JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Biophilic Design and University students' Cognitive Performance

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Abstract: Biophilic Design is claimed to have a number of benefits. One of these benefits is enhancing the cognition and performance of students. This paper aims to explore in the international literature the main biophilic attributes that have a positive impact on university students' cognition and performance. This will be done through a qualitative comparative analytical study for an international case studies analysis. Concluding from these the main biophilic attributes that can be applied in a university setting and different types of methodologies that can be used in this type of research. The main characteristics concluded from that study were: visual connection with nature, water presence, dynamic and diffuse light, natural system connection, material link to nature, prospect/refuge, and thermal and airflow variation.

***Keywords*- Biophilia, University Setting, University Student, Cognition, Performance**

1.INTRODUCTION

The transition from a secondary to a university learning environment is critical for students since it fosters independence and maturity. Nonetheless, research suggests that this period of uncertainty has a major impact on this population's mental health and academic output [1]. Numerous studies have found that mental health issues are a significant obstacle for university students [2]. University students, according to studies, have greater rates of depression than the general population and are more impacted by uncertainty, study-related stress, familial stress, and financial issues [3]. Additionally, many students find it difficult to regulate their stress levels at university since it is a competitive learning setting with high academic expectations [1]. Personal pressures such as identity, relationships, and living circumstances are also present. Integrating biophilic design features into university classrooms can help students by generating stress-relieving environments that also foster creativity and cognitive advancement [3, 2]. This paper aims to identify from the international literature the main biophilic attributes that enhance students' cognition and performance in the university setting. There are many factors that can impact university students' performance. However, here are some of the main attributes that research suggests can have a significant impact on student performance [4, 5]:

Study habits: Students who have good study habits, such as effective time management, goal-setting, and active learning strategies, are more likely to perform well academically.

Intelligence and cognitive ability: Intelligence and cognitive ability play a role in academic performance, although they are not the only factors.

Motivation and mindset: Students who are motivated and have a growth mindset, meaning they believe their abilities can be improved with effort, tend to perform better than those who lack motivation or have a fixed mindset.

Learning environment: The learning environment, including factors such as classroom management, teacher-student relationships, and peer interactions, can impact student performance.

Socioeconomic status: Students from lower socioeconomic backgrounds tend to have more difficulty in school due to a lack of resources, support, and opportunities.

Family support: Students who receive support and encouragement from their families tend to perform better academically than those who do not.

Health and well-being: Physical and mental health can also impact student performance. Students who are healthy and well-rested are better able to focus and learn.

These are just a few examples of the many factors that can impact student performance. It is important to note that each student is unique, and what works for one may not work for another.

Some of these factors are social and others are physical such as health and well-being, Learning environment, and cognitive ability. According to international literature, biophilic design is considered one of the tools that can enhance these physical factors to achieve better performance from students.

2.BIOPHILIA HYPOTHESIS

Biophilia refers to the innate human connection to nature and other living things. The term was first introduced by biologist Edward O. Wilson in 1984 to describe the instinctive bond between humans and other forms of life [6].

Biophilic design is an approach to designing spaces that incorporate natural elements and features to enhance the well-being of occupants. This can include incorporating plants, natural light, views of nature, water features, and other natural elements into the design of a building or space [7]. Biophilic design aims to create a more harmonious and beneficial relationship between humans and their built environment, by fostering a sense of connection to the natural world. It has been shown to have a range of positive effects on human health and well-being, including reducing stress, improving cognitive function, and enhancing creativity [8].

There have been several studies investigating the impact of biophilic attributes on student performance in university campuses. Biophilic attributes refer to elements of nature, such as sunlight, plants, and water, that can enhance our connection with the natural environment [6] [7].

One study conducted by Kellert and colleagues (2008) found that biophilic design features, such as natural light and vegetation, had a positive impact on students' cognitive performance, including their ability to focus and retain information [9]. The study also found that students in classrooms with biophilic design features reported higher levels of well-being and engagement.

Another study by Heschong Mahone Group (1999) examined the impact of natural light on student performance and found that classrooms with natural light had significantly higher test scores than those without natural light. The study also found that students in classrooms with natural light had better attendance rates and were more engaged in class.

In addition to natural light and vegetation, water features have also been found to have a positive impact on student performance. A study by the University of Twente (2017) found that students in a lecture hall with a water feature performed better on a creativity test compared to students in a lecture hall without a water feature.

Furthermore, a study by the University of Oregon (2013) investigated the impact of a green roof on students' academic performance and found that students in a building with a green roof had better test scores compared to students in a building without a green roof [10].

Overall, these studies suggest that incorporating biophilic design features, such as natural light, vegetation, and water, into university campuses can have a positive impact on students' cognitive performance, well-being, engagement, attendance rates, and creativity. These findings highlight the importance of designing university campuses that prioritize the integration of nature and biophilic attributes into the built environment.

3.BIOPHILIC DESIGN ATTRIBUTES

Using biophilic design comprises a number of design principles that incorporate varied experiences via the use of a range of components. These qualities are divided into three categories: direct experience of nature, the indirect experience of nature, and sense of space and place[7 [11] [2] [3] [6]]. The biophilic experience, according to global literature, is categorized into 72 traits presented by Kellert in 2005. These features were compressed and reduced to fewer attributes, as illustrated in figure (1), the development and contribution timeline for professionals, pioneers, and researchers.

