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"Rethinking Built Environment: Towards a Sustainable Future"

Organiser:
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Department of Built Environment Studies & Technology (JABT), Faculty of Architecture, Planning & Surveying (FSPU)

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The Influence of Biophilic Design to Learning Ability in Library Environment: A Systematic Review

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Abstract
The library is one of the important infrastructural facilities for university students to enhance their learning experience, providing various materials, equipment, gadgets, and spaces. A sustainable environmental design library could not only improve the quality of life and learning outcomes of university students but also help to improve the learning ability and emotion during the process of learning. While the impact of environmental design on people's ability and emotion has been extensively researched in some contexts, such as offices, hospitals, and elementary schools, the research on biophilic design in urban post-secondary educational environments has limited resources. For this reason, this paper thoroughly reviews literature that explores biophilic design as a strategy to increase students' learning ability in the library environment. The study investigates the design strategies, through a systematic literature review that includes the process of appraising the literature from a related fields, data extraction based on several keywords, analysis and synthesis and finally reporting the results. The results revealed a wide range of benefits, from the improvement of the learning environment to the promotion of pro-environmental behaviour toward learning ability and emotion. This study is expected could beneficial to designers, student researchers, academic instructors, building occupants, and sustainable development goals.

Keywords: *Biophilic design, universities, library, student ability*

1.0 Introduction

Learning ability has described as the act of changing an individual's knowledge and behaviour skills (Othman et al., 2016). Studies show that students who study in a pleasant atmosphere are more motivated, engaged, and have a higher overall learning capacity (Wan & Wong, 2015). In this aspect, students' abilities may generate possibilities in university libraries that have accommodated changes in usage patterns to assist better students in learning ability and intellectual pursuit (Kim, 2017), allowing them to enhance their roles in the academic community. It also shows that university libraries are frequently overcrowded and underutilized (Hall & Kapa, 2015). Therefore, when students cannot find a quiet place to study, they operate less effectively than in a less congested setting (Dong et al., 2017). Thus, an improved library interior and constructed environment should offer greater comfort and educational benefits (Baba & Affendi, 2020).

The growth of library concepts should be evolutionary, with new design and functionality developing as student needs change. The significant elements of a library's interior include lighting, furniture, materials, and finishes (Sufar et al., 2012). Thus, a biophilic design is applied to create sustainable architecture (McGee & Marshall-Baker, 2015). Biophilic design is "a deliberate attempt to convert knowledge of the innate human affinity to affiliate with natural systems and processes known as "biophilic into physical form," says researcher (Stephen R. Kellert, 2018). For example, a garden view may inspire creativity, while a shadow or height may inspire anxiety, and animal companionship and a walk in the park may be soothing and therapeutic (Browning et al., 2014).

The word biophilic design is used today to describe a design strategy that incorporates nature connections, many encounters, and experiences with the natural world, and human senses, emotions, intellect, and even culture into nature (McGee & Marshall-Baker, 2015). Our physical and mental health, productivity, and well-being are all dependent on our connection with the environment (Calabrese & Dommert, 2018). Thus, studies have linked biophilic design with mental fatigue, stress recovery, improved creativity, relaxation, and enthusiasm (Jim Determan et al., 2019). Moreover, research shows that nature may enhance human mood and emotions (Bringslimark et al., 2007). This article has summarized the benefits of biophilic architecture on students' learning capacity and emotions. As stated before, the university environment lacks research on the benefits of biophilic design (Peters & D'Penna, 2020). Studies of biophilic design in workplaces, hospitals, and elementary schools. Postsecondary environmental biophilic design is yet unknown and needs research. These studies confront distinct difficulties and employ therapeutic methods to enhance university student's quality of life and learning.

