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Biophilic Design for Restorative University Learning Environments: A Critical Review of Literature and Design Recommendations

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Abstract: The influence of environmental design on people’s wellbeing and productivity has been well studied in some settings such as offices, hospitals, and elementary schools, but salutogenic and biophilic design in urban post-secondary educational environments remains understudied and warrants closer investigation. There are unique challenges faced by these students and implementing health promoting and restorative, environmental design strategies could improve the quality of life and learning outcomes of university students. This paper identifies pertinent themes in published multi-disciplinary literature relating to the influence of the built environment on university students: emotional stress, happiness, stimulation, cognitive function, social support, belonging, places to study, lighting, and ventilation. The results of the semi-structured literature review identifies, analyzes, and categorizes relevant studies that examine nature views, nature images, natural colors, natural materials, auditory and olfactory aspects of nature, nature images with water, indoor plants, campus landscapes, study spaces, local materials and style, daylight access, and thermal and environmental comfort. These are organized according to the biophilic patterns identified by Browning, Ryan, and Clancy. Trends and gaps in understanding the influence of biophilic design on university settings are discussed, and the paper identifies evidence-based design recommendations for incorporating biophilic design in university settings.

Keywords: biophilic design; biophilic patterns; architectural design; university campus; learning environments; wellbeing; restorative environmental design; salutogenic design

1. Introduction

Biophilia is defined as people’s innate affinity to the natural world, and it has been explored in psychology and sociology since the 1980s [1]. In architecture and design, there has been a growing and recent interest in the impacts of nature on people in buildings [2,3] and in the past decade, there has been a significant increase in published peer-reviewed design research relevant to biophilic design [4–6]. In parallel there has been a growing interest both in architectural practice and in academia relating to better understanding the impacts of buildings and indoor environments on people’s health and wellbeing. The World Health Organization cites depression and mental health issues as the leading cause of disability worldwide [7] and since people spend 90% of their time in buildings [8], environmental design presents challenges and opportunities for designers.

In the context of COVID-19, there is increased anxiety around indoor environments and an urgent focus on creating spaces that promote emotional and physical health. Student and instructor behavior and interactions in university learning environments are changing rapidly; for example, many campuses are mandating online learning, social distancing, and for in person instruction, smaller

groups meetings [9]. While this is not the focus of this paper, it is worth noting that as universities move to reopen, or to integrate hybrid in-person and virtual teaching models for many classes, the design and qualities of the environments where face-to-face interactions take place takes on a special importance. With many aspects of university education being able to be successfully delivered online, such as large undergraduate lecture courses, the campus experience needs to offer something the digital world cannot, it needs to be “worth it” for students to make the effort and risk of gathering in person. Studies have shown that there are physiological and psychological health benefits to environments that incorporate biophilic design attributes such as higher than required levels of daylight, carefully placed windows to frame views outside, appropriate variety in lighting levels, using natural materials, bringing nature indoors by incorporating plants, utilizing green roofs, and maximizing green spaces around buildings [10]. University environments that incorporate these biophilic design elements could maximize the restorative qualities of the environment [11,12], helping students feel less stress, and be able to focus on their learning.

The vast majority of biophilic design studies to date have focused on the design of workplaces, elementary schools, and healthcare environments such as nursing homes or hospitals. More specific studies have examined benefits of biophilic design for extreme climates [13], at the scale of urban design [14], in the context of energy savings and climate change [15], and most recently relating to nature connectedness and COVID-19 [16]. However, there is a lack of research on the benefits of biophilic design in university settings. This paper has three main aims which focus on the urban university setting. First, this paper identifies and analyzes several established environmental psychology theories that can be related to the impact of the design of learning environments. These theories are used to better understand the benefits of biophilic design in learning environments: Place Attachment Theory, Restorative Environmental Design, Attention Restoration Theory, Stress Reduction Theory, and Prospect-Refuge. Second, this paper analyzes and summarizes recent literature relating to biophilic design and nature connectedness with a particular focus on studies that are relevant to university learning environments. This paper draws on studies from numerous fields including architecture, engineering, and psychology that have shown that biophilic design benefits mental health, enhances creativity, improves productivity, and creates more comfortable spaces for learning (see Table 1). Finally, this paper presents evidence-based design recommendations for incorporating biophilic design in university settings.