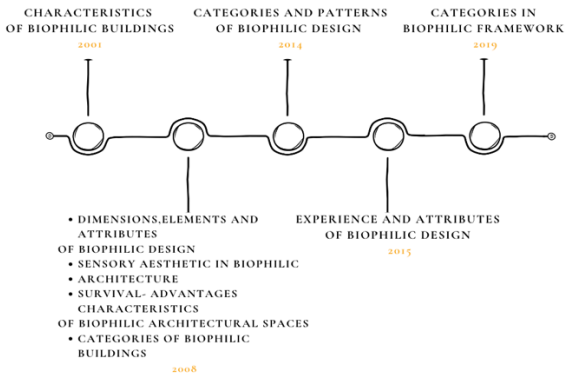

Figure 1 Biophilic Attributes Development [12]

3.1 Direct experience of nature:

Natural light: Natural light exposure is critical for human health and well-being because it helps us to distinguish between day and night and seasons based on the location and cycles of the sun. It may be easier to wander about and find your way when you are conscious of natural light. It can also make you feel more at ease and satisfied. Natural light may create aesthetically pleasing patterns and forms that go beyond simple exposure by combining light and shadow, diffuse and changeable light, and merging of light with spatial features [13].

Natural Ventilation: Human comfort and productivity are enhanced by natural ventilation. Airflow, temperature, humidity, and air pressure variations may all improve the experience of natural ventilation in the built environment. These criteria can be met by basic methods such as movable windows or through more complicated technology and technical solutions.

Presence of Water: Water is necessary for life, and its presence in the built environment has been shown to reduce stress, increase contentment, improve well-being, and promote productivity. When the numerous senses of sight, sound, touch, taste, and movement are combined, the attraction to water may be extremely intense. Viewing of large water features, fountains, aquariums, man-made wetlands, and other design methods may alleviate the need to contact water. When considered clean, in motion, and experienced via several senses, water is often the most pleasurable element in the built world (although at muted sound levels).

Presence of greenery: One of the most successful ways for integrating the direct experience of nature into the constructed environment is the use of vegetation, particularly flowering plants. Plants can improve your comfort, physical health, performance, and productivity while lowering your stress levels. The use of a single or isolated plant, on the other hand, seldom has a significant positive effect. The vegetation that surrounds man-made landscapes and structures should be plentiful, ecologically integrated, and favor native species over invasive and exotic species.

Animals: Birds, green roofs, gardens, and bird cages, as well as the creative application of contemporary technologies such as webcams, video, binoculars, and spotting scopes, may provide a good link with animal life. Interaction with isolated and infrequent animals frequently has little impact. Contact with animal life, if possible, should encompass a variety of species, with a preference for native rather than exotic organisms.

Weather: Throughout history, people have had a fundamental understanding of and ability to respond to weather, which has been crucial to their fitness and survival. Weather perception and interaction in the built environment may be both enjoyable and stimulating. This may be accomplished by physically exposing oneself to external situations as well as mimicking weather-like properties by varying airflow, temperature, barometric pressure, and humidity. Among the strategies used are outside views, movable windows, porches, decks, balconies, colonnades, pavilions, gardens, and other design elements.

3.2 The Indirect Experience of Nature

Natural Images: Nature's portrayal in the built world, including plants, animals, landscapes, water, and geological characteristics, may bring emotional and intellectual fulfillment. Photographs, paintings, sculptures, murals, movies, computer simulations, and other forms of representational media can be used to generate these pictures. A single or isolated snapshot of nature has little impact. Nature should be depicted frequently, in themes, and in quantity [14].

Natural Material: Natural materials are particularly notable because they exhibit the dynamic qualities of living matter in an adaptive response to the demands and barriers of long-term life. Few man-made materials can match the favorable aesthetic and tactile experiences elicited by natural materials when transformed. Wood, stone, wool, cotton, and leathers are natural building and ornamental materials utilized in a variety of objects, fabrics, and other interior and exterior designs.

Natural Color: Color has historically been employed to aid in the discovery of food, water, and other resources, as well as in mobility and navigation. Because humans are a daylight species, color has historically been a significant assistance in locating these resources. With today's ability to manufacture artificial hues, particularly vivid ones, it may be difficult to properly integrate color in the built environment. For successful biophilic color application, muted "earth" tones that imitate soil, rock, and plants should be preferred. Vivid colors should be used sparingly and only to highlight visually appealing natural forms such as flowers, sunsets and sunrises, rainbows, and individual plants and animals. Very unnatural, clashing, or "vibrating" colors should be avoided.

Simulating Natural Light and Air: Because of advances in building technology and construction, indoor lighting and processed air are now available. The trade-off has traditionally been stagnant settings that can be physically and mentally taxing. Artificial lighting may simulate the spectrum and dynamic qualities of natural light. By altering airflow, temperature, humidity, and barometric pressure, processed air may also mimic the benefits of natural ventilation.

Naturalistic Shapes and Forms: Investigating the shapes and forms noticed in nature might be highly intriguing. Naturalistic designs may include leaf-like patterns on columns, plant forms on building facades, and animal impersonations woven into fabrics and coverings. Naturalistic shapes and forms may give a static site the dynamic and ambient characteristics of a living system.

