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THE IMPACT OF BIOPHILIC DESIGN ON COGNITIVE ABILITIES IN UNIVERSITY LIBRARY SETTINGS AND URBAN EDUCATIONAL ENVIRONMENTS

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Abstract

This study explores the potential of biophilic design to enhance student learning within university libraries, an often-neglected aspect of urban design. While offices and hospitals have been extensively studied for their impact on well-being and performance, post-secondary education settings have received limited attention. A mixed-methods approach was conducted in this study, including interviews, VR simulation experiments, and a questionnaire survey. The results revealed a significant reduction in participants' blood pressure and heart rate following the implementation of the biophilic design. There were also unanimous reports of improved learning experiences; statistical analysis confirmed these positive effects, highlighting the calming influence of biophilic indoor environments on students. The study emphasised the benefits of creating conducive learning spaces and fostering pro-environmental behaviours. This research underscores the importance of integrating sustainable and biophilic design principles into urban educational environments, ultimately enhancing student well-being and academic performance in a student-centric urban design theme.

Keywords: Biophilic design, Student well-being, Learning ability, Urban design, VR simulations

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INTRODUCTION

In high-expectation university settings, student stress is common. To address this challenge, integrating biophilic design into learning spaces is crucial, reducing stress and fostering innovation (Peters & D'Penna, 2020). Academic libraries, the "heart of the university," have evolved to enhance student experiences but encounter challenges like limited space (Kim, 2017; Sufar et al., 2012). Many library design initiatives neglect student-centric environments (Abdelaal, 2018). To address this, academic libraries should prioritise user-centred services and spaces based on user needs. Research shows that nature immersion enhances creativity and productivity (Abdelaal & Soebarto, 2018), and learning spaces impact academic performance (Ryan & Browning, 2018). Coordinated by "Terrapin Bright Green LLC biophilic patterns," this research fills gaps in understanding the impact of biophilic design in university libraries, offering evidence-based design recommendations (Peters & D'Penna, 2020) to enhance student learning.

Insights from psychology, physiology, sociology, and anthropology inform architects, interior designers, and urban planners that nature exposure improves cognitive performance and reduces stress in educational settings (Benfield et al., 2015; Li, D., & Sullivan, W.C., 2016). Yet, research on architectural features promoting cooperation and creativity is limited (Yin et al., 2019). Biophilic design in universities creates healthier environments, reducing stress and enhancing focus (Berman et al., 2012; Kaplan, 1996). However, studies connecting biophilic design to imagination in higher education are lacking. Thus, this research assesses student learning within university library interiors based on Terrapin Bright Green LLC biophilic patterns (Ryan & Browning, 2018), which comprise 14 natural patterns that evoke positive biological responses. It employs a questionnaire and physiological measurements (blood pressure and heart rate) to evaluate learning abilities before and after implementing biophilic design. Unlike prior biophilic design studies in workplaces, elementary schools, and healthcare settings, this research fills a critical gap by examining the impact of biophilic design in university libraries. It offers valuable insights for enhancing student learning in academic settings.

LITERATURE REVIEW

Biophilic design, as defined by Wilson and Kellert (1993), involves consciously incorporating humanity's innate affinity for natural systems and processes into the physical structure of environments, particularly in healing settings, thereby utilising natural elements to enhance built spaces. This approach has been associated with numerous health benefits (Kellert, 2008) and is supported by various studies that highlight its positive effects on physical well-being, productivity (Marzukhi et al., 2020; Shibata & Suzuki, 2004), and emotional well-being (Gillis & Gatersleben, 2015). It promotes relaxation and mood enhancement (Wijesooriya & Brambilla, 2020) and fosters survival instincts, leading to increased engagement, curiosity, and compatibility (Hartig et al., 2003). In addition to its mental health benefits, biophilic design has been found to enhance creativity, efficiency, and learning environments (Browning, 2018). Furthermore, contact with natural environments in learning spaces, as emphasised by Saleh, Latip, & Rahim (2018), offers advantages such as language development, improved academic achievement, higher scores, increased learning opportunities, and enhanced educational performance, while also providing a peaceful and motivating environment that stimulates knowledge seeking, curiosity, and attentiveness.