2.0 Biophilic Design Strategies

Biophilic design techniques should be used early in the concept's development. Designers, contractors, and users must understand the problems and goals of the site. The project's success requires close collaboration with designers and engineers and experts informed about the project's specific circumstances: sociologists, geologists, botanists, and historians (Ryan & Browning, 2018). The strategy of biophilic design concerning Browning's creativity and research is based on "14 patterns of biophilic design (Ryan & Browning, 2018). The paper covers the three experiences and 14 biophilic design patterns representing the built learning space's nature-health connections. The three experiences and 14 patterns are listed in Table 1. The Biophilic configuration is categorized as Spaces:

i. Nature in the space
ii. Natural analog
iii. The essence of the space

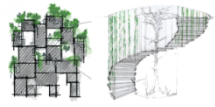
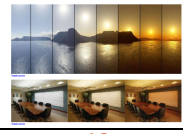
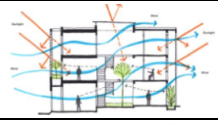
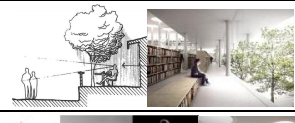
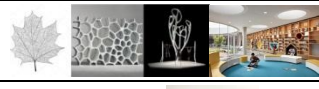
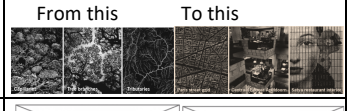
Browning and his team used it to create 14 biophilic designs in three groups (Table 1). Biophilic design patterns and built-nature interactions (Table 2). They help designers educate, advise, and assist in the design process. These patterns may explain how individuals benefit from their built and natural surroundings.

Table 1. 14 Biophilic design patterns

Categories	Biophilic design pattern
Nature in the Space	[P1]. Visual Connection with Nature [P2]. Non-Visual Connection with Nature [P3]. Non-Rhythmic Sensory Stimuli [P4]. Thermal & Airflow Variability [P5]. Presence of Water [P6]. Dynamic & Diffuse Light [P7]. Connection with Natural system
Natural Analogues	[P8]. Biomorphic Forms & Patterns [P9]. Material Connection with Nature [P10]. Complexity & Order
Nature of the Space	[P11]. Prospect [P12]. Refuge [P13]. Mystery [P14]. Risk/Peril

(Source: Ryan & Browning, 2018)

Table 2. 14 Biophilic design patterns with the purpose

Categories	14 Pattern	Purpose	Images / Sketches
Nature in the Space	**[P1] Visual connection with nature**	It is the perception of the elements of nature living with nature	
	[P2] Non-visual connection with nature	Ambiance: sounds, scents, and emotions of nature that are complex and unexpected.	
	[P3] Non-rhythmic sensory stimuli	An environment that stimulates the senses makes you feel momentarily fortunate.	 Circadian Rhythms
	[P4] Access to thermal and airflow variability	Good temperature and airflow variation feel refreshing, energetic, alive, invigorating, and relaxing.	
	[P5] Presence of water	An area with a good water presence is entertaining and exciting.	
	[P6] Dynamic and diffuse light	A space with shifting light and shadow.	
	[P7] Connection with natural systems	Nature-friendly places make you aware of seasons and life cycles.	
Natural Analogues	**[P8] Biomorphic forms and patterns**	A natural curved, patterned, textured, or numerical arrangement.	
	[P9] Material connection with nature	A locally sourced natural materials and artifacts.	
	[P10] Complexity and order	Nature has rich touch detail after spatial development.	
Nature of the Space	**P11] Prospect**	An unlimited view over a way to control and arrange.	
	[P12] Refuge	The evolving stream protects the Person against aerial surroundings and trailing.	
	[P13] Mystery	Partially limited views stimulate the human desire to explore nature.	
	[P14] Risk/Peril	A discoverable threat with an accurate shield	