Evoking Nature: Nature's pleasurable experience may also be communicated through imaginative and enchanting pictures. Even though they do not appear in nature, these representations use design ideas found in nature.

Information Richness: The natural world is thought to be the most information-rich environment a person will ever experience due to its richness and unpredictability. Humans tend to respond positively to information-rich, diversified surroundings that offer a variety of alternatives and opportunities, whether natural or artificial, as long as the complexity is seen rationally and understandably.

Age, Change, and the Patina of Time: Nature is always changing and altering, with life displaying the dynamic processes of aging and development. Humans are drawn to these dynamic forces and the ensuing patina of time because it demonstrates nature's ability to adapt to ever-changing situations. These dynamic inclinations are usually most pleasant when balanced by the complementary characteristics of unity and stability. Natural aging materials, weathering, a sense of time passing, and other ways can be used in design to create change and a time patina.

Natural Geometry: Natural geometry is the study of mathematical characteristics found in nature. Hierarchical scales, flowing artificial geometries, as opposed to rigid geometries, self-repeating yet variable patterns, and other examples, are provided. Fractals, for example, a geometric pattern found in nature that repeats a fundamental shape in various yet predictable ways, adding both diversity and resemblance to an environment.

Biomimicry: The term "biomimicry" refers to the acceptance or suggestion of solutions to human wants and problems that are based on natural forms and functions, particularly those seen in other species. Such examples include some animal hairs' ability to trap heat, termite mound bio-climatic control, spider web structural robustness, and others. In addition to obvious practical benefits, digitally capturing these aspects of nonhuman nature can inspire humans to value the resourcefulness of other species and the uniqueness of the natural environment.

3.4 The Experience of Space and Time

Prospect and Refuge: Human adaptive evolution evolved from the combined benefits of prospect and sanctuary. Although refuges give areas of shelter and security, prospect refers to extensive views of the surrounding area that allow people to perceive both opportunities and threats. The built environment may aid and delight in accommodating these complementing conditions. This biophilic impact may be accomplished by including architectural elements such as outside views, visual connections between internal sections, and the provision of safe and secure surroundings [15].

Complexity and order: Humans are drawn to both natural and man-made environments because they are rich in possibilities and opportunities. In contrast, overcomplicated procedures are typically chaotic and unclear. The most pleasurable settings have components of complexity, but only complexity is experienced in an orderly and structured manner. Rich and complex settings are more prevalent in complicated environments, whereas ordered regions display qualities of connectivity and coherence.

Integration of Parts to Wholes: Humans are drawn to environments in which numerous elements come together to produce a cohesive whole. The concept of a rising totality is often helped by distinct and visible borders, as well as sequential and successional connectedness of areas. A functional or thematic primary focal point can strengthen this appealing spatial integration.

Transitional Spaces: The ability to properly explore a space often relies on an awareness of the linkages between areas, which is provided through clear and obvious transitions. Hallways, thresholds, entrances, gates, and locations that connect the inside and outside, such as porches, patios, courtyards, and colonnades, are examples of transitional spaces.

Mobility and Wayfinding: People's comfort and well-being are often dependent on their ability to freely roam between a variety of, often difficult, locations. Well-defined routes and ports of entry and exit typically promote mobility and a sense of security, whereas their absence frequently results in uncertainty and fear.

Cultural and Ecological Attachment to Place: Since it facilitated resource management, provided safety and security, and facilitated movement and mobility, humans evolved as a territorial species. This territorial inclination, which may be influenced by both cultural and environmental factors, appears as a preference for familiar settings. Designs that are culturally appropriate convey a feeling of location as well as a setting's specific human identity. Ecological ties to a place, notably knowledge of local landscapes, distinctive flora and fauna, and weather patterns, can also contribute to an emotional connection to a place. Cultural and ecological ties to a certain location typically urge individuals to maintain and safeguard both the natural environment and the built environment.

4.Biophilic Design and University Students

The biophilic hypothesis focuses on closing the gap between existing buildings and the natural environment in order to increase the presence of nature inside the built world.
According to Kellert, one of the most significant factors in improving space performance is the use of natural materials, including plants, and the permitting of natural ventilation and lighting [16].

Human behavior and performance studies have revealed that a person's physical and mental health is greatly impacted by their environment, whether natural or man-made, and that this precisely improves human well-being. Living in a green environment that encourages a healthy lifestyle can improve people's well-being since it has a direct impact on their behaviour, productivity, performance, and learning capacity. students who study in a biophilic environment perform better and learn more effectively, according to Grinde and Grinde-Patil (2009). According to research, the natural environment promotes concentration and stimulates the brain throughout the learning process.

Accordingly, this paper focuses on investigating in the international literature the biophilic attributes that have a high positive impact on students' cognition and performance, this will be done through an analysis of international case studies. Concluding from the analytical comparative analysis the main biophilic attributes that are suitable for university settings and the different methodological approaches for this type of research.

5.Methodology

This paper follows a qualitative comparative analytical study of international case studies [17]. Case study analysis is considered a powerful research methodology that provides a deep understanding of complex issues.
The case studies were chosen according to their university sizes and different methodological approaches in countries.

Case study analysis

Previous international case studies were examined to corroborate generally utilized methodology and the key research results that emerged from that prior study to aid in the creation of the empirical framework.