Specific Challenges for University Students in Their Environments

Over 1 million undergraduate students are currently learning at Canadian university campuses [17]. The transition from a secondary to post-secondary learning environment is important for students and is linked to increased independence and maturity. However, studies also show it is a time of uncertainty that affects mental health and academic productivity in a way that is unique to this demographic group. Numerous studies have identified mental health issues as a major obstacle for university students. In fact, studies show university students experience higher depression rates than the general population [18] and they experience uncertainty stress, study-related stress, family stress, and financial stress [19]. In addition, university is a competitive learning environment and there are high academic expectations [20] that cause the stresses to become more difficult to manage for many students. There are also personal stresses of identity, relationships, and living situations [21]. Incorporating elements of biophilic design in learning spaces can positively support university students, creating environments that are stress reducing, and enhance creativity and cognitive development.

There are numerous studies about productivity in office buildings [22,23], and the requirements for university learning environments are similar, but not the same. For example, university students often attend a variety of lectures and workshops on campus on any given day, and could be traveling between buildings to get to classes and learning in a number of different spaces in the course of their day. There are also differences between office workers and students relating to expectations, motivation, and addressing diverse learning needs. University classrooms must be optimized for a wide variety of

visual tasks such as participating in lectures, collaborating in group work, writing exams, observing demonstrations, note taking, viewing blackboards and slides, participating in discussions, reading handouts, and using technology [24,25]. Recent studies have evaluated the perceived comfort of study facilities in terms of lighting, spatial, and indoor air quality in classrooms [26–30]. Not only lighting, but also air quality and thermal comfort play significant roles in the quality of learning environments. Indoor air quality in classrooms has been shown to be a major indicator of comfort and productivity in classrooms (and is directly related to the learning efficiency of students and hence must be optimized [30,31]).

2. Materials and Methods

2.1. Multi-Disciplinary Literature Review

The concept of biophilia is relatively new and studies are emerging in a number of fields and hence the studies examined in the literature review span multiple disciplines. The papers analyzed in this study were selected because the authors found they incorporated biophilic ideas, but did not always directly address the term “biophilia” or “biophilic design”. Critically analyzing the biophilic elements and theories, as defined by Kellert [3] and Browning, Ryan, and Clancy [10], for their applicability to university settings informed the criteria for inclusion of studies in our findings. The research strategy referenced the individual biophilic elements or theories within studies that examined university students in learning environments. The semi-systematic review yielded thematic findings and contributed to the categories of stress reduction, happiness, stimulation, cognitive function, social support, belonging, and physical comfort that defined the scope of challenges and biophilic benefits for students in the university setting. These are categorized according to the biophilic patterns identified by Browning, Ryan, and Clancy [10] in order to establish common areas of implementations and make the comprehension and potential applications of the research more accessible.

2.2. Relevant Theories in Environmental Psychology

This paper considers biophilic design through the lens of both environmental psychology and architectural design, and identifies six theories that are particularly applicable in providing context for this literature review.

2.2.1. Restorative Environmental Design (RED)

The aim of RED is to recover and replenish people’s emotional resources and to support people through times of stressful mental activities or in environments with potential distractions [11]. RED purports that Directed Attention resources are needed for strenuous activities that require concentration and alertness. Studies shows that people’s Directed Attention resources recover better in nature [11]. Directed Attention is needed for prolonged mental activity, problem solving and being able to take a step back from problems and make adaptive and effective decisions [11]. University learning spaces can be restorative and help replenish student attention resources. The concept of “Restorative” spaces describes those that contain the properties of being away, extent, fascination, and compatibility [32] and that liberate us from stressors and replenish our Directed Attention resources.

2.2.2. Place Attachment Theory

Place Attachment Theory is connected to a person’s sense of ease and adjustment to a particular place. This is often defined as a link between an individual and a place [31] and a place having “a sense of community” or “a sense of place”. The human experience of any environment is more than just the visual or sensory aspects, as emotional connections are tied to memories that our influence attachment to place [33]. Universities aim to foster social relationships and to facilitate student adjustment and school pride. A campus can be thought of as a neighbourhood [33] that must establish place bonding in order to encourage students to stay near the campus and utilize its facilities. Place Attachment also

has a role in development of a student's identity [31], personal growth, relaxation, psychological and physical comfort, belonging, freedom, and connection to nature [34].

2.2.3. Attention Restoration Theory (ART)

ART is a theory relevant to biophilic design in university settings as it relates to the fatigue of attention and depletion of cognitive resources which commonly occurs in learning environments [35]. ART requires the recognition of attention as a resource and the understanding that attention aids in adaptability to the environment and to completing tasks [11]. Directed Attention abilities are vulnerable to fatigue and reduced performance if used for a sustained period, and any loss of these resources results in fatigue and stress [11]. Studies have shown that nature can not only calm but also stimulate the mind to continue working, improving wellbeing and performance [11,36].

