchically organized ratios and scales	
	4. Light and Space	Natural and dynamic lighting and spatial configurations.	Natural Light- Filtered and diffused light Light and Shadow- Reflected Light-Light Pools Warm light- Light as shape and form	**Direct Experience**
			Spaciousness, Spatial variability - Space as shape and form - Spatial harmony - Inside-outside spaces	**Experience of Space**
Place-Based / Vernacular	**5. Place-Based Relationships**	Design rooted in local culture, climate, and ecology.	Geographic connection to place - Historic connection to place - Ecological connection to place - Cultural connection to place - Indigenous materials - Landscape orientation Landscape features that	**Experience of Space and Place**

			define building form -Landscape ecology - Integration of culture and ecology - Spirit of place - Avoiding placelessness	
	6. Evolved Human–Nature Relationships	Designing for emotional and psychological responses to nature.	Prospect and refuge - Order and complexity - Curiosity and enticement - Change and metamorphosis - Security and protection - Mastery and control – Affecti/on and attachment - Attraction and beauty - Exploration and discovery - Information and cognition Fear and awe - Reverence and spirituality	**Experience of Space and Place**

Biophilic Design and Human Well-being

Biophilic design integrates natural elements into built environments to enhance human well-being [21]. Rooted in biophilia, the innate human connection to nature, it improves aesthetics while supporting physical and mental health [15, 22]. Incorporating greenery, natural light, and nature views has been shown to boost emotional and sensory experiences, even through simple features like indoor plants or natural imagery [14].

Applied in healthcare, workplaces, classrooms, and homes, biophilic design fosters human–nature interaction that reduces stress and enhances cognitive and psychological health. Exposure to daylight, greenery, and natural soundscapes promotes satisfaction, productivity, and emotional resilience, ultimately supporting overall well-being and performance [2].

Biophilic Design as a Strategy for Sustainable Architecture

Sustainable architecture and biophilic design are complementary: sustainable strategies reduce environmental and economic impacts [14, 23], while biophilic approaches restore the human–nature connection often lost in modern buildings [24, 25]. Together, they reduce resource consumption and enhance human well-being, addressing the building sector's significant energy use and emissions [26]. Biophilic design supports sustainability while improving physical and emotional satisfaction, transforming buildings into spaces that foster health, resilience, and ecological responsibility [10, 27]. Table 2 compares sustainable design, which emphasizes environmental performance, with biophilic design, which focuses on human–nature interactions and experiential quality. Biophilic interventions,

including natural light, greenery, soundscapes, and local materials [10, 12], enhance psychological resilience, productivity, and satisfaction [5]. The "14 Patterns of Biophilic Design" have been aligned with the United Nations SDGs to maximize benefits while minimizing resource use [28].

Evidence shows that incorporating nature into urban and workplace design improves productivity, reduces health issues, and mitigates urban heat islands, with green office spaces outperforming conventional designs in user satisfaction and efficiency. Figure 2 illustrates how human–nature interactions combined with environmental performance metrics can generate measurable economic benefits [29].

Overall, the literature shows that biophilic design links human well-being with environmental stewardship, providing a framework to address contemporary challenges in the built environment. Evidence consistently associates nature-integrated spaces with improvements in psychological health, cognitive performance, and social connectedness, as well as reductions in resource use and ecological impact. These findings support the methodological approach of this study, which examines how biophilic principles are implemented across different architectural typologies.

Table 2. Difference between sustainable design and Biophilic Design (by author).

Biophilic design provides several strategies for promoting sustainability in construction.		
Aspect	**Sustainable Design**	**Biophilic Design**
Primary Focus	conserving energy and leaving a small footprint on the earth	Enhancing human-nature connection and well-being
Key Strategies	Passive design techniques, material efficiency, resource conservation	Integration of natural elements (light, air, water, greenery) into built environments
Benefits	• Focuses on reducing the consumption of resources	• Improved occupant health and productivity • Emotional and psychological well-being
Design Approach	Design approaches physical and material-oriented to the natural processes required by people.	Emotionally and psychologically oriented
Sustainability Contribution	Indirectly supports human comfort through environmental performance	Directly supports sustainability by fostering affinity for nature and ecological awareness

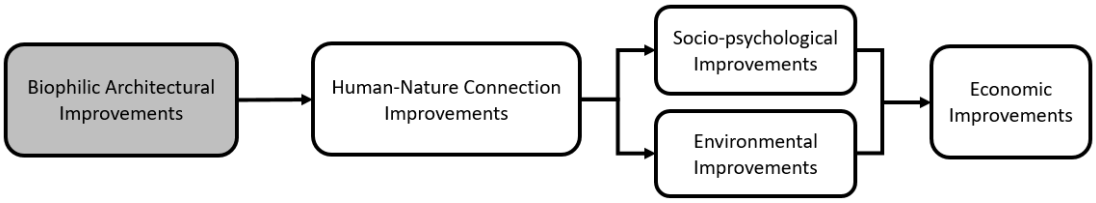

Figure 2. Biophilic architectural benefit flow [29].

Methodology

This research used a systematic literature review to explore biophilic design and its impact on human well-being and environmental sustainability. The process ensured transparency, replicability, and alignment with the study's goal of assessing how biophilic design supports human-centered and sustainable interior architecture. Relevant studies were collected from Scopus, Web of Science, PubMed, and Google Scholar using keywords such as "biophilia," "biophilic design," "architecture and health," "sustainable architecture," and "human well-being."

The review focused on peer-reviewed articles, conference papers, books, and reports published between 2000 and 2025, emphasizing urban and architectural contexts. Studies on biophilic design in educational, healthcare, residential, hospitality, and commercial settings were prioritized. Inclusion criteria required clear methodologies and measurable supported outcomes, while exclusion criteria removed works lacking rigor or using non-comparable metrics. The process included abstract screening and full-text evaluation to confirm relevance and research quality.