5.1 Turkey and United State Universities

A survey was done in two separate nations using the same methods to determine students' preferences for greenery on campus.
The study focused on three major hubs in universities: the whole campus, the campus center, and the area around academic buildings. The major purpose of the study was to capture students' impressions of campus greenness, restorativeness, and quality of life. Students (n = 1079) studying business, design, or psychology at two universities in Turkey and the United States (U.S.). Participants were asked to score the present and modified conditions using the following criteria:
Perceived greenness: if their campus included formal gardens, densely planted trees, natural plants, and the availability of bike lanes or pedestrian lanes.

Perceived restorativeness: Being away from daily attention demands, fascination with the setting that allows for effortless and restful engagement with it, a sense of connectedness among the parts of a setting that come together to form a coherent whole, and a sense of compatibility between one's abilities and the demands of the environment. The following factors contribute to life quality:

Physical health includes everyday activities, reliance on pharmaceuticals and medical assistance, energy and weariness, mobility, pain and discomfort, sleep and rest, and job capability.

Body image and appearance, negative sentiments, good feelings, self-esteem, spirituality/religion / personal beliefs, and thinking, learning, memory, and attention are all aspects of psychological health.

Personal ties and social support are examples of social relationships.

Environment - financial resources, freedom, physical safety and security, health, and social care: accessibility and quality, home environment, opportunities for acquiring new information and skills, participation in and access to recreation/leisure activities, physical environment (pollution/ noise/ traffic/ climate), and transportation. These are the primary aspects that determine a student's life and perspective, according to this study, and are vital in any academic context. SPSS software was used to analyse the data gathered from the questionnaire survey. Because students spent so much time in their classrooms and lecture halls, the presence of a natural environment near academic buildings provided the best rankings. As a result, it provides student comfort through good environmental quality and a high number of natural components, such as the presence of water features and green spaces. [18].

5.2 Attention Restoration Theory and University Campus Case Study

Universities demand continuous focused attention from students, which can cause to attention fatigue. The purpose of this research is to learn about the demands and aspects that might improve the cognitive skills of campus users. This was accomplished using a picture survey questionnaire distributed to students, in which they were asked to score certain areas on campus in their current and remodeled states. Examples of images from the student questionnaire are presented below.

Figure 2 University Gathering Area Redesign

These renovated sceneries include varying densities of flora and water components. Pictures were graded based on the attention restoration criteria of absence, extent, attraction, and compatibility. The main finding was that students thought views of actual or simulated nature were critical to the healing potential of interior campus surroundings. Additionally, students prefer relatively dense water elements and vegetation to dense scenery [19].

5.3 Dutch University Case Study

This study was conducted on the campus of a Dutch university. The goal of this study is to identify students' preferences for the availability of green areas. The study then looked at preferences for university indoor and outdoor spaces with and without greenery, as well as the perceived restoration likelihood of university outdoor spaces with and without greenery. The photographs were evaluated by 722 students in four categories: (1) standard design, (2) standard design with a bright poster, (3) standard design with a nature poster, and (4) standard design with a green wall. (5) A traditional design with a green wall and an indoor plant. The outdoor space at the institution has two designs: (1) the standard design and (2) the standard design with seats. (3) the traditional style with brilliant antiques (4) the conventional design with environmentally friendly components (5) the classic

design with loads of greenery. The offered stimuli for participants to rate are depicted in the image below. Each photo was tagged by the author, and each question was addressed in accordance with the labels.

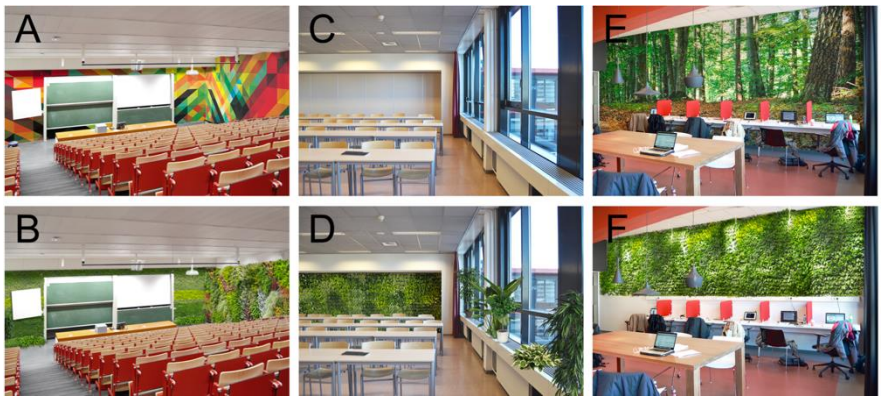

Figure 3 University Lecture Hall Redesign Alternatives

Interior design inspiration. A- colorful poster in the lecture hall; B -a green wall in the lecture hall; C- a standard classroom design; D- a green wall classroom with indoor plants; E -a nature poster study space; and F- a green wall study area.