Recent studies have explored the links between nature and creativity. Researchers have examined the creative process and divided it into four stages: preparation, incubation, idea generation, and evaluation [37]. During the incubation phase, experiences that use few Directed Attention resources, providing what is called "soft fascination" in nature, which uses few Directed Attention resources, should be used for restoration of attention control [37]. Exposure to nature has been shown to promote positive mind-wandering or daydreaming [37] and creativity [38]. For example, in one study, after four days of immersion in nature, and disconnection from multi-media and technology, participants scored 50% higher in creativity and problem solving compared to a control group [39]. While urban university settings cannot provide immersion in nature on campus, it is worth recognizing not only preferences but also improved scoring of nature settings by participants in studies relating to nature and creativity. Enhancing the environment to foster creativity is an important issue that can be tackled by biophilic design.

2.2.4. Stress Reduction Theory (SRT)

Like ART, SRT relates to restoration and identifies the benefits of natural outdoor environments after excessive psychological and physiological arousal, or excessively low arousal [40]. SRT also considers the element of fatigue, but as a result of emotional stressors [40]. Positive changes have been shown to occur in physiological systems, behavior, emotional states, and cognitive functioning as a result of nature exposure [40]. This theory established the groundwork for later studies that assessed benefits of other forms of nature such as images, smells, and nature views regarding stress recovery in a variety of settings.

2.2.5. Prospect-Refuge Theory

Prospect-Refuge Theory developed in landscape aesthetics relating to people's preferences for certain kinds of spatial experiences and argues that specific kinds of spatial configurations defined as "Prospect" and "Refuge" are natural, inborn evolutionary preferences that all people experience [41]. Prospect is defined as the idea that people have a natural preference of clearings that allow surveillance and view of potential threats [41]. The concept of Refuge is that people seek out protected spaces away from activity where they can retreat. For example, people may seek out a privileged view down onto a place that gives a sense of Prospect or look out, and also require the choice of being able to stand back and observe a scene in a protected view can be a sense of Refuge. This concept can be applied to preferences in multiple spaces including in university environments [42]. Prospect-Refuge can be utilized in the design of interior spaces like classrooms and social areas or they can be present in outdoor views such as viewing decks or balconies. Prospect-Refuge are patterns in biophilic design as they serve inherent human needs and spatial preferences similar to that of nature connectedness, and RED [10].

3. Results

3.1. Review of Studies Specific to University Settings

A main finding of the literature review is that published studies conducted in or about university students and campus settings are lacking in design-specific findings. Instead, there are many discrete studies of certain environmental design parameters that are relevant, yet few holistic studies of university campuses or learning environments. Studies that relate specifically to qualities of biophilic design in university settings are presented in Table 1 and organized the relevant biophilic patterns [10]. As expected, almost all of the relevant studies we identified did not include reference to “biophilia” or “biophilic design” nor did they mention the biophilic patterns we have used to categorize them. Themes in the conclusions of the studies were analyzed and coordinated based on the closest biophilic pattern that described them. Eleven of the fourteen patterns we identified as most applicable to the research questions are: (1) Visual connection with nature; (2) Non-visual connection with nature; (3) Non-rhythmic sensory stimuli; (4) Thermal and airflow variability; (5) Presence of water; (6) Dynamic and diffuse light; (7) Connection with natural systems; (8) Biomorphic forms and patterns; (9) Material connection with nature; (11) Prospect; and (12) Refuge. The four patterns of (10) Complexity and order; (13) Mystery; and (14) Risk/peril have far less published material available on this topic, and we found no relevant sources on these patterns in university settings.

Table 1. Identification of Relevant Literature Relating to Biophilic Design Specific to University Settings and Participants.