Data were systematically extracted on biophilic design applications, health outcomes, sustainability impacts, and best practices. A thematic analysis was conducted to identify recurring themes, significant findings, and knowledge gaps. Sources emphasizing the human experience in

interior environments were prioritized to align with the study's focus on interior architecture. Key themes were manually coded based on their relevance to biophilic design principles, psychological and physiological outcomes, and contributions to sustainable architectural strategies. This interpretive synthesis integrated theoretical foundations with applied design practices, ensuring a rigorous and transparent review process aligned with the study's aim to advance evidence-based biophilic design in interior architectural settings.

Case Study Analysis: Applications of Biophilic Design in Building Typologies

This section reviews evidence from various building types showing that biophilic elements consistently reduce stress, enhance cognition, aid recovery, and provide economic benefits, despite implementation challenges [1]. Natural features such as daylight, vegetation, water, and plant-based materials improve emotional well-being, physical health, and social connections while supporting sustainability [2, 5, 9].

In educational, commercial, hospitality, office, and healthcare settings, biophilic design improves focus, satisfaction, and recovery. It fosters learning, productivity, and relaxation, demonstrating its broad value for human well-being across environments [3,25, 30, 31].

The study integrates various research findings to present an overview of current practices and emerging trends. By combining empirical evidence and theoretical insights across educational, commercial, hospitality, healthcare, workspace, and residential buildings, it highlights how biophilic strategies enhance diverse environments and bridge the gap between modern architecture and environmental stewardship. Overall, these findings offer a foundation for developing policies and design approaches that promote human well-being and sustainability in urban contexts.

Biophilic design in Education buildings

Biophilic architecture enhances productivity and well-being in educational settings by reducing stress and creating environments that support learning and personal growth [15]. Since education has notable environmental impacts, effective facility planning is vital [28]. Integrating biophilic elements in schools promotes social-emotional learning, boosts memory and attention, and reduces cognitive fatigue. Natural views, daylight, and indoor greenery help alleviate stress and improve academic performance [31]. Table 3 highlights challenges in standardizing evaluations and balancing safety with natural elements.

Mustafa and Yaseen (2019) [32] evaluated 14 biophilic features under "Nature in the Space," "Natural Analogues," and "Nature of the Space." Designs prioritizing natural light, open views, and fresh air achieved the highest connection scores, with 95% for thermal and airflow comfort. Even without water features, the framework showed that partial biophilic integration reduces stress and supports cognitive and psychological health, offering a replicable model for contexts like Erbil. Similarly, Ghaziani et al. (2021) [3] found that biophilic design in primary schools improved test scores by 14.4% through better ventilation and 7% through outdoor access, supported by emotional benefits from natural light, cross ventilation, and natural materials.

Nevzati et al. (2021) [33] found that interior water features in educational spaces reduced stress, with females benefiting more; over 70% of participants reported lower stress and 74% improved mood. Mehta and Mahamood (2022) showed that daylight, plants, varied lighting, and natural ventilation in transitional areas reduced stress for 86% of users and improved attention for most, as students preferred nature-based spaces for relaxation and social interaction [3]. Siham (2023) [15] confirmed that integrating daylight, water, air, plants, and landscapes enhanced well-being and academic performance through sensory engagement and stress reduction, while fire and animal motifs were less effective. Together, these studies offer an evidence-based framework for applying biophilic strategies in education.

Studies show that biophilic design in education improves cognition and emotional well-being but has limited effects on physical recovery. Academic pressures and schedules may reduce nature's restorative impact. While daylight, ventilation, and greenery enhance mood and focus, they do not fully support physiological recovery. Overall, biophilic design offers clear benefits, but more research is needed to develop consistent, context-specific strategies.

Table 3: Summary of the educational building studies (by author)

Study		Methodology	Key result	Strength	Weakness	Research gaps
Education building	**Mustafa and Yaseen. (2019)**	Quantitative ratings of 14 features in 3 categories.	The implementation of biophilic principles reduces stress and enhances cognitive/psychological well-being.	Structured & replicable measurements.	Excludes water features due to safety.	Explore safe water integration; broader measures.
	Ghaziani, Lemon, and Atmodiwirjo. (2021)	Mixed-methods: quantitative test scores and qualitative feedback.	The integrated design elements led to improved cognitive performance and a stress-alleviating environment.	Combines performance metrics & emotions.	Focusing on primary schools limits generalizability.	Expand research to other educational levels and cultural contexts.
	Nevzati, Demirbas and Hasirci. (2021)	quantitative assessments; independent t-test analysis.	Gender-based differences: females benefited more significantly from the presence of interior water elements compared to males.	Statistical rigor isolates water effects.	Limited to one transitional area.	Study additional features and varied demographics.
	Mehta and Mahamood. (2022)	Mixed-methods: surveys and observations	Biophilic design affects experienced stress relief and noted attention improvement.	Blends subjective and observational data	Self-reports may be biased; they have a narrow spatial focus.	Incorporate academic performance metrics; wider scope.
	Siham (2023)	Quantitative survey on biophilic elements.	Full integration of biophilic features enhanced circadian rhythms, reduced stress, and boosted cognition; some elements.	Evidence-based framework from expert insights.	Small, expert-only sample lacks actual user input.	Validate with empirical user data; larger, diverse samples.

Biophilic Design in Commercial Buildings (Shopping centers)

Biophilic design integrates natural elements like daylight, greenery, and organic materials into shopping centers to create engaging retail environments. Table 4 summarizes studies showing that such features enhance mood, satisfaction, and engagement while suggesting further research on long-term and economic effects. Andria and Salim (2024) [10] found that greenery and water features improved mood and extended visits, with emotional experiences strongly influencing consumer behavior. Alzamil (2023) [34] observed that skylights, plants, vertical gardens, and water features in Kuwaiti malls enhanced sensory quality, mitigated harsh conditions, and increased satisfaction. Overall, biophilic design promotes emotional well-being and functional performance in retail spaces. Cheng and Marzuki (2023) [35] found that biophilic design in shopping malls enhances visitor experiences, with natural features, landscape appeal, and restorative qualities improving mental rejuvenation and aesthetic satisfaction while encouraging revisits and recommendations. Similarly, Bahauddin et al. (2021) [18] observed that ornamental plants and natural light in heritage shophouses in Penang

improved comfort, aesthetics, and air quality, with added potential for local plant use to strengthen cultural and health value.