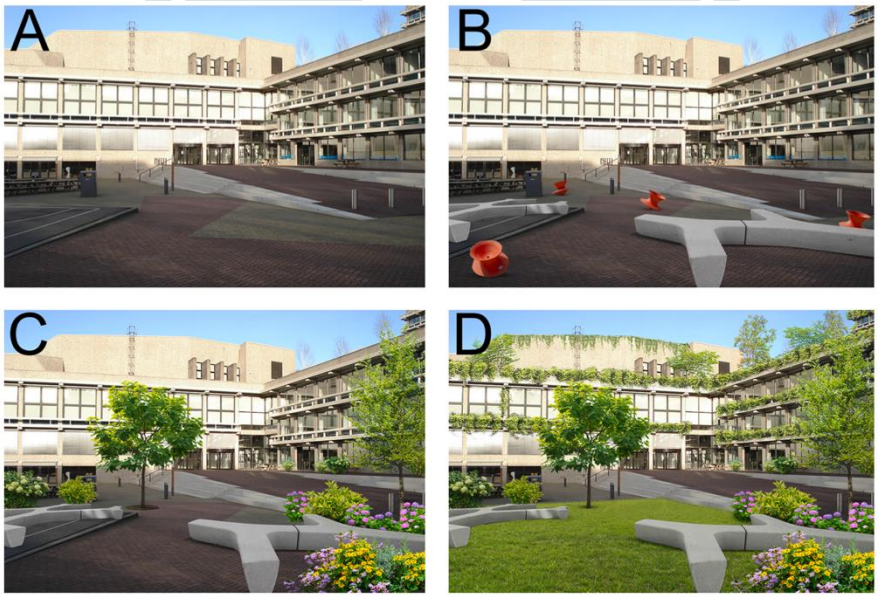

Figure 4 Outdoor Redesign proposed Alternatives

Outdoor area designs for universities. (A) Standard design; (B) Constructed seats with colorful antiques; (C) Built seating with green components; (D) Built seating with plentiful plants.

According to the data, students like and regard actual greenery and wildlife posters on campus to be more restorative than a standard design or a design with colors [11].

5.4 University of Chicago Student Wellness Centre, USA

The primary goal of this study was to improve students and faculty's cognitive performance and physical health while minimizing environmental effects through the use of biophilia. The designers began by replacing the furniture with more sustainable options in order to lower the danger of Volatile Organic Compounds (VOCs) in the air and to make the building a calm, restorative area for students to relax and focus on their studies. Furthermore, because daylight is an essential aspect of biophilic design, designers altered the lighting in the university building to create quiet places of leisure with warm in interior corridors, yellow lights, and sections ideal for productivity are lit entirely by white light. In addition, a plantation was added throughout the building to provide green areas for students' mental wellness. In addition to improving the building's internal environmental quality, the university saw a shift in students' cognition and performance as a result of these modifications. [20]

Figure 5 Physical Redesign for the Outdoor Space in the University Campus

5.5 British University in The United Kingdom

The study's major purpose is to see if being exposed to actual plants and a green hue helps visual and verbal creative thinking in classroom settings. The study included 108 business department students from a British institution. Participants were assigned at random to one of two groups: controlled or experimental. The experimental group was split into two subgroups: the first experimental group was placed in a classroom with no plants present and blinds drawn to block views of naturalistic environments, while the second experimental group was placed in a classroom with no plants present and blinds drawn to block views to nature but completed the creative thinking tasks on green paper. The second experimental group was kept in the same room as the others but was surrounded by living plants and had views of nature via the large classroom windows. Both groups' participants were directed to engage in creative tasks that required both visual and verbal originality. The findings show that exposure to natural vistas, plants, and the color green promote visual creativity but have no influence on verbal creativity in classroom settings after grading the replies of the two groups [21].

5.6 University of Exeter in the UK

The University of Exeter in the United Kingdom is one example of a university campus that has used biophilia to improve building thermal performance. To increase the thermal efficiency of its buildings, the campus has included a number of biophilic design features, such as natural ventilation, green roofs and walls, and thermal mass components.

Figure 6 Exeter in UK University Campus

The Forum building, for example, was built to be very energy efficient and to integrate biophilic design aspects. The structure has a green roof, which serves to insulate it and increase its thermal efficiency. The building also contains a variety of "sky gardens" that give natural light and vistas of nature, as well as a central courtyard that draws natural light into the center of the structure. A rainwater collection system and a green wall also serve to enhance interior air quality and create a visual link to nature.
The Forum building was certified as BREEAM "Outstanding," which is a widely regarded measure of a project's environmental efficiency. The Passivhaus standard, an internationally renowned norm for energy efficiency and environmental design, has also been given to the building. The approach to biophilic design and building thermal performance developed by the University of Exeter has been acknowledged as a paradigm for sustainable and energy-efficient design and has been highlighted in a number of publications and industry awards. It should be noted that the precise features employed and how they are included will be determined by the setting, geography, and special demands of the institution and its students. When building or assessing university spaces, a comprehensive approach that considers the interaction between thermal performance and biophilic design should be applied [22].

5.7 The University of Utah's

The research was conducted in the S.J. Quinney College of Law building. This structure was planned to be a sustainable design model with biophilic design components.
The building incorporates a variety of thermal efficiency methods, including
• A green roof, which helps to insulate the building and decrease the heat island effect.
• Natural ventilation decreases the demand for mechanical cooling while also improving interior air quality.
• Daylight harvesting decreases the demand for artificial lighting while improving thermal comfort.
• The use of thermal mass components, such as concrete floors, which aids in temperature regulation.