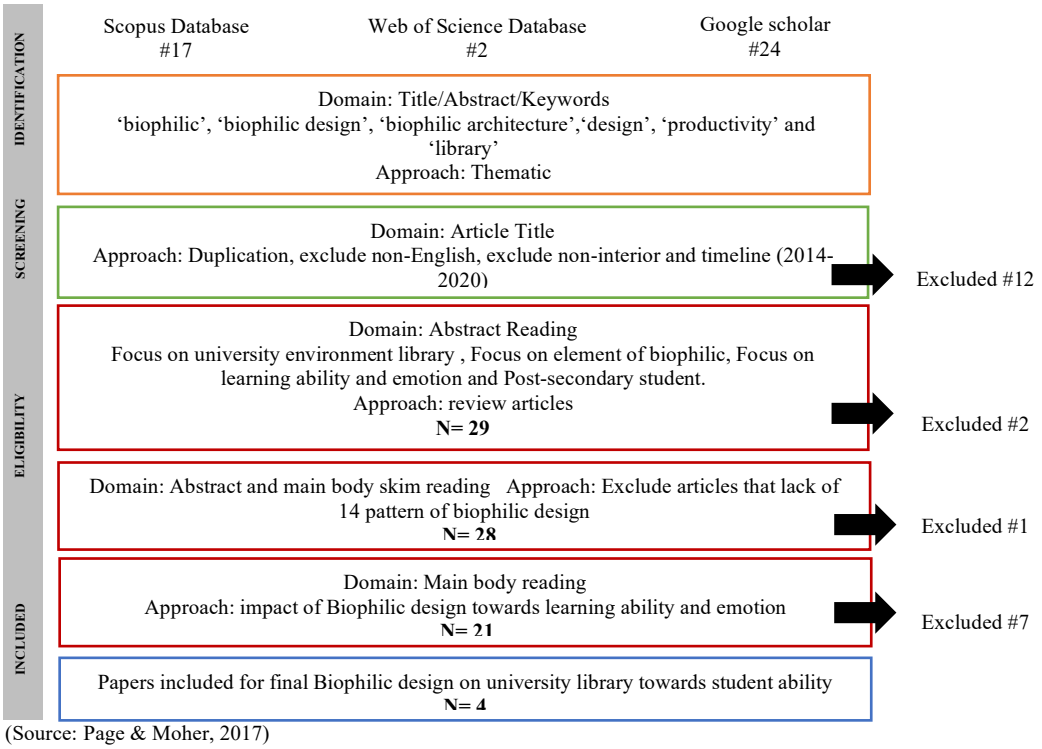
(Source: Ryan & Browning, 2018)

3.0 Multi-Disciplinary Literature Review

The approach uses a systematic literature review to examine, summarise, evaluate, and distribute current scientific knowledge (Babalola et al., 2019). The recommended reporting items for the Systematic Reviews and Meta-Analysis (PRISMA) method (Page & Moher, 2017) was chosen as the most appropriate systematic literature review framework. In PRISMA method, there are four steps:

i. Identification: search of relevant records in different databases;
ii. Screening: selection of relevant literature;
iii. Eligibility: compliance check of selected records against eligibility criteria;
iv. Inclusion and exclusion: selection of the eligible records.

These four steps concerning this study are presented below, in Figure 1:



(Source: Page & Moher, 2017)

Figure 1. Systematic Review Process: Adapted from the PRISMA Flow Chart.

3.1 Scope and Limitations

This research conducted a comprehensive literature review on biophilic design and university libraries. The study only uses three databases: Scopus, Web of Science, and Google Scholar, and is supported by secondary data from a website, although they are the most extensive and comprehensive in the field. A similar limitation may be imposed by the terms selected in this study's literature search. Several studies examined the impact of natural components on building performance and occupants without naming or referring to 14 biophilic design patterns. This research identified 14 patterns of biophilic design as a method to improve student ability in university libraries, minimising the potential restriction of keyword selection.

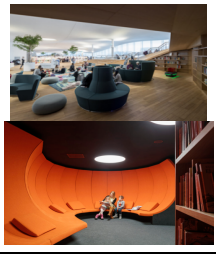
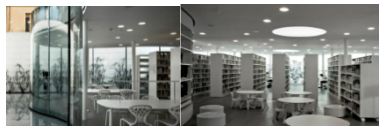
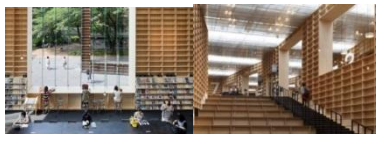
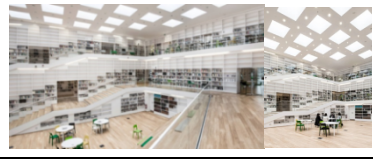
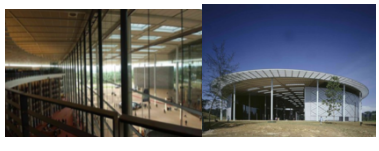
4.0 Synthesis and Discussion

The articles examined 14 biophilic design patterns in the learning environment in a university library. The main goal was to identify and categorise biophilic design implications on student ability and emotions.