Overall, biophilic design in commercial spaces improves mood, enjoyment, and perceived recovery, promoting positive behavior, though physiological recovery remains limited due to cultural, environmental, and activity-related factors. Designers should therefore create thermally comfortable and culturally sensitive biophilic refuge areas, and assess outcomes using both subjective and objective measures.

Table 4 Summary of the Commercial (Shopping center) Buildings studies (by author).

Study		Methodology	Key result	Strength	weakness	Research gaps
Commercial building (Shopping centers)	**Andria and Salim (2024)**	Quantitative survey with 210 respondents; SEM analysis	Emotional uplift, increased dwell time; emotional touches impact consumer behavior	Robust quantitative analysis in a defined metro area	Focuses on emotion over long-term behavior; region-specific	How biophilic touches can drive repeat visits and broader impacts ?
	Alzamil. (2023)	Qualitative case study; observations in four malls in Kuwait.	Improved sensory perception and comfort; mitigates harsh desert conditions	Context-specific evidence shows nature's benefits in extreme climates.	Subjective observations; limited geographical scope	Opportunity to expand cases, integrate quantitative data, and explore correlations with visitor satisfaction and spending; further embed local cultural/ecological references.
	Cheng and Marzuki's (2023)	Quantitative survey in a major mall; PLS-SEM analysis	Direct boost to mental rejuvenation and aesthetics; indirect influence via landscape and restoration cues	Detailed breakdown of direct and indirect impacts	Single mall focus; potential cultural/contextual nuances	Broader samples and longitudinal tracking of repeated visits
	Bahauddin, et al. (2021)	Qualitative case study of heritage shop houses in Penang	Enhanced indoor ambiance, comfort, and air quality via ornamental plants	Highlights cultural heritage and multisensory benefits	Context-dependent qualitative data; lacks economic quantification	Future work should incorporate quantitative assessments- Broadening the sample size across various

			and natural light			heritage settings - Systematic Cataloguing of Local Plant Species

Biophilic Design in Healthcare Buildings

Biophilic design in healthcare leverages nature's healing potential to create restorative and therapeutic environments, as summarized in the healthcare buildings studies Table 5. Ryan et al. (2014) [25] identified fourteen evidence-based design patterns—such as natural views, multisensory engagement, and dynamic environmental conditions—that reduce stress and enhance patient recovery. Building on this, Mohamed et al. (2021) [37] demonstrated that integrating natural light, green spaces, large windows, and organic motifs accelerates healing and reduces stress for patients, visitors, and staff, while also offering economic benefits through improved building performance. Similarly, Zhao et al. (2022) [38] found that daylight access, vegetation, and natural materials in twelve Chinese hospitals lowered stress and enhanced the healing environment. Their findings highlight strategies such as multisensory integration, functional spatial design, and sustainable interventions to promote well-being. Extending this research, Ebaid (2023) [39] showed that biophilic design in cancer care facilities increased patient comfort satisfaction by 18%, with natural light, water features, and sensory elements reducing stress and stabilizing physiological indicators. Similarly, Al Khatib et al. (2024) [40] conducted a systematic review of 63 high-quality studies from 379 sources, confirming that natural elements such as sunlight, greenery, water, and organic materials create therapeutic environments that reduce stress and anxiety, improve physiological outcomes, and promote faster recovery. These strategies also enhance staff well-being, demonstrating that biophilic design can improve hospital environments at minimal cost.

Overall, the reviewed studies show that biophilic design in healthcare lowers blood pressure and heart rates while enhancing psychological well-being for patients, visitors, and staff. However, evidence for cognitive improvement remains limited, unlike in educational environments, indicating that healthcare design focuses more on emotional restoration and stress reduction. This underscores the need for standardized assessment methods across different cultural and infrastructural contexts.

Table 5: Summary of the healthcare Buildings studies (by author).

Study		Methodology	Key result	Strength	Weakness	Research gaps
Healthcare buildings	**Mohamed. (2021)**	Mixed-methods: literature review, comparative case studies, and empirical surveys.	Use of Natural elements speeds recovery, relieves stress, and boosts psychological well-being.	Integrates multiple data sources and links design benefits to both clinical and economic outcomes.	Potential issues in merging qualitative insights with measurable outcomes: context-specific variables may influence results.	Longitudinal studies and larger samples are needed to quantify both clinical and economic benefits.
	Zhao, Zhan, and Xu. (2022)	Study across 12 hospitals using interviews, psychological assessments, and observational techniques.	Multisensory design improves recovery, reduces stress.	Provides actionable recommendations from real-world hospital cases and integrates diverse assessment techniques.	Limited sample size (12 hospitals) might affect generalizability; the extension to non-healthcare contexts requires further testing.	Studies with larger, more diverse healthcare facilities and parallel examinations in non-health sectors.

	Ebaid. (2023)	Mixed-methods (lit review, observations, surveys)	Biophilic design improves comfort satisfaction, reduces stress, and helps stabilize key physiological markers such as blood pressure and heart rate	Rich, multi-attribute framework	May require further empirical validation across various patient demographics and clinical settings beyond cancer care.	Long-term impact studies and scalability of the framework across different healthcare specialties and regions.
	Al Khatib, Samara, and Ndiaye. (2024)	Systematic literature review of 63 high-quality studies selected from 379 sources.	Integrating natural elements effectively reduces stress and anxiety, improves physiological parameters, accelerates patient recovery, and creates a better work environment for staff.	Comprehensive review underscoring the widespread benefits of biophilic design with minimal extra cost.	Reliance on secondary, literature-based data limits insight into on-site context-specific effects.	Empirical studies to measure the economic and behavioral impact of specific design interventions.