Peer-Reviewed Papers	Biophilic Patterns	University Setting	University Student Participants
Yang et al., 2019 [19]	1	✓	✓
Tennessen, C.M., Cimprich, B., 1995 [43]	1	✓	✓
Hami, A., Abdi, B., 2019 [44]	1,5	✓	✓
Gulwadi et al., 2019 [45]	1,2	✓	✓
Windhorst, E., Williams, A., 2015 [46]; 2016 [47]	1,3	✓	✓
Stigsdotter et al., 2017 [48]	1,2,3		✓
Van den Berg, A.E., Jorgensen, A., Wilson, E.R., 2014 [49]	1		✓
van den Bogerd et al., 2018 [50]; 2020 [51]	1	✓	✓
Studente, S., Seppala, N., Sadowska N., 2016 [52]	1	✓	✓
Felsten, G., 2009 [32]	1,5,8	✓	✓
Nisbet, E.K., Zelenski, J.M., 2011 [53]	1	✓	✓
Putri, N.T., Amrina, E., Nurnaeni, S., 2020 [54]	1,9	✓	✓
Kaya, N., & Epps, H.H., 2004 [55]	1		
Chow, K., Healey, M., 2008 [56]	1,2	✓	✓
Qingjiua, S., Malikia, N.Z., 2013 [33]	1,2,9	✓	✓
Berman, M.G., Jonides, J., Kaplan, S., 2008 [57]	1		✓
Gladwell et al., 2012 [58]	1		✓
Roetzel et al., 2019 [59]	1,11,12	✓	✓
Jahncke et al., 2011 [60]	2		
Song, C., Ikei, H., Miyazaki, Y., 2019 [61]	2	✓	✓
El Asmar, M., Chokor, A., Srour, I., 2014 [27]	4	✓	✓
Marchand et al., 2014 [28]	4	✓	✓
Shi et al., 2017 [62]	4	✓	-
Mallen et al., 2020 [63]	4	✓	-
Cha, S., Kim, T., 2015 [30]	4	✓	✓
de Rubeis et al., 2018 [64]	6		-
Hui, S.C.M. and Cheng, K.K.Y., 2008 [26]	6,7	✓	-
Bellia, L., Pedace, A., Barbato, G., 2013 [65]	7	✓	-
Ridoutt, B.G., Ball, R.D., Killerby, S.K., 2002 [66]	9		✓
Kim, T., Cha, T., Kim, Y., 2018 [29]	11,12	✓	✓

3.2. Strength of Research Supporting Biophilic Design in University Settings

Our review found a large number of studies and strong evidence for the benefits of visual connection to nature in university settings. Studies show multiple avenues of visual biophilic implementations such as views of landscapes and green views through windows [59], nature posters [50], images [49], murals [32], indoor plants [51,52] the color green [52], and nature walks [43,46–48]. A recent study found that images of nature can help recover students’ Directed Attention resources [58]. Our study found almost no published studies relating to the integration of water elements in university design, other than in water images or sounds separately. Studies found simulated sounds of birds and

water are proven to speed up Directed Attention recovery times after stressors as tracked through physiological changes [67]. The images of a nature in murals depicting water were perceived to be the most restorative [32] and images of a study area with a water feature were found to be preferred [44]. Preference studies found that students prefer natural colors like green, blue, and yellow [55] and wood materials for furniture in work spaces [66], reinforcing preferences for natural materials. When given options of potential lecture classrooms, students preferred posters depicting nature over colorful murals [50]. The research pertaining to these biophilic design strategies is spread across a wide range of discrete studies that are largely in the field of environmental psychology.

In considering the role of biophilic design in university settings as promoting a sense of place, there is some evidence that suggests that nature can help shape an overall feeling about an environment. Studies that looked at campus features determined that Place Attachment was an important aspect of the university experience and it correlates to a student's happiness with the campus [33]. Place Attachment was found to be achieved primarily through campus landscapes, pace of life, resources, and cultural events according to students [33]. Students who reported higher levels of nature connectedness were also found to be innovative and holistic thinkers [68]. Furthermore, a recent study found that university students prefer to study in "refuge" spaces that provide "prospect" views to experience privacy, security, and stimulation [59].

Some studies focus on the comfort and wellbeing of students in university settings; however, these studies are not usually designed to inform biophilic design. Studies show that lighting systems in university settings can help to make a classroom environment attractive and pleasant, reinforce feelings of spaciousness, delineate areas, stimulate learning, and improve learner behavior [69,70]. Students in classrooms with natural daylight perform better than those without [71,72] and varying levels of light are reported to stimulate visual interest [25] and therefore engagement. Indoor air quality in classrooms is shown to impact perceived comfort and student productivity while learning. Studies show the benefits of intentional arrangement of classroom activities in order to reduce humidity as a result of human heat radiation and breathing, and to account for better air conditions for learning near windows and in the middle of the classrooms [62]. Carbon dioxide levels in classrooms can also be improved with natural ventilation [62,73]. In addition, a study in a university setting found that vegetation was an effective mediator of microclimate [63], while in a general study, it was found to also be effective in the perception of environmental noise [74].

While not relating specifically to university students, during the course of this study, we found there are many studies of biophilic design that examined other groups of people with relevant findings. For example, in many building types and settings, with different subject groups, studies have shown evidence of people's restoration through green views. The effects of nature connectedness in some groups of people is well studied, but not specifically relating to university students. For example, there are relevant studies on the effects of nature connectedness on participants with depression [12], and Attention Deficit Hyperactivity Disorder (ADHD) [75].

Our review found almost no studies examining the biophilic design pattern of Non-rhythmic sensory stimuli, which can be defined as "stochastic and ephemeral connections with nature that may be analyzed statistically but may not be predicted precisely" [10]. Examples of non-rhythmic sensory stimuli include the sound of rustling leaves, swaying grasses in a field, rippling water and it appears that these qualities are not often examined in university settings as sensory nature conditions are more often simulated for more general studies. In addition, we found no examples of studies regarding the biophilic patterns of Complexity and order, Mystery, and Risk/peril in university settings.