4.1 Library Adopt With Biophilic Design

Many library projects use Ryan & Browning's biophilic design concept (2018). Their surroundings should promote attention, reflection, pleasure, and integration. Libraries should be able to participate in cultural development actively. This biophilic building was selected as the most significant in a study (Table 3).

Table 3. The selected library has been used biophilic as a strategy for design in the library

No	Library	Location & date	Images	Website Sources	Biophilic Patterns
1	**Oodi Central Library**	**Finland** by ALA Architects & **Opened in 2018**		http://ala.fi/work/helsinki-central-library/	**P1, P2, P3**
2	**Maranello Library**	**Italy** by Andrea Maffei Architects & **Opened in 2011**		http://www.amarchitects.it/portfolio-item/nuovabiblioteca-maranello/	**P1,P2,P3, P4,P5,P6**
3	**Musashino Art Univerist y Library**	**Japan** by Sou Fujimoto Architects **opened in 2010**		https://arcspace.com/feature/musashinoart-university-library/	**P1- P14**
4	**Dalarna Media Library**	**Sweden** by Sou Fujimoto Architect **Opened in 2014**		http://www.adept.dk/project/dma-library	**P1,P2,P3, P4,P5 P6**
5	**Vac-Library**	**Vietnam** by Farming **Architects in 2018**		https://www.dezeen.com/2019/01/20/vac-library-farming-architects-hanoi/	**P1,P2,P3 P4,P5,P6, P7,P13**
6	**Information Resource Center UTP**	**Malaysia** Norman Foster Architect **Opened in 2005**		https://www.archilovers.com/projects/4013/petronas-university-of-technology.html	**P1,P2,P3, P4, P5,P6**

The biophilic design ideas utilised in the previous library samples are practical. A range of building types and biophilic design choices are shown. The goal should be to create buildings that not only function effectively but also improve people's lives while protecting the environment. Architects and interior designers may benefit from biophilic assumptions (Nursalam, 2016).

Thus, eleven of the fourteen patterns most relevant to the research questions are: (P1) visual connection with nature; (P2) non-visual connection with nature; (P3) non-rhythmic sensory stimuli; (P4) thermal and airflow variability; (P5) water; (P6) dynamic and diffuse light. In addition, we identified no relevant sources on the four patterns of (P10) Complexity and order; (P13) Mystery; and (P14) Risk/peril in university library contexts.

4.1.1 Review of Studies Specific to Biophilic Design in University Library Settings

Table 4. Impact of biophilic design on ability and emotion

Peer-Reviewed Papers	Author	Biophilic Patterns	University Library Setting	University Student Participants
Energy-efficient Lighting and Biophilic Design Concept to boost Reading Interest in Social Facilities' Library	Dewi et al. (2020)	P3,P4,P7	✔	✔
Designing of a library using biophilic Attributes	Kaur. (2017)	P1,P2,P5,P6, P7,P8,P9,P10	✔	✔
Biophilic Principles for Energy Efficient Library Building Design	Nursalam et al. (2016)	P1,P4,P7	✔	✔
Application of biophilic design in contemporary library architecture	Gierbienis (2019)	P1,P2,P3,P4,P5, P6,P7	✔	✔

The literature study found that published research in or about university students and libraries lacks design-specific results. Instead, there is numerous research on specific environmental design factors, but few on university campuses or learning environments on libraries. Studies that relate specifically to qualities of biophilic design in university library settings are presented in (Table 4) and organized the relevant biophilic patterns (Ryan & Browning, 2018).

The most relevant articles we discovered made no mention of "biophilia" or "design", nor of the biophilic patterns we described. Themes in the research results were analyzed and categorized based on their biophilic pattern. Eleven of the fourteen patterns we identified as most applicable to the research and others three patterns of (P10) Complexity and order; (P13) Mystery; and (P14) Risk/peril have far less published material available on this topic, and we found no relevant sources on these patterns in university library settings.

4.2 Impacts of Biophilic Design on Emotion and Ability

The results or conclusions that could be categorized as impact and the biophilic pattern was presented in most of the literature are summarized in Table 5.