Biophilic design should be integrated early in the concept's development, necessitating collaboration among designers, contractors, and experts from various fields such as sociologists, geologists, botanists, and historians (Ryan & Browning, 2018). This approach is based on the "14 patterns of biophilic design," which encompass three experiences and 14 design patterns, enhancing the nature-health connections within built learning spaces. These experiences and patterns are detailed in Table 1 and fall into three categories:
i) Nature in the Space,
ii) Natural Analogues,
iii) Nature of the Space.

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 and Airflow Variability [P5]. Presence of Water [P6]. Dynamic and Diffuse Light [P7]. Connection with Natural system
Natural Analogues	[P8]. Biomorphic Forms and Patterns [P9]. Material Connection with Nature [P10]. Complexity and Order
Nature of the Space	[P11]. Prospect [P12]. Refuge [P13]. Mystery [P14]. Risk/Peril

Source: Ryan and Browning, (2018).

Learning is the biological process of acquiring knowledge or skills, involving various mechanisms from molecules to the mind (Lafontaine et al., 2020). It results in improved knowledge, skills, and behaviours. Learning abilities progress from basic reactions to complex information encoding, enabling more accurate responses (Lafontaine et al., 2020). Customised learning environments enhance control over learning (Gerber et al., 2001). Effective brain function is crucial for attention and learning, and neurodevelopmental analysis can help in understanding maturity differences (Lafontaine et al., 2020).

These skills are crucial for learning and can be assessed through various methods, including performance curves, recall, recognition, response time, and neuropsychological tests. Learning measures often involve multiple cognitive processes, making them comprehensive. Biophilic design, influenced by Ryan and Browning (2018), is evident in various library projects worldwide and fosters cultural hubs that offer diverse sensory experiences and promote cultural development. Notable examples include Oodi Central Library (Finland), Maranello Library (Italy), Musashino Art University Library (Japan), Dalarna Media Library (Sweden), Vac-Library (Vietnam), and IRC UTP (Malaysia), each of which showcases unique biophilic elements. This design underscores the importance of architects and interior designers embracing biophilic principles for creating environmentally friendly, functional, and enriching spaces in libraries (Nursalam, 2016). From Table 1, ten key biophilic design patterns are identified as relevant to library contexts, emphasising the integration of nature into architectural concepts (P1-P10). However, no pertinent sources are found for four patterns: Prospect, Refuge, Mystery, and Risk/Peril (P11-P14).

The ability to learn is closely linked to an individual's capacity for adapting knowledge and behaviours (Othman et al., 2016). Multidisciplinary studies have consistently shown that exposure to nature improves academic and cognitive performance (Benfield et al., 2015). Biophilic design, as highlighted by multiple researchers, enhances student productivity, creativity, cognition, and physical activity (Li & Sullivan, 2016). Additionally, biophilic design fosters a deeper connection to nature, nurturing curiosity and facilitating innovation (Abdelaal & Soebarto, 2018). Nature views provide students with valuable mental breaks, supporting attention and learning (Li & Sullivan, 2016). Factors like spatial proportions, natural ventilation, indoor plants, and daylight within educational spaces promote innovative thinking and well-being (Shi et al., 2020). Emotions significantly impact human abilities, including learning, making a view of nature crucial for student learning (Tyng et al., 2017).