3.3. Benefits of Biophilic Environmental Design Specific to Challenges Faced by University Students

University students experience certain specific physical and psychological consequences of stress that impact their quality of life. Implementing biophilic design patterns in university campus settings can be used to address some of these (Table 2).

Table 2. University Student Challenges and Biophilic Design Patterns.

University Student Quality of Life [76]	Biophilic Design Patterns [10]
Physical Health Stress—University students experience unique stressors [16,17,67,77–79] Stress raises blood pressure [58] and hemoglobin [61] The noise of a busy campus can influence cortisol levels if not mediated [60]	Visual —Nature spaces/trails [46–48], views [61], posters [50], photos [49,58], and colors (green, blue, and yellow) [55] Non-Visual —Visual, auditory [60], olfactory elements of nature [61] Presence of Water —Nature murals with water [32] Biomorphic Forms and Patterns —Nature murals [32]
Psychological Wellbeing Happiness—University students experience higher rates of depression than the general population [18]. Stimulation—Fostering creativity prepares students for the workforce [80] Cognitive Function—University students experience mental fatigue that affects academic performance [32]	Visual —Campus landscapes can improve students' happiness [33] Green views, indoor plants, and the color green improve visual creativity [52] Nature images [51], window views [43], or walks can result in cognitive improvements [57] Non-Visual —Peacefulness of nature provides attention restoration [57] Material Connection with Nature —Natural materials (wood and ornamental stone) [54,66] are preferred by students
Social Relationships Social Support—Social supports may buffer against college student suicide risk [81]; Commuting and minority students [81] may feel less socially involved [33] Belonging—University settings are places of transition [34] and many students fail or withdraw due to adjustment issues [82]	Visual —Nearby green features may provide social support [46]; convenience of green spaces directly around buildings also important [45] Campus landscapes that provide pleasant natural views may enhance Place Attachment [33] Material Connection with Nature —Students prefer local materials and local styles as it creates a sense of place [54]
Environmental Comfort Places to Study—70% Canadian students prefer to study in their rooms [83] Campus spaces lack group environments resulting in 'space rejection' [29] where space, crowd, and noise are issues [30] Lighting—University requires diverse visual tasks and technology use [24] Ventilation—The indoor environment is directly related to learning efficiency and health [62]	Prospect-Refuge —Preference for refuge study spaces with nature-connected Prospect views [65] Presence of Water —Study areas with a water feature were preferred by students [44] Dynamic and Diffuse Light —Lighting makes a classroom more pleasant [69,70] and daylight improves student performance [71,72] Connection with Natural Systems —Circadian lighting synchronizes the biological clock [65] Thermal and Airflow Variability —Natural ventilation reduces carbon dioxide levels so air quality nearer to the operable windows may be best for learning [62]

4. Discussion

Studies analyzed in this literature review to determine the influences of various biophilic design concepts and implementation used three main approaches. There were in-person studies that tested the benefits of nature views and allowed the participant to experience the physical environment and then surveyed or tested the participant about their preferences before and after. Another type of study involved a digital simulation of an environment in unrelated classrooms or offices and then based on the simulation, participants were surveyed or tested. For example, a paper by Emamjomeh, Zhu and Beck (2020) examined people's responses to working for short periods of time in biophilic or non-biophilic spaces using a head-mounted device to create an immersive virtual environment [84]. The most common format was to show the participant the environment through photos, videos, or slideshows and then based on this, survey or test the participant about their experience. Some studies conducted tests before and after the experimental factors in order to determine effectiveness against a control. The types of tests taken were preference surveys, mood and wellbeing surveys, creativity tests, sensors of daylight or temperature, or collection of physiological data such as heart rate and cortisol levels. With preference studies and surveys, there is a risk that people report that they prefer a certain environment or attribute, and then their actual behavior will not match the report. We did not find that studies on preferences adequately accounted for the gap between what people say they want and what they choose in the moment. We conclude there is a need for studies that ask students about relevant biophilic design preferences and then follow up with a study of what factors influence or alter the student's perceptions or choices in a real context. This would allow for more comparable and reliable findings.