Table 5. Impact of biophilic design on ability and emotion

Categories	Keyword	Author	Nos	Biophilic Patterns	University Student Participants
Studies that related to **Emotional**	Enhances satisfaction	Tifferet & Vilnai-yavetz, (2016)	2	P1,P2,P7	
	Provides relaxation	Bies et al.(2016),	1	P1,P7,P8,P10	✔
	Increases happiness	Capaldi A. et al.(2014), Zelenski & Nisbet (2014)	2	P1,P7	
	Impacts positive emotion	Obiozo and Smallwood (2015) ,Yin et al.(2018) Demers et al.(2017)	2	P1,P2,P3,P4,P5 ,P6,P7	✔
	Reduces stress	Li & Sullivan, (2016)	2	P1,P2,P6,P7	✔
	Reduces anxiety	Yin et al., (2020)	1	P1,P2,P6,P9	✔
Studies that related to **Ability**	Promotes physical activity	Stoltz & Schaffer, (2018)	1	P1	
	Increases productivity	Ayuso et al.(2018) , Obiozo and Smallwood (2015), Mangone et al. (2017)	4	P1,P3,P6	
	Impacts creativity	Ayuso et al. (2018), Mangone et al. (2017)	2	P1,P3,P6	
	Improves cognition	Soebarto et al. (2018), Benfield et al. (2015), Yin et al. (2018)	3	P1,P2,P6,P8.P9	

Above all, the potential focus of two sub-categories only, ability and emotional impact with selected 14 patterns of biophilic design : (P1) Visual connection with nature; (P2) Non-visual connection with nature; (P3) Non-rhythmic sensory stimuli; (P4) Thermal and airflow variability; (P5) Presence of water; (P6) Dynamic and diffuse light; (P7) Connection with natural systems; (P8) Biomorphic forms and patterns; (P9) Material connection with nature; (P10) Complexity and order ; (P11) Prospect; (P12) Refuge (P13) Mystery; and (P14) Risk/peril (Table 3). Studies on ability show an improvement in cognitive efficiency, inventiveness, and output. Biophilic design may also influence human emotions including pleasure, contentment, pleasant emotions, aesthetic preference, and self-worth.

4.2.1 Ability Impact

This ability effect is linked to learning ability, defined as the act of altering an individual's knowledge and behaviour skills (Othman et al., 2016). Multidisciplinary studies have demonstrated the links between exposure to nature and improved performance of academic, intellectual, and cognitive tasks in the workplace and other educational spaces (Benfield et al., 2015). Studies show that biophilic design can enhance student productivity (Epyfei et al., 2018), student creativity (Ayuso Sanchez et al., 2018; Shi et al., 2020), improve cognition (Yin et al., 2018) promotes physical activity (Li & Sullivan, 2016). Indeed, the biophilic design can also enhance human nature connectedness to nourish intellectual curiosity and improve cognitive capacity, to facilitate creativity and innovation (Abdelaal & Soebarto, 2018).

Nature views have a significant role in providing students with opportunities for mental breaks during the class day, thus making a case for improved attention functioning rather than daylight being the cause of improved learning (Li & Sullivan, 2016). These factors include space proportions (Park & Newman, 2017), natural ventilation, indoor plants (Shibata, 2017), and daylight (Shi et al., 2020). As a consequence of these findings, research has described how natural characteristics may stimulate innovative and paradoxical thinking. Thus, research indicates that nature may calm and stimulate the

mind, improving wellness and performance (Li & Sullivan, 2016). Indeed, a view of nature is beneficial for student learning.

4.2.2 Emotional Impact

Emotions affect human abilities such as perception, attention, learning, memory, reasoning, and problem-solving. Thus, attention and executive control are intimately connected to learning processes since naturally limited attention capabilities focus better (Tyng et al., 2017). Nature has a significant influence on emotions. Emotional, psychological, and physiological benefits of biophilic design (Peters & D'Penna, 2020). Therefore, Individuals who are more connected to nature are happy, regardless of their demographics (Capaldi A. et al., 2014). Thus, the biophilic design encourages relaxation (Bies et al., 2016), improved self-esteem (Stavrianos, 2016), and overall good feelings via blood pressure and heart rate (Yin et al., 2018).