Numerous studies support the benefits of “Visual Connection with Nature” and “Natural Analogues” in university libraries, including views through windows, nature posters, images, murals, indoor plants, and green colour schemes (Roetzel et al., 2019). Recent research suggests that images of nature can aid students in emotional recovery (Kaur, 2017). Other studies focus on the impact of lighting systems, showing they can enhance student behaviour and the appeal of learning spaces (Shi et al., 2020). Natural light access positively affects student performance, and varying light levels increase visual interest (Yin et al., 2020). Additionally, indoor air quality is also crucial for student comfort and performance, with findings suggesting that locating learning activities near windows and study areas can improve air quality (Walimbe & Chitgopkar, 2018). Natural ventilation helps reduce CO_2 levels (Atchley et al., 2012), and vegetation contributes to microclimate regulation and noise reduction (Li & Sullivan, 2016).

Nature influences overall attitudes in university library environments, impacting place attachment and student satisfaction (Dewi et al., 2020). Students with a strong connection to nature exhibit more inventive and holistic thinking (Ayuso Sanchez et al., 2018). University students prefer "refuge" spaces with "prospect" views for privacy, security, and excitement (Roetzel et al., 2019). However, there is limited research on "Non-Rhythmic Sensory Input" in academic settings (Browning, 2018). This category includes unpredictable encounters with nature, like rustling leaves and rippling water. Additionally, no studies were found on "Complexity and Order," "Mystery," and "Risk/Peril" biophilic patterns within "Nature of the Space" in university library contexts.

METHODOLOGY

This study utilised a mixed-methods approach, including qualitative interviews and quantitative VR simulation experiments. The aim was to assess how biophilic library design impacts students' learning abilities. Qualitative data were collected through interviews, and the data were then analysed using thematic content analysis. VR simulations measured students' learning abilities before and after exposure to biophilic library settings. This included an emotional reaction test. This was further examined through a questionnaire assessing the difference in emotions before and after exposure to biophilic library settings. The university selection process for this study was based on Malaysia's QS World University Rankings by Subject, which assesses universities across 51 fields. Other criteria taken into consideration was that a university must offer both undergraduate and postgraduate programmes and engage in research in at least two of the five fields. For this research, only three universities from the 2021 Asia QS rankings that met these criteria were interviewed: i) University Sains Malaysia (USM), ii) University Technology Malaysia (UTM), and iii) University Technology MARA (UITM). The research employed open-ended interviews using a checklist, which were conducted through tele-conversation using Google Meet video communication with the librarians of the selected universities' libraries.

Data collection for the experiment was conducted on Level 1, which serves as the central open space designated for student use, as illustrated in Figure 1. This particular space is predominantly frequented by students who engage in book searches, establishing it as the library's primary area for both students and staff. The primary focus of this experiment was on the open spaces available on Level 1. These spaces encompass e-resource terminals, open reading areas, meeting rooms, and presentation rooms, all of which are widely utilised by students. Indeed, the focus of the experiment is on the students. For a visual representation of the experiment layout, see Figure 2. Additionally, it is worth noting that the chosen location for the experiment setup was deliberately positioned at the centre of the open space to facilitate participant interaction with the existing design.