Biophilic Design in Residential Buildings

Biophilic design offers an effective way to reconnect residents with nature in increasingly urbanized environments, as summarized in Table 5. Ahmed and Shukur (2022) [41] found that natural ventilation, dynamic daylight, and greenery enhance indoor quality and well-being, though their use in Erbil's homes remains limited by financial and spatial constraints, with higher adoption among affluent households. Similarly, Abouelela (2023) [42] reported that incorporating daylight, ventilation, green spaces, and organic materials improves mental health, reduces stress, and supports physiological balance, reinforcing the strong connection between biophilic design and overall well-being. Shakhshir and Sheta (2023) [43] demonstrated that biophilic design increases occupant satisfaction by strengthening human–nature connections. Surveys and expert interviews revealed residents' preference for windows, open views, and greenery, features less common in high-rise buildings than in villas or townhouses. They recommended adaptive balconies, roof gardens, and indoor planting to enhance visual appeal, well-being, and community cohesion through people- and environment-centered urban planning. Yahya (2024) [44] found that applying biophilic principles to traditional Middle Eastern courtyard houses improved comfort and well-being through varied lighting, water features, and thermal diversity.

Comparative case studies from Baghdad, Damascus, and Mardin showed that local climatic, geographic, and cultural factors shape biophilic patterns, optimizing airflow, shading, and social integration for healthier spaces. Overall, biophilic residential design enhances comfort and emotional well-being, although evidence on recovery and productivity remains limited due to behavioral, socioeconomic, and environmental influences such as routines, caregiving, space constraints, and urban noise. Future residential strategies should incorporate circadian lighting, acoustic refuge areas, and ergonomic layouts supported by comprehensive multi-variable analyses to create scalable, context-sensitive solutions.

Table 6. Summary of the Residential Buildings studies (by author).

Study		Methodology	Key result	Strength	weakness	Research gaps
Residential building	**Ahmed and Shukur (2022)**	Structured observations and interviews of 60 houses in Erbil	Natural ventilation, dynamic daylight, and greenery enhance indoor quality and well-being; however, implementation is limited by financial/spatial constraints	Highlights residents' awareness versus practical constraints	Limited implementation in low-income contexts	How to overcome financial and spatial barriers in residential contexts
	Abouelela. (2023)	Descriptive analytical approach with a structured questionnaire and literature review	Integration of natural elements enhances mental well-being and supports balanced body rhythms and recovery.	Combines quantitative feedback with literature insights	May not capture deeper cultural or regional differences	Investigate region-specific design adaptations and long-term well-being impacts
	Shakhshir and Sheta (2023)	Surveys and interviews with experts regarding biophilic features in high-rise vs. villas	Enhanced occupant satisfaction and stronger connection to nature; innovative strategies like adaptive balcony controls and roof gardens boost appeal and community ties	Compares different housing typologies and provides practical recommendations	Focus on fewer traditional residential forms; may overlook broader urban contexts.	Explore innovative, scalable strategies for high-density residential developments.
	Yahya (2024)	Qualitative-comparative analysis of case studies in Baghdad, Damascus, and Mardin	Incorporating lighting, water features, and thermal variability in Middle Eastern courtyard houses improves comfort and well-being by optimizing airflow and shading.	Integrates socio-cultural, climatic, and geographical factors clearly	Limited to traditional courtyard houses; not directly transferable to modern residential layouts	Extend comparative analysis to diverse modern housing typologies and explore hybrid models

Biophilic Design in Hospitality (Restaurants) Buildings

Table 7 summarizes key hospitality studies showing that biophilic design in restaurants fosters harmony between people and nature through greenery, organic materials, and dynamic lighting. These elements create multisensory environments that promote relaxation, purify air, and enhance psychological comfort. Talukdar and Kaur (2019) [45] found that plants, sustainable materials, and natural lighting improve air quality, reduce stress, and create adaptable, appealing spaces. Kansal and Rana (2024) [46] reported that natural materials, greenery, and daylight increase comfort, attentiveness, and satisfaction, encouraging longer stays and higher spending.

Similarly, Alabdali et al. (2024) [47] showed that incorporating greenery, glass panels, and soft colors improves air quality, circulation, and spatial functionality, aligning with Oman Vision 2040 through community-oriented design. Ibrahim et al. (2024) [48] observed in Klang Valley, Malaysia, that natural materials and dynamic lighting enhance enjoyment, reduce stress, and improve overall dining satisfaction. Collectively, these studies demonstrate that biophilic design in restaurants delivers environmental, psychological, and economic benefits. However, since dining experiences are typically brief and socially driven, factors such as atmosphere, culture, and layout may exert greater influence on satisfaction. Broader evaluation frameworks that incorporate experiential, aesthetic, and social dimensions are therefore needed to assess the performance of biophilic design in hospitality settings.

Table 7: Summary of the Hospitality (Restaurants) Buildings studies (by author).

Study		Methodology	Key result	Strength	Weakness	Research gaps
Hospitality (restaurants) buildings	**Talukdar and Kaur. (2019)**	An extensive literature review and a focused case study of an eco-friendly restaurant in Ahmedabad.	Natural elements improve air quality, reduce stress, and create appealing, flexible environments addressing urban issues.	Rich contextual insights; links design to environmental well-being.	Limited to one case in Ahmedabad; lacks broader quantitative validation.	Need for multi-site studies and quantitative data to generalize findings.
	Kansal and Rana. (2024)	Mixed approach: customer satisfaction surveys, stakeholder interviews, and observations.	Use of natural materials, greenery, and natural light creates a welcoming dining mood, increases customer dwell time, and boosts economic gains.	Combines qualitative and quantitative methods for robust insights.	Potential sample limitations: focus may be narrow in scope.	Expanded studies across diverse restaurant types and long-term impact analysis.
	Alabdali et al. (2024) study	Comprehensive case study including qualitative site analysis and benchmarking of similar restaurants with community input.	Incorporation of greenery, glass panels, and a soft colour palette improves air quality, layout, and traffic flow, aligning with broader	Integrates community involvement and benchmarking best practices.	Context-specific (Oman), which may limit broader applicability.	Broader cross-cultural studies to test the generalizability of design impacts.

			urban visions (Oman Vision 2040).			
	Ibrahim et al. (2024)	Combined approach based on Browning's 14 Patterns: qualitative observations	Access to nature and dynamic light enhances the dining atmosphere, reduces stress, and increases customer contentment.	Multimodal methods provide detailed visual and customer feedback.	Limited by geographic focus (Klang Valley) and potentially small sample size.	Larger-scale studies to explore the link between design patterns and economic benefits.