Generally, research about biophilic architecture is rarely studied through people engaging with actual experiences and is mostly examined through images of options for biophilic spaces. This is not ideal because biophilic design concerns far more than visual qualities and is multi-sensory and context-specific. Entire experiences of spaces should be studied in order to obtain more accurate results regarding restorative effects of nature connectedness. In addition, in evaluating the success of learning

environments, care should be taken that the surveys or tests are relevant. Cognitive and creativity tests and questionnaires are used to conclude on the most basic level that these aspects of the learning environment can be improved with biophilia. Instead, evaluating Attention Restoration and creativity during activities that are already occurring in classrooms could be more effective and applicable to the demographic. Areas of research that should be examined in university settings are biomorphic forms, fractals, natural materials, and social connectedness in classroom and campus environments. In some studies, the overall campus conditions are examined; however, ordinary classroom settings and lecture spaces are rarely studied. Future research should examine the qualities of these spaces and test biophilic interventions to better understand the potential impacts on students and their learning.

4.1. Approach to Biophilic Design Guidelines Based on Literature Review

Given the variety of different sizes and qualities of buildings and spaces, the university campus can be considered as a community or neighborhood. The biophilic implementations should not only be considered for classrooms or other learning environments as there are many more relationships and activities impacting quality of life in campus. Transition spaces and areas in and between classrooms and buildings help form an experience of a place and should be acknowledged by designers. Isolation of biophilic design elements in specific parts of a campus will decrease the impact and the beneficial qualities.

While the paper considers fourteen biophilic design patterns to organize information and themes, we have translated the findings into design guidelines that holistically encompass these design values. Research has shown that multi-faceted and multi-sensory experiences of nature are the most effective in terms of restoration. It is important for designers to understand that biophilic design, much like nature, works together to create experience.

4.2. Considerations for Evidence-Based Design Guidelines for Biophilic Design in University Settings

The qualities of a university setting are dependent on numerous qualities and contexts. Universities in different countries and even different parts of a country will have different needs and different expectations. There are urban and suburban campus environments and in each, students may have specific concerns and needs. The design guidelines in this paper are focused on universities in an urban environment and are concerned about the impact of the surrounding city on the comfort, belonging, and safety of the campus.

Universities consist of a large variety of spaces and activities. There are academic buildings such as buildings containing lecture halls, classrooms, study rooms, and libraries. Recreational facilities for wellness and sports teams exist in indoor and outdoor spaces. Certain buildings on a campus would be designated for extracurricular activities and student support. Residential buildings for student housing also commonly exist in a campus environment. There are also restoration and place-defining spaces such as central courtyards, campus landscapes, and social spaces where events may be held. Another important aspect of the university setting are spaces within the campus that do not always feel pleasant or secure, such as alleys, building facades without windows, and spaces at the edges of the campus that are exposed to the surrounding city.

The university setting also includes a variety of occupants on the campus. There are professors, researchers, staff, students, and in some spaces, the general public. The variation in occupants influences not only the types of spaces but also how and when the spaces are used. Students spend a certain amount of time in a building for a class while a professor may be spending an entire day there teaching classes. Other university staff may be required to stay late in certain buildings after classes are over. In a specific classroom space, students will have different needs to a professor. From the student perspective, seating arrangement, views, and lighting may be a priority in design. An instructor may require certain spatial qualities for a lecture and lighting that benefits both the instructor's lecture notes as well as a projection at the front of a room.

4.3. Design Guidelines for the Biophilic Renovation of University Learning Environments

In North America, many university campuses were built in the 1960s and 1970s and are now undergoing renovation for various reasons including improving building performance. The development of design guidelines regarding specific biophilic design elements for universities may help link the scientific research with practical application. In the context of COVID-19, as mentioned, the atmosphere and purpose of a university campus have changed and many universities are looking for new ideas. For example, Rice University in Houston, Texas has decided to implement outdoor learning structures [85]. Using outdoor tents, the school aims to create safe spaces for learning that are exposed to the environment. In these design guidelines, there is consideration for how various outdoor spaces can be used to improve the comfort and also the safety of students on campus.

The first set of guidelines (4.3) acknowledges the constraints of renovation projects for biophilia. These renovation guidelines consider renovations on the campus scale and then the classroom scale. The guidelines mainly include improving the spaces between buildings and specific interior implementations such as those within a classroom.

The following design recommendations for biophilic design in university settings are supported by research.

4.3.1. Campus Setting

Campus-Defining Landscapes

Landscapes on a campus can enhance unique features for the university that facilitate student connection to place. A study found that campus landscape design has a significant correlation to Place Attachment for university students [33]. Designers should aim to provide campus landscapes that produce quality views and stimulation for students. Relating to SRT and ART, multi-sensory consideration of local nature [49,61] views of Prospect [86], and views of biodiversity have been found to reduce stress more effectively than plain or flat landscapes [87].

Improve Vegetation on Campus

Incorporating more nature in campus environments can provide green views, improve thermal comfort by creating microclimates [63], mediate noise [74] of the city, and encourage students to spend more time in outdoor spaces. Designers can ensure continuous exposure to nature by planting vegetation that lasts throughout all seasons in cold climates, such as coniferous trees, and considering local plants.