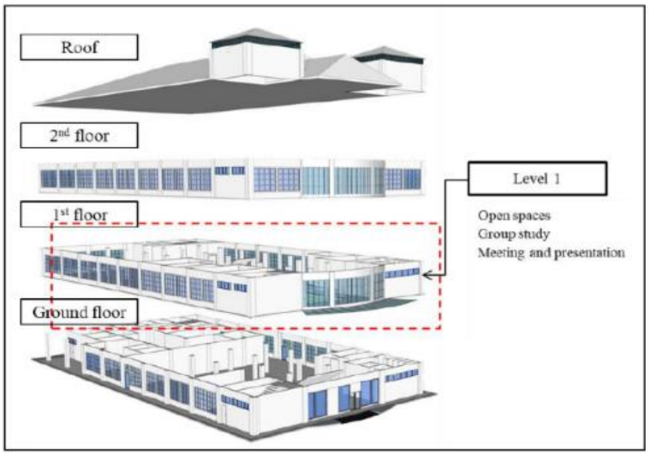

Figure 1: The 3D Illustration of level 1
Source: Author

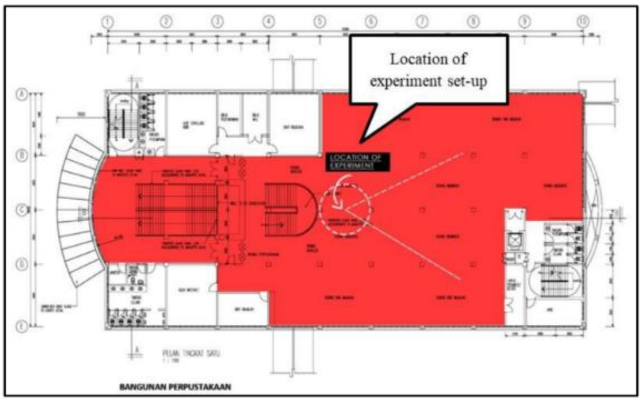

Figure 2: The Experiment Layput of Level 1
Source: Author

The experiment involved 50 students, each representing different faculties. The number of participants was chosen based on previous research that looked at how biophilic design affects learning ability both before and after exposure. The participants in this type of study are typically between 30 and 100 students. According to past research, a sample size of 50 participants is deemed sufficient to yield reliable and accurate results, as supported by Yin et al. (2020).

To conduct the simulation experiment, participants were required to abstain from engaging in strenuous activities the day before the experiment and were instructed to rest for a period of 20 minutes to achieve emotional and physical balance. During the simulation experiments, participants were asked to complete a survey questionnaire, which employed a Likert scale consisting of five levels. The Likert scale is a crucial psychometric tool extensively employed in educational and social sciences research. The use of this scale often sparks debates and controversies regarding how the scale points are analysed and aggregated (Joshi & Pal, 2015). For this study, the participants consisted of 50 healthy students, both male and female, selected from various faculties at UiTM Seri Iskandar. Their ages ranged from 18 and above. All participants were required to adhere to the proper attire guidelines stipulated by UiTM's library regulations. Additionally, participants followed the standard operating procedure (SOP) prior to commencing the experiment.

FINDING AND DISCUSSION

Based on the interviews with the librarians of selected universities' libraries, it is evident that Malaysian universities have incorporated biophilic design into their library spaces. Universiti Sains Malaysia (USM) currently integrates 13 out of 14 biophilic design patterns, achieving a score of 92.8%. In addition, Universiti Teknologi Malaysia (UTM) also incorporates 13 biophilic design patterns, attaining a matching score of 92.8%. Next, Universiti Teknologi MARA (UiTM) implements 9 out of the 14 biophilic design patterns, resulting in a score of 64.3%. Despite the variations, all three universities exhibit elements of biophilic design within and around their library spaces.

The pattern of biophilic design that was adopted in three universities' libraries found eight patterns were the most adopted, which are: (P1) Visual connection with nature; (P6) Dynamic and diffuse light; (P7) Connection with natural systems; (P8) Biomorphic forms and patterns; (P9) Material connection with nature; (P11) Prospect; (P12) Refuge; and (P14) Risk/Peril as shown in Table 2.

Table 2: Pattern That Being Adopted in Three Universities' Library

No	Biophilic Patterns	Biophilic	Categories
1	P1	Visual connection with nature	Nature in the Space
2	P6	Dynamic and diffuse light	
3	P7	Connection with natural systems	
4	P8	Biomorphic forms and patterns	Natural Analogues
5	P9	Material connection with nature	
6	P11	Prospect	
7	P12	Refuge	Nature of the Space
8	P14	Risk/Peril	

Source: Author

The data provided in Table 2 were employed in the VR simulation experiment. Within the context of a 3D design, all the patterns were subjected to testing using a series of questions aimed at assessing the effects of biophilic design before and after its implementation, as perceived by respondents. There were 171 items designed in the questionnaire in order to determine student learning ability. There were 41 items under the dimension of biophilic design, which were based on the selected biophilic pattern, and 130 items under the dimensions of learning ability. All scores for every dimension observed are considered reliable and valid if they are greater than 0.70.