Results and Findings

This section summarizes the key biophilic design patterns identified in the systematic review, expanding on the earlier conceptual framework and typology analyses. The review examined how principles related to environmental features, natural forms, light and space, place-based relationships, and human–nature connections appear across educational, commercial, healthcare, residential, and hospitality settings. Using both quantitative and qualitative evidence, the analysis addressed how biophilic design influences psychological and physiological well-being, supports urban sustainability, and identifies effective strategies for integrating these principles across diverse building types.

The findings reveal clear but context-dependent outcomes within each setting. Results are presented thematically, connecting core patterns to methodological and contextual factors while identifying broader implications for sustainable and health-focused design.

Educational Buildings

Biophilic design in educational environments consistently shows positive effects on student well-being and cognitive performance. Quantitative studies indicate that natural light, open views, and effective ventilation improve environmental quality by up to 95% and correlate with higher academic achievement. Qualitative evidence further suggests that students feel calmer, more focused, and more engaged in biophilic classrooms. Berman et al. (2008) demonstrated that contact with natural settings supports attention restoration, a key concept in biophilic theory [47]. However, several studies are limited by safety-related exclusions, such as the omission of water features, and by a narrow focus on primary education.

Overall, the evidence highlights strong cognitive and psychological benefits in learning environments and provides a foundation for exploring whether similar outcomes can be achieved in commercial settings.

Commercial Buildings (Shopping Centers)

Research in commercial environments shows that integrating natural elements such as greenery, water features, and natural lighting improves consumer mood and extends dwell time. Andria and Salim (2024) reported that while biophilic design is not the main factor driving repeat visits, it enhances emotional comfort and engagement.

Studies by Alzamil (2023) and Cheng and Marzuki (2023) found that in challenging climates, such as Kuwait's desert context, biophilic strategies improve spatial quality, user satisfaction, and thermal comfort. However, cultural and climatic differences strongly influence how biophilic elements are perceived and applied. For example, lush vertical gardens may be desirable in humid Southeast Asia, where greenery aligns with local aesthetics and climate, but they are often impractical in arid regions, where water scarcity and thermal expectations shape design choices. Similarly, shopping rituals and cultural traditions affect how users engage with natural features, meaning that strategies must be adapted to local contexts rather than transferred wholesale.

Most commercial studies emphasize emotional and behavioral outcomes—such as mood, comfort, and time on site—rather than physiological or cognitive measures. This contrasts with educational and healthcare research, which often employs structured frameworks for stress recovery and attention restoration. To address this gap, future research should reframe shopping centers as potential

restorative environments, testing biophilic impacts with standardized cognitive and physiological indicators alongside behavioral metrics.

Healthcare Settings

Biophilic design in healthcare environments contributes to both therapeutic outcomes and operational efficiency. The literature consistently shows that exposure to natural elements—such as daylight, greenery, and water features—reduces physiological stress markers (e.g., blood pressure and heart rate) and accelerates patient recovery. Studies by Mohamed (2021) and Zhao et al. (2022) confirm that biophilic interventions enhance patient satisfaction, recovery rates, and the overall work environment for healthcare staff. These findings align with the broader evidence presented in this review, underscoring the clinical and organizational value of biophilic integration.

However, variations in research methods and measurement criteria highlight the need for standardized evaluation frameworks to ensure comparability across healthcare contexts. Building on these insights, it becomes essential to examine how similar design principles influence individual well-being and daily life in residential settings, where restorative benefits may be equally significant but less systematically studied.

Residential Buildings

Research on residential environments demonstrates that biophilic design substantially enhances indoor environmental quality and occupant satisfaction. Ahmed and Shukur (2022) found that while residents recognize the benefits of natural elements, adoption in Erbil is constrained by financial and spatial limitations. Conversely, Abouelela (2023) reported that incorporating natural light, ventilation, and greenery improves mental health and physiological balance. Shakhshir and Sheta (2023) further proposed adaptive strategies—such as adjustable balconies and roof gardens—to address challenges in high-rise housing.

These findings underscore the importance of context-sensitive and flexible approaches to maximize biophilic benefits in homes. While residential applications primarily support daily comfort and individual well-being, the hospitality sector extends these advantages to shared experiences, directly shaping customer satisfaction and business performance.

Biophilic design demonstrates consistent psychological, physiological, and experiential benefits across educational, commercial, healthcare, residential, and hospitality settings, though outcomes vary by context. Figure 3 presents a network-style correlation map linking building typologies to their most frequently reported outcomes, while Table 8 synthesizes these findings across studies. Shared mechanisms—daylight, vegetation, water, and ventilation—are strongly associated with stress reduction, mood enhancement, and improved air quality, while typology-specific effects include cognitive gains in classrooms, faster recovery in healthcare, extended dwell time and economic uplift in retail and hospitality, and enhanced comfort in residential environments.

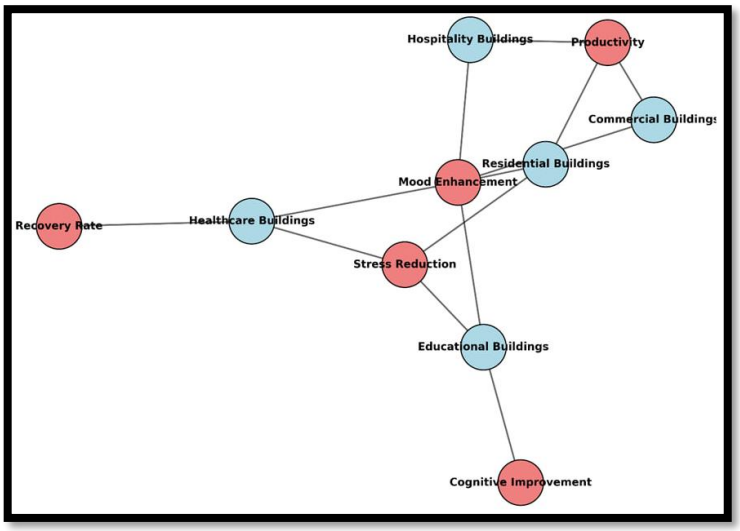

Figure 3: Network Style Correlation of Biophilic Design Benefits Across Five Building Typologies (by author).