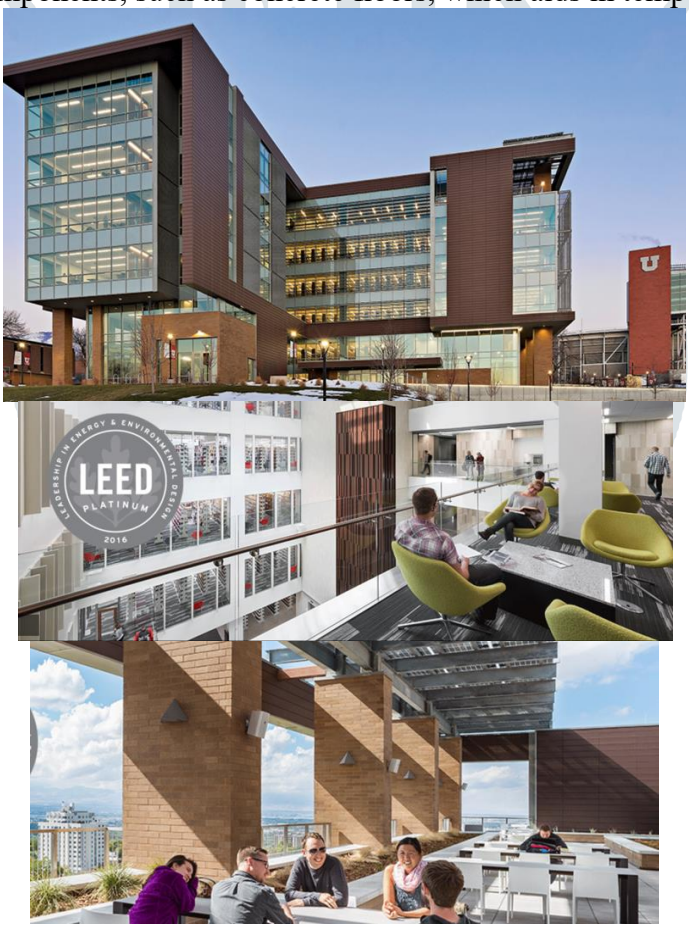

Figure 7 The University of Utah's

In addition to these efforts, the building contains a variety of biophilic design elements to promote the well-being of its users. Here are a few examples:
• A central courtyard that brings natural light into the building's heart.
• A green wall that improves indoor air quality and provides a visual connection to nature.
• A rooftop terrace that provides outdoor space and views of the surrounding landscape; and
• The use of natural materials such as wood and stone, help to foster a sense of connection to nature.
The structure was awarded LEED Gold certification, which is a well-known indicator of a building's environmental efficiency. Energy and water-efficient technology, the use of recycled and local materials, interior environmental quality, and architectural innovations were all included into the building's design and construction.

The University of Utah's S.J. Quinney College of Law building demonstrates how biophilic design and building thermal efficiency may be combined to produce a comfortable, healthy, and sustainable workplace for university students and employees [23].

5.8 The University of British Columbia's (UBC)

The case study took place in the Earth Sciences Building. This structure was planned to be a sustainable design model with biophilic design components. Any publicly owned building developments in British Columbia that are larger than 600 square meters must be LEED Gold certified beginning in 2008. UBC's green building rules are critical for ensuring that green building methods are implemented in a way that promotes UBC's sustainability goals.

The building incorporates a variety of thermal performance methods, including:

• A green roof, which helps to insulate the building and decrease the heat island effect; and
• Natural ventilation, which reduces the requirement for mechanical cooling while enhancing indoor air quality.
• Daylight harvesting, which reduces the need for artificial lighting and improves thermal comfort.
• use of thermal mass elements, such as concrete flooring, which helps to regulate indoor temperature; and • use of geothermal systems, which heat and cool the building by utilizing the earth's constant temperature.

Figure 8 The University of British Columbia's (UBC)

In addition to these indicators, the building incorporates a number of biophilic design features to improve the building's occupants' well-being. These include:

• A central courtyard that brings natural light into the building's core
• A green wall, which improves indoor air quality and provides a visual connection to nature
• A rooftop promenade, which provides an outdoor area and views of the surrounding landscape

The Earth Sciences Building at UBC was LEED Platinum certified, which is a well-recognized measure of a building's environmental efficiency. The building's design and construction incorporated sustainable elements such as energy and water-efficient technologies, recycled and local materials, indoor environmental quality, and architectural developments. This structure exemplifies how biophilic design and building thermal performance may be used in combination to provide a comfortable, healthy, and long-lasting environment for university students and staff. It also indicates that by considering a range of environmental aspects, a building may achieve a high level of sustainability and energy efficiency [24].

5.9 The University of North Carolina at Chapel Hill (UNC)

This building was intended to be a sustainable design model with biophilic design components. The construction includes a variety of measures to increase thermal performance, including

• Passive solar design, which uses solar energy to heat and cool the structure.
• Natural ventilation reduces the need for mechanical cooling while also enhancing interior air quality.
• Daylight harvesting decreases the demand for artificial lighting while improving thermal comfort.
• The use of thermal mass components, such as concrete floors, which aids in temperature regulation.
• The use of a geothermal system, which heats and cools the structure by utilizing the constant temperature of the earth.

Figure 9 The University of North Carolina at Chapel Hill (UNC)

In addition to these measures, the building incorporates a number of biophilic design elements to improve the well-being of its occupants.