Paths and Transitions

The qualities of circulation routes through and around a campus can be important in developing an overall experience and impression of the environment. The paths and transition spaces between buildings serve as restorative spaces after 'stressors' like participating in classes. According to SRT and ART, a period of restoration as one transitions from one building to the next may help students get ready for the next class [12,46]. A recent study at Carleton University in Canada found that outdoor walks resulted in more positive effects, relaxation, and fascination than indoor walks [53]. Pathways and transition spaces between buildings should be improved through biophilic elements such as increased vegetation [46,47], the design of spaces providing Refuge with larger Prospect views of the campus, and elements of local culture that express place.

4.3.2. Classroom Setting:

(1) Windows in all Classrooms and Offices

Staff and instructors may spend extended amounts of time in one space and will require continued exposure to daylight. Introduction of daylight into all occupied spaces will establish the biophilic pattern

of connection to natural systems and provide more productive workspaces [71,72]. Every classroom and office should either have windows on the exterior facade of the building or, if that is not possible, windows that look into an atrium that brings natural light into the space.

(2) Operable Windows and Enhanced Ventilation

In classrooms and other areas where students spend any amount of learning time, operable windows should be used to supply natural ventilation which is shown to enhance comfort as well as cognitive function [88]. Prior to renovation, surveys and tests should be taken to determine the current indoor environment quality in learning spaces and improved conditions should be developed. Enhanced ventilation has been proven to improve cognitive function scores [88] and operable windows facilitate the non-rhythmic sensory stimuli biophilic pattern and encourage experience of multi-sensory aspects of nature which improve restoration more effectively. Operable windows can provide access to nature views, olfactory aspects of nature, and auditory aspects of nature.

(3) Daylight and Lighting Variability

Lighting variability throughout a day includes the use of diffuse light, circadian light, and colored light in order to stimulate student learning. Variability of lighting throughout a classroom should also be considered in order to stimulate engagement and vary the experience for class activities [69,70]. Diffuse light should be established through shading devices in order to optimize use of natural daylight and compliment learning spaces that use technology such as projectors or computers. Lighting levels should be able to be adjusted in classrooms to reflect the time the class takes place and the specific needs of class activities.

(4) Lighting and Shading Adaptability

Adaptability of classroom lighting and shading devices attributes a level of control of comfort to both the students and instructors. Classrooms should be able to be used for many purposes and be able to be adjusted based on the variety of activities in a classroom [26]. Lighting adaptability and lighting control allow instructors to respond to educational needs [26]. Allowing for light adaptability in study spaces, classrooms, library spaces, and even social spaces establishes comfort in the knowledge that these spaces were designed to manifest the individual's compatibility.

(5) Nature Inspired Patterns

Nature inspired patterns such as fractals provide visual stimulation and a subtle connection to nature. Indoor plants and 'green views' are a main idea of nature connectedness that is considered in many studies of biophilic design. Redesigning to incorporate nature views can be difficult to achieve once a campus is already built, whereas natural patterns can be applied through wall coverings, floor wood grain, light filtered through trees and leaves [6], and patterns on furniture.

(6) Natural Materials in the Classroom

In addition to natural patterns, incorporation of natural materials in learning environments subtly enhances nature connectedness and prevents the isolation of the classrooms from the surrounding environment. Natural materials facilitate non-rhythmic sensory stimuli [61], Place Attachment [54], and favorable workspaces [66]. Designers can incorporate natural materials such as wood and stone into classroom walls and furniture to connect the indoors and the outdoors.

(7) Natural Colors in the Classroom

Natural colors stimulate the mind while also providing restorative qualities to students. Studies of university students have shown that the color green enhances creativity [52], stress reduction [89], and positive feeling of comfort [55]. Designers can easily implement natural colors in classroom walls, lighting, seating, and social areas.

4.4. Considerations in the New Building of University Learning Environments

Building a new university campus presents many opportunities to configure spaces that optimize comfort and function for both students and staff (Section 4.4). Therefore, this set of guidelines focuses on aspects of the site as well as campus scale and the building scale interventions. Guidelines on the campus scale mainly focus on interaction with the site through configuring the buildings to connect with the context and establish place. The guidelines that consider the building setting focus on formal configurations and orientation on the site.

The following design recommendations for biophilic design in university settings are supported by research.

4.4.1. Campus Setting

(1) Campus Site Configuration

The configuration of university buildings should consider the diverse needs of all the occupants throughout a day. A university campus should “intersperse learning spaces with places in which to play, rest, and restore” [45]. Designers should incorporate outdoor green space for each building to facilitate social interaction and encourage green views from the building. Configuration should take into account routes and paths that students may take between buildings and support restorative spaces along the way.