Table 8: Comparative Summary of Biophilic Design Across Building Typologies. (by author).

Building Type	Common Biophilic Elements (Influencer)	Key Outcomes (Influenced)	Challenges	Recommendations
Educational	Natural light. Open views. Enhanced ventilation. Selective use of water elements.	Reduced stress, improved cognitive performance, enhanced attention, and mood	Safety concerns (e.g., water elements), limited scope (primary schools vs. higher education)	Develop safe water integrations; expand research to diverse educational levels; standardize method frameworks for consistent comparisons.
Commercial	Greenery, indoor water features, natural lighting, nature-inspired aesthetics	Elevated visitor mood, increased dwell time, greater sensory engagement, potential economic uplift	Often based on cross-sectional surveys, regional specificity limits generalizability.	Conduct longitudinal and mixed-method studies; assess long-term economic impacts; compare outcomes across diverse cultural contexts.
Healthcare	Daylight, green views, water features, organic and natural motifs	Lowered stress and anxiety, accelerated patient recovery, improved physiological markers, and better staff environments	Variability in measurement methods; context-specific outcomes (e.g., different hospital settings)	Create standardized evaluation protocols; include objective on-site physiological assessments; enlarge sample sizes for broader validation
Residential	Natural ventilation, dynamic daylight, indoor greenery, integrated landscaping	Enhanced indoor air quality, improved mental well-being, reduced stress, and better overall living quality.	Financial and spatial constraints, especially in low-income or high-density urban contexts	Tailor design solutions to local economic and spatial realities; explore modular, scalable interventions for urban environments
Hospitality	Greenery, dynamic lighting, natural materials, and eco-friendly design elements	Improved dining ambience, reduced customer stress, higher satisfaction, longer customer, and economic benefits	Reliance on subjective assessments, limited geographic sampling, and short-term data	Integrate objective metrics (e.g., air quality monitoring, physiological stress indicators); expand research across multiple regions; adopt mixed-method approaches.

Analysis of environmental element usage across typologies (Figure 4) reveals distinct sectoral emphases: healthcare prioritizes natural light, ventilation, and restorative views; hospitality favors natural materials and planting; education emphasizes daylight and airflow but avoids water features for safety; residential settings show balanced but modest integration; and commercial spaces adopt greenery and lighting strategies shaped by climate and culture. These variations highlight the importance of adaptive, context-sensitive design.

Methodologically, the evidence base remains heterogeneous. Healthcare and commercial studies employ more structured, quantitative approaches, while educational and residential research often relies on participant perceptions. Short study durations and limited coverage of dense, low-income contexts constrain comparability. Moreover, commercial research privileges behavioral and economic metrics over cognitive or physiological outcomes, leaving restorative potential underexplored. Figure 5 maps how core biophilic elements influence human outcomes, while Figure 6, together with Table 8, summarizes consistent psychological and physiological benefits across all building types

Future work should pair subjective and objective measures (e.g., surveys with physiological and air-quality indicators), reframe commercial environments as restorative spaces, and deploy adaptive, sensor-informed strategies responsive to cultural and climatic conditions. In sum, biophilic design emerges not as an aesthetic supplement but as a scalable, human-centered framework that aligns health, comfort, and sustainability—a practical pathway toward resilient, evidence-based urban environments.

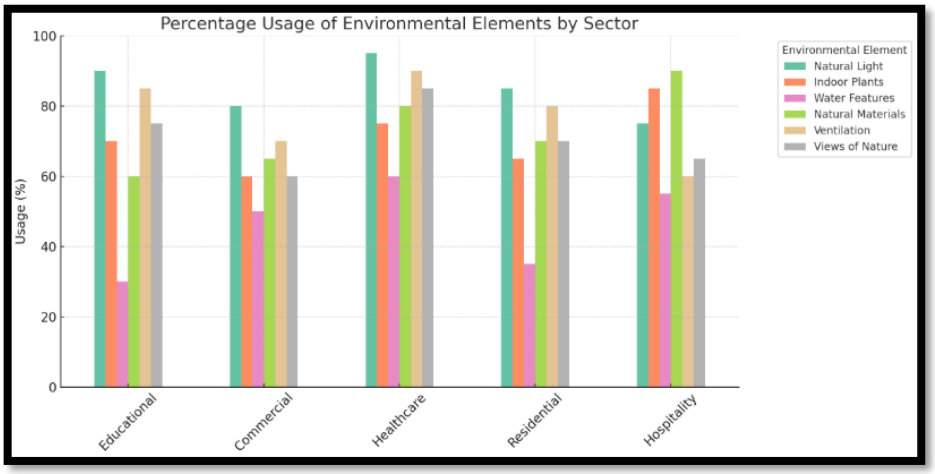

Figure 4. Use of key environmental elements across five building sectors (by author).

Figure 5 maps how biophilic elements influence human outcomes, and Table 8 with Figure 6 summarize consistent psychological and physiological benefits across all building types. Shared mechanisms—daylight, vegetation, water, and ventilation—enhance mood, reduce stress, and improve air quality. Differences arise from varied methods, short study durations, and limited research in dense, low-income areas. Future work should pair subjective and objective measures and apply adaptive, climate-responsive design strategies. Overall, biophilic design emerges as a scalable, human-centered approach that aligns health, comfort, and sustainability.