To assess the impact of biophilic design on learning ability, a paired-sample t-test was performed to compare the participants' heart rate readings before exposure to non-biophilic design conditions and after exposure to biophilic design conditions. The increase in heart rate readings observed during biophilic exposure indicated a noticeable influence on participants' learning abilities. The statistical analysis revealed a significant difference between the pre-test heart rate ($M = 81$, $SD = 16$) and post-test heart rate ($M = 88$, $SD = 12$) conditions; $t(49) = 3.157$, $p = 0.003$, which was less than the significance level of 0.05 (refer to Table 3). These findings suggest that the biophilic design intervention had an effective impact on enhancing participants' learning abilities in the library. Furthermore, the results indicate that the degree of improvement in learning ability depended on the participants' experiences within the indoor environment designed with biophilic patterns.

Table 3: Mean and standard deviation of heart rate (HR) before and after

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Before Heart rate - After Heart rate	7.24	16.21	2.29	-11.84	-2.63	3.15	49	.003

In addition to monitoring the heart rate (HR) readings of the participants, the blood pressure (BP) readings were also monitored. The paired t-test was used to determine if participants' physiological responses after completing the tasks were significantly lower than their initial baseline measurements. This analysis was carried out using a one-sided alpha level of 0.05 to determine the statistical significance.

The paired-sample t-test was used to compare the participants’ learning ability before and after the exposure to biophilic design in terms of blood pressure readings, including systolic (BPS) and diastolic (BPD) measurements. The results showed that BPS and BPD readings were lower after exposure to biophilic design, indicating a positive impact on learning ability. Specifically, there was a significant difference between post-test BPS (M = 120, SD = 13) and pre-test BPS (M = 113, SD = 12) conditions; t (49) = 3.555, p = 0.001. Additionally, there was a significant difference between post-test BPD (M = 71, SD = 11) and pre-test BPS (M = 69, SD = 12) conditions; t (49) = 3.157, p = 0.003. These findings suggest that biophilic design creates a calming effect on students, leading to lower blood pressure. The significant difference in blood pressure between biophilic and non-biophilic design settings indicates that biophilic design positively affects students' well-being and learning performance.

Furthermore, a paired-sample t-test was used to compare the participants’ heart rate readings before and after the implementation of the biophilic design. There was a significant difference in the scores between the pre-test heart rate (M = 46, SD = 4) and the post-test heart rate conditions (M = 47, SD = 4); t (49) = 2.674, p = 0.01, which was less than the significance level of 0.05. These findings demonstrate that the application of biophilic design had a positive impact on improving students' learning abilities in the library, reaching a significance level of 0.05. The results highlight the enhancements in students' learning abilities following the implementation of biophilic design patterns in the library.

CONCLUSION AND RECOMMENDATION

The output of this study indicates that there is a statistically significant difference between the conditions before (non-biophilic design) and after (biophilic design) the implementation of biophilic design elements, emphasising the significance of biophilic design within the context of urban design. This means that the introduction of biophilic design patterns into the library has a measurable impact on various aspects, such as learning abilities and physiological responses (e.g., heart rate and blood pressure), highlighting the relevance of urban design principles in shaping educational environments. By comparing the two conditions, the research has demonstrated the potential benefits of incorporating biophilic design in the library environment, underscoring the importance of integrating urban design considerations in educational spaces. This information can be valuable for decision-makers and stakeholders, including library administrators and designers, as it provides empirical evidence of the positive effects of biophilic design on students' learning experiences and well-being within library spaces. Consulting a biophilic design expert is a noteworthy step, as such experts can provide valuable insights into the application of biophilic principles, ensuring that the design aligns with best practices and enhances the overall quality of the library environment within the broader context of urban design. This collaboration with experts adds credibility and expertise to the decision-making process regarding the adoption of biophilic design in the library, promoting a holistic approach to urban design principles in educational settings.

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