• A central courtyard that allows natural light to enter the core of the building
• A green roof that enhances insulation and decreases the heat island effect
• A rooftop terrace with outdoor space and views of the surrounding terrain.
• The use of natural materials such as wood and stone, which assist to create a sense of connection to nature; and
• The incorporation of natural features such as rock, water, and plant into the building's design.

The UNC Green Building was awarded LEED Platinum certification, which is a well-recognized indicator of a building's environmental efficiency. The design and construction of the building include ecologically friendly components such as energy and water-efficient systems, the use of recycled and local materials, indoor environmental quality, and architectural innovations.

This structure exemplifies how biophilic design and building thermal performance may be used in combination to provide a comfortable, healthy, and long-lasting environment for university students and staff. It also indicates that by considering a range of environmental aspects, a building may achieve a high level of sustainability and energy efficiency [25].

6 Discussion

As concluded from the international case studies provided there are main characteristics that studies have verified have a direct favorable influence on student performance. These aspects are **visual connection with nature, water presence, dynamic and diffuse light, natural system connection, material link to nature, prospect/refuge, and thermal and airflow variation**.

Visual Connection to Nature: Connecting with nature has been shown to have several benefits for university students' cognitive function and overall well-being. Here are some ways in which nature connection can positively impact students in universities:

• Improved mental health: Nature exposure has been linked to reduced symptoms of anxiety, depression, and stress. Studies have shown that spending time in green spaces or even viewing nature from a window can improve mood, reduce cortisol levels, and increase feelings of relaxation and well-being.

• Increased creativity: Exposure to nature has been shown to enhance creative thinking and problem-solving abilities. Studies have demonstrated that nature walks or simply being in a green space can improve cognitive flexibility, divergent thinking, and imaginative capacity.

• Enhanced attention and cognitive performance: Exposure to nature can also improve attention and cognitive function. Studies have shown that viewing natural scenery or taking a nature walk can improve working memory, attentional control, and task-switching abilities.

• Increased physical activity: Connecting with nature can also encourage physical activity and exercise, which can have numerous benefits for physical and mental health.

• Improved social connections: Nature-based activities and outdoor experiences can also provide opportunities for social interaction and community-building, which can enhance social support and promote a sense of belonging.

In summary, connecting with nature can have significant benefits for university students' cognitive function, mental health, and overall well-being. Therefore, universities should strive to incorporate nature-based activities and experiences into their curriculum and campus design to promote a healthy and thriving student body.

Dynamic and Diffuse Light: Daylight plays a crucial role in promoting the cognitive function and well-being of students in universities. Several studies have demonstrated that access to natural light and exposure to daylight positively impact students' academic performance, alertness, and mood.

One of the main benefits of daylight exposure is that it helps regulate the body's circadian rhythm, which affects the sleep-wake cycle and influences the ability to concentrate and learn. Exposure to natural light during the day can also enhance mood, reduce stress levels, and improve overall health and well-being.

Additionally, daylight exposure has been linked to improved memory and cognitive function. Studies have shown that natural light can increase attention and alertness, leading to better performance on tasks that require concentration and focus.

In contrast, inadequate access to daylight can have negative consequences on students' cognitive function, mental health, and academic performance. For instance, poor lighting conditions can cause eye strain, headaches, and fatigue, leading to reduced productivity and increased stress.

Therefore, providing students with access to natural light and optimizing daylight exposure in university settings can have a significant impact on their cognitive function, academic performance, and overall well-being.

Natural System Connection: When compared to equivalent time spent outside in urbanised surroundings, as little as 10-20 minutes spent sitting or wandering in nature had a positive effect on the mental health of college-aged individuals. Although while green campuses are designed to attract students, the health advantages gained from interactions with and within campus landscapes, particularly in a post-pandemic environment, are still little understood. Students are frequently uninformed of the ecological significance of green areas on their campuses, despite the fact that their choice of university is heavily influenced by impressions and evaluations of outdoor spaces. Campuses provide extraordinary opportunities for place-based learning, which may be supplemented by the possibility of strong relationships with, and usage of, their green spaces. In order to establish what sorts of accessible and sustainable "doses" of nature have a good influence on mental health, researchers must first comprehend the mechanisms via which students perceive, feel, and emotionally relate to campus nature. We define connectivity as passive and active involvement with natural components and features on campus, and we claim that these processes help students connect on numerous levels.

Material Link to Nature: According to the Biophilia theory natural materials and designs, textures, or colors, when inspired by nature, can alter our feelings with a beneficial physiological consequence. For example, using wood in the interiors can lower blood pressure and increase the sensation of coziness. In schools, wood can be used for desks, seats, floors, and shelving. In addition to natural patterns, the inclusion of natural materials in learning settings gently improves nature connectivity and prevents classrooms from being isolated from their surroundings. Natural materials provide non-rhythmic sensory stimulation, place attachment, and pleasant working environments.

Prospect/Refuge: Prospect tries to offer a favorable atmosphere for a visual scan and consideration of the surrounding environment for both opportunity and hazard. This pattern is related to increased comfort and feeling safe and is believed to alleviate stress, boredom, irritability, and weariness. Prospect conditions may be created by providing focal lengths of more than 20 feet and restricting partition heights to 42" while employing transparent materials, balconies, and open floor layouts. As humans have developed in an adaptive response to the complementary benefits of these environments, refuge gives protection and security and is intimately related to prospects. Places with Refuge conditions seem safe and distinct, and they are connected with enhanced focus, attentiveness, and safety perception. Some design considerations that may help with this pattern include covering sides, complete concealments, ceiling heights, weather, and climate-protected rooms.