Key findings include reduced stress, improved well-being, and better indoor air quality. Educational settings report cognitive gains, commercial spaces show higher engagement and profitability, healthcare environments highlight faster recovery, residential studies emphasize comfort, and hospitality research focuses on experiential and economic benefits.

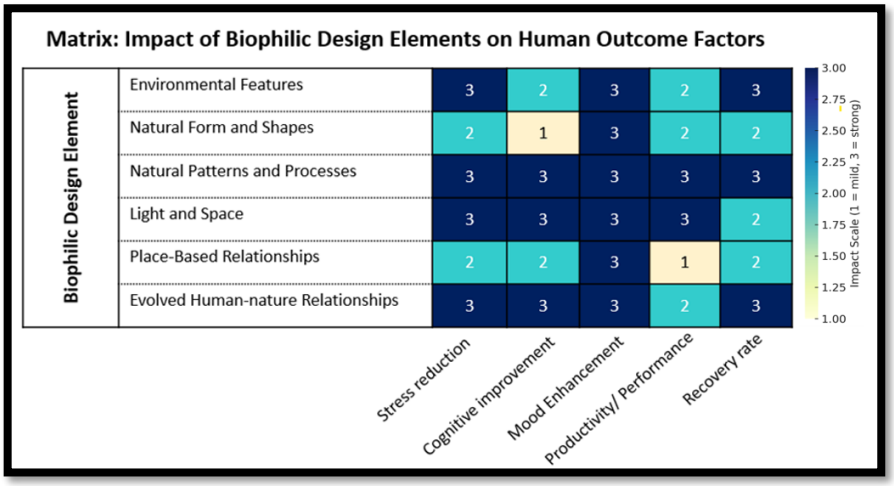

Figure 5. Heatmap showing the impact of various biophilic design elements on key human outcome factors (by author)

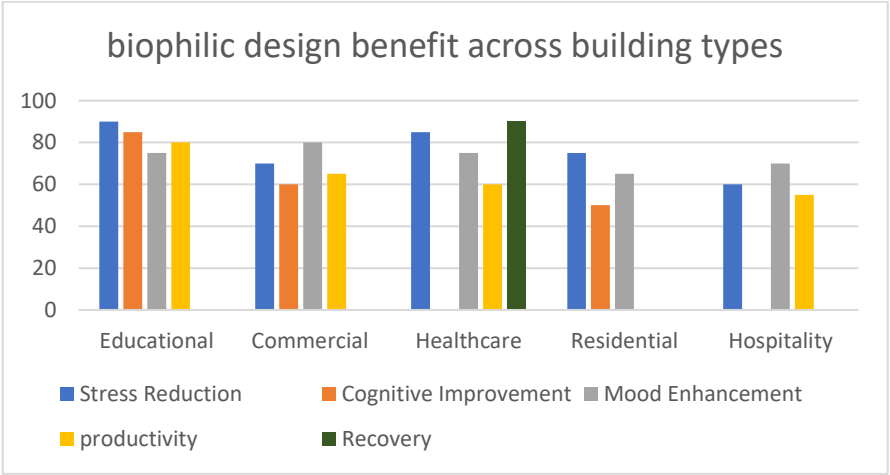

Figure 6. Comparative chart of psychological and performance benefits of biophilic design across five building types (by author).

Hospitality (Restaurants)

The literature on hospitality highlights biophilic design's capacity to create multisensory, restorative dining experiences that enhance customer comfort, reduce stress, and generate economic value. Case studies by Talukdar and Kaur (2019) and Ibrahim et al. (2024) provide qualitative evidence that elements such as dynamic lighting, greenery, and organic materials foster inviting atmospheres. Complementary research by Kansal and Rana (2024) and Alabdali et al. (2024) emphasizes that these interventions can increase customer retention and drive measurable economic gains.

Despite these promising outcomes, many studies rely heavily on subjective assessments and geographically limited samples. Future research should incorporate objective measures—such as air quality, physiological indicators, and long-term behavioral validation and expand current findings. This would strengthen the evidence base for biophilic design as a driver of both experiential quality and business performance in hospitality settings.

Synthesis and Future Directions

Across all building types, biophilic design proves effective in enhancing human well-being and advancing sustainable development. Evidence highlights three main outcomes:

• Psychological and physiological benefits such as improved mood, reduced stress, and enhanced cognitive performance across environments.

• Sustainability contributions through reduced energy consumption and improved indoor environmental quality, supporting economic and ecological goals.

• Context-specific challenges arising from safety limitations in schools, spatial and financial barriers in residential settings, and varying cultural or climatic conditions, emphasizing the need for localized design approaches.

Despite strong evidence supporting biophilic interventions, methodological and contextual gaps persist. As summarized in Table 9, consistent benefits are observed across educational, commercial, healthcare, residential, and hospitality settings, though outcomes vary by context. The most effective design patterns include Environmental Features and Light & Space, which strongly influence stress, mood, cognition, and recovery; Natural Forms & Patterns, which enhance focus where direct nature is limited; Place-Based Relationships, which reinforce cultural identity; and Evolved Human–Nature Relationships, which support emotional balance and engagement.

Key research gaps include the absence of standardized evaluation frameworks, limited integration of objective physiological and environmental data, few longitudinal studies, and insufficient representation of low-income or high-density contexts. Future studies should aim to:

- ✓ Establish universal metrics for comparing biophilic impacts.
- ✓ Combine physiological and environmental measures with qualitative data over time.
- ✓ Examine cultural, climatic, and economic influences to develop scalable, sustainable design models.

Addressing these gaps will refine best practices and translate observed benefits into actionable, evidence-based guidance for professionals across disciplines.