The positive emotions associated with biophilic design are likely due to the visual, auditory, and olfactory stimulation that comes with it (Yin et al., 2018). Moreover, floral fragrances have been proven to improve human moods (Capaldi A. et al., 2014), while natural visual components are preferred over neutral views (Mangone et al., 2017). Thus, the literature indicates considerable potential for biophilic design to influence the indoor environment positively.

4.3 Strength of 14 Patterns of Biophilic Design Research in University Libraries

A study found a lot of research and evidence for the benefits of visual connection to nature in university libraries. Views of landscapes and green views through windows (Li & Sullivan, 2016; Roetzel et al., 2019), nature posters (Van Den Bogerd et al., 2018), images (Rompay & Jol, 2016), murals (Jim Determan et al., 2019; Abboushi et al., 2019), indoor plants (Yin et al., 2018), with the colour green (Studente et al., 2016) and nature walks are examples of visual biophilic implementations (K. E. Lee et al., 2015; Li & Sullivan, 2016; Joye & Berg, 2011). A recent study discovered that pictures of nature could aid in the recovery of students' emotions (Kaur, 2017).

There is evidence that nature may help form an overall attitude about an area, particularly in university library environments. According to research, place Attachment is an essential part of the university experience and is linked to student satisfaction (Dewi et al., 2020). According to students, campus landscape determined the pace of life, resources, and cultural activities to be essential in achieving place attachment (Li & Sullivan, 2016; Kaur, 2017). Moreover, students who reported higher degrees of nature connectivity were more inventive and holistic thinkers (Rompay & Jol, 2016; Ayuso Sanchez et al., 2018). Furthermore, according to a recent study, university students prefer to study in "refuge" places with "prospect" views to feel privacy, security, and excitement (Roetzel et al., 2019).

Some research focuses on student comfort and wellbeing in university libraries. Therefore, studies demonstrate that university lighting systems may enhance student conduct and make a learning space more appealing and enjoyable (Shi et al., 2020; Wang et al., 2015). Students who have access to natural light perform better (Li & Sullivan, 2016), and changing light levels increase visual interest (Yin et al., 2020). Indoor air quality in the classroom impacts student comfort and performance. These findings support the advantages of placing learning activities near windows and in the study area to reduce humidity from human heat radiation and enhance air quality (Walimbe & Chitgopkar, 2018). Natural ventilation can also help reduce CO2 levels in learning spaces (Atchley et al., 2012). University research also revealed that vegetation was an effective mediator of microclimate, while a general investigation found it to be effective in perceiving ambient noise (K. E. Lee et al., 2015; Li & Sullivan, 2016).

Our search turned up almost little research on the biophilic design pattern of Non-rhythmic sensory inputs, which may be defined as "stochastic and transient encounters with nature that can be statistically assessed but not precisely predicted" (Browning et al., 2014). Rustling leaves, swaying grasses in a field, and rippling water are examples of non-rhythmic sensory inputs. These aspects are not usually examined in academic settings because sensory nature situations are more commonly reproduced for

more comprehensive study. Furthermore, we found no study including the biophilic patterns of Complexity and order, Mystery, and Risk/peril in university library contexts.

5.0 Conclusion

The body of literature cited here is part of a nascent effort to gather evidence recording responses to nature experiences for student university learning ability and emotion. It is intended to enlighten a broad audience engaged with designing university libraries and those who occupy university libraries every day. As more of the world's population shifts to urban settings, the need for biophilic design will become more critical. Applying the biophilic method in buildings positively results in physical, mental, and behavioural benefits for university students, after the detailed analysis made by previous research and experiments on physical and psychological effects on student learning abilities.

There is also a lack of educational research on biophilic design. Sustainable Design and the environmental movement have been embraced by architectural education. However, most institutions have yet to fully explore the link between biophilic design and higher education innovation. This topic requires further research to grasp its consequences on student learning fully. This design idea allows students to stay longer and concentrate better in the library. As the library's visiting population increases, so will participation and contributions. Hence, it will instantly increase the property's worth, and it would allow for the development of new biophilic design teaching tools, methods, and approaches for university libraries.

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