(2) Plan for Outdoor Activities

A university should provide the options to conduct certain activities either outside or inside. A recent study evaluated the preference and perceived restoration likelihood of outdoor university spaces for study breaks, restoration, and socializing [50]. The outdoor space that had built seating and extensive greenery was the most preferred as opposed to the same space without greenery or the same space with colorful artifacts [50]. Provision of outdoor eating spaces, lounge spaces, study spaces, and potentially even outdoor classrooms will naturally enhance nature connectedness in students and improve connection to place.

(3) Consider Indoor/Outdoor Transition Spaces

Threshold spaces between indoor and outdoor can house a variety of activities and promote connection to the surrounding environment and nature. A preference study at Deakin University in Australia found that students prefer exposure to fresh air, and a position of Refuge with a Prospect view of the campus [59]. Transition can be achieved through sheltered porch-like spaces on a building, balconies, and study spaces or cafeteria spaces that have sliding doors that expose the activity to the surroundings.

(4) Reflect the Cultural and Environmental Context

Establishing a sense of place through the use of local design can facilitate a sense of compatibility with surroundings and a more restorative learning experience for students. A study found that the use of local style and materials as part of a sustainability initiative were rated by the students to be the most important to them [54]. In a new building or campus, designers should aim to use local styles, products, and materials in order to accurately represent the socio-cultural and physical context of the campus.

(5) Encourage Place Attachment at Outer Areas of Campus

Facilitating Place Attachment in areas that might feel less central or secure on campus can help encourage students to utilize those spaces. When the edges of a campus seem to bleed into the surrounding environment, students may not have a strong sense of place in those areas. A study of

the transition from home to a university campus described security and expression of the aesthetic of place as comforting factors for new students [56]. Potentially using the spaces at the outer areas of campuses as landscapes, gardens, cultural spaces, or social spaces can help create a sense of purpose and place in a space that is otherwise uncertain or uncomfortable.

4.4.2. Building Setting:

(1) Orientation of Building and Classrooms for Daylight

Optimizing classroom configurations in buildings to allow access to daylight conditions in all classrooms and occupied spaces will have a large impact on the overall wellbeing, stimulation, and productivity of students. Studies show that students in classrooms with natural daylight access can perform better than those without [71,72]. Predictably, windows oriented to the south have the most daylight and thermal comfort needs to be considered [64].

(2) Positioning, Size, and Orientation of Buildings and Classrooms for Views

Orientation of glazing towards pleasant and favorable nature views can have positive effects on students during classroom activities. A study found that a room with an outdoor view had better effects on reducing anxiety than a regular room or a room with indoor greenery [90]. Another study found that 12% window-to-floor-area ratios garner the highest daylight autonomy [64]. On a larger scale, the classroom becomes the space of Refuge with Prospect views established through the correct proportion and position of window views.

(3) Spatial Configuration—Prospect-Refuge

In a new building, there is an opportunity to design for spaces of Prospect and Refuge, thereby providing the necessary spatial variety specified in Prospect-Refuge theory. A recent study evaluated the spaces students chose to study in and found that all participants chose positions on campus where there was a balance of Prospect and Refuge [59]. Designers can create Prospect and Refuge spaces through formal compositions and views.

(4) Restorative Corridors and Wayfinding

Providing restorative spaces between classes can help replenish Directed Attention resources and improve the wellbeing of students after stressors. Studies show that greenery and images of nature provide restoration from stress and attention for students [32,50,51,58]. Designers should incorporate rest spaces interspersed with indoor greenery and nature posters or murals that depict water. The colors and sizes of hallways can improve wayfinding.

(5) Biomorphic Forms

In a new building, there is an opportunity to incorporate biomorphic forms into the design of buildings and spaces. Historically, subtle naturally occurring patterns and shapes have been used in architecture and can inspire, provide comfort, and improve nature connectedness [10]. Designers can employ biomorphic design through form, structural appearance, ornamentation, and other details.

5. Conclusions

This paper identified salient themes in published multi-disciplinary literature relating to the influence of the built environment on university students and analyzed published studies in biophilic design to see how these issues can be addressed through environmental design. In the context of COVID-19, there is an urgency in considering the role of the built environment on our health and wellbeing and a heightened relevance for studies on the role of building design on people's health. The results of our multi-disciplinary literature review identified, analyzed, and categorized relevant

studies that illustrated the benefits of biophilic design specific to urban university campus settings. We discussed the gaps in understanding relating to the influence of biophilic design on university settings, and presented evidence-based design recommendations for incorporating biophilic design in university settings.

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