Thermal and Airflow Variation: Operable windows should be utilized in classrooms and other locations where students spend any length of time learning to provide natural air, which has been proven to improve comfort as well as cognitive performance. Prior to restoration, surveys and testing should be conducted to assess the present indoor environment quality in learning spaces, and better circumstances should be constructed. Improved ventilation has been shown to increase cognitive function scores, and moveable windows promote the biophilic pattern of non-rhythmic sensory stimulation and stimulate the experience of multi-sensory parts of nature, which improves repair more efficiently. Nature vistas, olfactory components of nature, and auditory parts of nature may all be accessed through operable windows.

Table 1-1 Comparative Analysis for Case Studies

Case Study Name	Location	Reference	Aim	Biophilic Attributes	Building Thermal Performance Attributes	Methodology	Setting	Results
Turkey and United State Universities	Turkey and United States	(Gulwadi G. , et al. , 2019).	Comparitive analysis to identify the biophilic attributes that can enhance students performance in different cultures	Presences of greenery Presences of natural views Presenee of water Feature	Applying natural lements near acadmenic building to reduce (noise, traffic, climate) Pollution	Questionnairs Based on Percieved restorivness scale (PRS) SPSS was used for Data analysis	University campus: Academic Buildings	Results shows that students pperformance was enhanced in the two different cultures after applying biophilic attributes
Dutch University Case Study	Dutch Land	(Bogerd N. ,et al., 2018).	Exploring the diffrence between the availibility of the green color and physical plantation on students performance.	Green walls Green Colors Green Posters		Students were divided into three different groups providing the three main settings and then Questionnairs provided to Students (PRS) where analyzed through SPSS	University campus in the dutch land	Actual greenery and nature posters in the university environment are preferred and percieved as more restorative by students than the standard design or a design with colors
University of Chicago Student Wellness Centre	USA	(Pintos, 2020)	Enhance the cognitive and performance for student through biophilic design and minimizing building environmental impact	Natural Lighting Plantation Inside the building Views and Vistas		Comparing students results before and after appling the biophilic elements	University Campus	Students perofomance were enhanced as well as indoor environmental quality
British university	United Kingdom	(Studente, Seppala, & Sadowska, 2015)	Identifing either the green color or the physical plantations have impact on students performance	Plantations		Selcted partiepants was divided into controlled group and experimental group then both group took visual tasks in the two different settings the psychological testing took place	University Campus: Class rooms	Access to natural views, plants, and the color green increase visual creativity
University of Exeter	UK	(Exeter University, 2014).	To achieve a sustainable building through the use of biophilic attributes	Natural light Views of nature Green wall	A central courtyard Green wall Rooftop terrace (views and vistas) Use of natural materials	Physical change in the selected building and comparing the impact of students actual performance before and after applying biophilic attributes	University Campus	The building waws LEED Certified and got award from Passivhaus standard.
University of Utah's: S.J. Quinney College	Utah	(Utah Construction and Design, 2015).	To achieve a sustainable building through the use of biophilic attributes	A central courtyard Green wall Rooftop terrace (views and vistas) Use of natural materials	A green roof, Natural Ventilation,Daylight Harvesting, Use of thermal Math elements	Physical change in the selected building and the building was recognized for the diffrence in energy consupnution	University Campus: Law building	The building waws LEED Certified.
The University of British Columbia's (UBC)	Columbia	(University of British Columbia, 2016).	To achieve a sustainable building through the use of biophilic attributes	A central courtyard Green wall Rooftop terrace (views and vistas) Use of natural materials Use of geothermal system	Energy and Water-efficient systems, Use of recycled and local materials, Indoor Environmental Quality, and Innovations in Design		University Campus	LEED Platinum certification, which is a widely recognized measure of a building's environmental performance enhancement in students and staff productivity was reognized
The University of North Carolina at Chapel Hill (UNC)	North Carolina	(Cates, et al., 2014).	To achieve a sustainable building through the use of biophilic attributes to enhance building thermal performance	A central courtyard Green wall Rooftop terrace (views and vistas) Use of natural materials Use of geothermal system			University Campus	The Green Building at UNC was awarded LEED Platinum certification

7 Conclusion

Finally, while creating university facilities, biophilic design and students' performance are also critical things to consider. These two factors can work together to produce surroundings that are comfortable, healthy, and long-lasting, promoting well-being and cognitive function in university students and employees. University spaces can be designed to create a connection to nature, enhances student well-being, and enhance cognitive performance by incorporating natural ventilation, thermal mass elements, natural daylight, and natural materials, as well as elements such as plants and greenery, water features, and views of nature. The University of Exeter, the University of California, San Diego, the University of Utah, the University of British Columbia and the University of New South Wales Design, Architecture, and Building studio, and the University of North Carolina at Chapel Hill Green Building all demonstrate how biophilic design and building thermal efficiency can be integrated to create high-performance, sustainable, and healthy buildings. It is critical to note that while planning and assessing building

thermal efficiency and biophilic design, a holistic approach that takes into account the institution's and student's unique needs, as well as the climate and location, should be used.

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