Table 9: Effectiveness of Biophilic Design Patterns in Various Contexts

Pattern	Key Benefits	Example Applications	Impact Level by Sector
Environmental Features & Light & Space	Stress reduction, mood enhancement, improved cognitive ability, faster recovery rate	Bright classrooms, daylight-filled hospital corridors, well-lit workspaces and dining areas, and the use of natural materials	Educational: Very strong Commercial: Strong Healthcare: Very strong Residential: Strong Hospitality: Strong
Natural Forms & Patterns	Improves mood and concentration, especially in environments lacking direct nature	Biomorphic shapes, fractal patterns, simulation of natural processes, high-rise apartments, or windowless commercial interiors	Educational: Medium–Strong Commercial: Strong Healthcare: Medium Residential: Strong Hospitality: Medium
Place-Based Relationships	Enhances local identity, increases emotional connection, supports authenticity	Locally sourced materials, vernacular motifs, cultural references, traditional courtyard houses, heritage retail arcades	Educational: Medium Commercial: Medium Healthcare: Low–Medium Residential: Very strong Hospitality: Medium
Evolved Human–Nature Relationships	Supports cognitive recovery, emotional calming, curiosity stimulation, and sensory variety	Prospect & refuge elements, curiosity-inducing forms, sensory variability	Educational: Very strong Commercial: Medium Healthcare: Very strong Residential: Medium Hospitality: Medium

Despite consistent evidence that biophilic design enhances psychological and physiological well-being across building types, the diversity of analytical methods—spanning quantitative surveys, physiological testing, and qualitative case studies—limits comparability of results. This variation reflects not flawed research but a broader methodological inconsistency, emphasizing the need for a unified evaluation framework that standardizes metrics, methodologies, and reporting across typologies.

Discussion

The comparative analysis across educational, commercial, healthcare, residential, and hospitality environments shows that while biophilic design consistently enhances psychological and physiological well-being, the extent and character of benefits depend on the design pattern and contextual conditions. This section interprets these differences based on the cross-typology synthesis (Table 8) and pattern-specific performance (Table 9).

Cross-Pattern Performance

Environmental Features and Light and Space proved most effective across all typologies, strongly linked to stress reduction, mood improvement, and, in education and healthcare, better cognition and recovery. Their direct sensory impact supports Attention Restoration and Stress Recovery theories. Natural Forms and Patterns showed context-dependent results. In enclosed or high-rise settings, biomorphic shapes and textures aided focus and mood, while their added value was less evident in nature-rich environments.

Place-Based Relationships enhanced authenticity and attachment in residential and heritage commercial spaces but had limited influence in large healthcare or hospitality facilities, where exposure is brief. Evolved Human–Nature Relationships, such as prospect-refuge balance and sensory variety, were most beneficial in educational and healthcare environments, improving focus and emotional stability, and in commercial or hospitality settings, they supported engagement and perceived uniqueness.

Typology-Specific Contrasts

Educational buildings: Delivered the strongest cognitive gains (up to 85% improvement in attention metrics) when Environmental Features and Light & Space were combined. Safety constraints (e.g., exclusion of water features) limited full application.

Commercial (shopping centers): Produced mood enhancement and extended dwell time through Environmental Features, but negligible cognitive or physiological benefits—likely due to goal-directed behavior and sensory overload.

Healthcare: Showed the most consistent recovery outcomes (e.g., reduced blood pressure, faster healing) from Environmental Features and Evolved Human–Nature Relationships. Place-based cues played a minor role, constrained by universal design standards.

Residential: Benefits centered on comfort and emotional well-being, with Place-Based Relationships and Natural Forms & Patterns enhancing identity and satisfaction. Financial and spatial constraints moderated implementation.

Hospitality: Gains were primarily experiential and economic—improved ambience, customer satisfaction, and spending—driven by Environmental Features and Light & Space. Cognitive or physiological effects were minimal, reflecting short-term, socially oriented visits.

Mechanisms Behind Divergence

Differences in outcomes stem from three factors.

Exposure Duration: Long-term use in education and housing enhances cognitive and emotional gains, while short visits in hospitality and retail yield brief mood effects.

User Behaviour: Passive recovery in healthcare supports restorative impact, whereas goal-driven activity in commercial spaces reduces it.

Cultural and Climatic Context: Local traditions, climate, and materials shape feasibility and response, especially in Place-Based Relationships.

Implications for Design Practice

Effectiveness depends on context rather than a single pattern.

- Use Environmental Features with Evolved Human–Nature Relationships in healthcare and education.
- Pair Light and Space with Natural Forms and Patterns in enclosed or dense settings.
- Apply Place-Based Relationships in housing and heritage projects to enhance identity.

Research Gaps

Methodological variation limits comparability. Future work should:

1. Standardize evaluation methods.
2. Combine physiological and perceptual data.
3. Track long-term effects.
4. Develop low-cost, scalable models for limited-resource settings.

Conclusion

This study examined how biophilic design principles rooted in environmental features, natural forms and patterns, light and space, place-based relationships, and evolved human–nature connections can be applied across different building types to enhance well-being and support sustainable development. The systematic review and cross-typology analysis showed that while the main mechanisms of biophilic design are consistent, their effects depend on context, user behaviour, and implementation conditions.

Across educational, commercial, healthcare, residential, and hospitality settings, consistent psychological and physiological benefits were observed. Elements such as daylight, vegetation, water, natural ventilation, and multisensory cues reduced stress, improved mood, and enhanced perceived environmental quality. Outcomes varied by building type: education showed cognitive improvement, healthcare promoted faster recovery, commercial and hospitality spaces enhanced user experience, and residential environments increased comfort and emotional well-being. These differences reflect the influence of culture, climate, economy, and spatial constraints on both design feasibility and user response.

The results confirm the study's aim to connect theory with practice by providing evidence for adaptive and context-sensitive design strategies that align human health with environmental performance. The research contributes to scholarship by clarifying where biophilic design offers the most value and identifying methodological gaps such as the lack of standardized evaluation frameworks and integrated physiological and environmental metrics. For practice, it offers guidance for architects, planners, and policymakers to adopt nature-based strategies that are culturally appropriate, climatically responsive, and economically viable.

Biophilic design should be understood not as an aesthetic addition but as a practical framework for creating human-centred, resilient, and environmentally responsible spaces. When informed by evidence and adapted to local needs, it provides a clear path toward healthier communities and more sustainable cities.

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