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BIOPHILIC ARCHITECTURE APPROACH FOR A THE SCIENCE LIBRARY IN MEDAN CITY AS A LEARNING AND KNOWLEDGE PRODUCTION TO ENHANCE USER PRODUCTIVITY

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ABSTRACT

The low level of science literacy and utilization of public educational facilities in Indonesia, particularly in the city of Medan, demonstrates the need for the development of more productive and human-centered learning spaces. Science libraries no longer function solely as repositories of information, but have evolved into active, collaborative learning spaces and centers for knowledge production. This study aims to examine the application of biophilic architecture in the design of science libraries as an attempt to increase user productivity. This study is qualitative and based on literature reviews and case studies of educational buildings and libraries that apply biophilic principles. The analysis is descriptive and thematic in order to identify the relationship between biophilic architectural principles, the nature of the science library space, and its impact on users' cognitive, psychological, and social aspects. The research results show that the integration of biophilic elements, both through direct connection with nature, analogies to nature, and spatial experiences, contributes positively to increasing users' concentration, comfort, creativity, and quality of interaction. The biophilic architectural approach has the potential to transform science libraries into sustainable, adaptive, and productive learning environments that are relevant to the social and environmental context of the city of Medan.

Keywords: *Biophilic Architecture; Learning Space; Medan City; Productivity; Science Library*

1. INTRODUCTION

In recent years, Indonesia has continued to face significant challenges, especially in the field of education. Based on the results of Programme for International Student Assessment (PISA) 2022, it is known that Indonesia is still in the group of countries with achievements below the Organization for Economic Co-operation and Development average in the three main domains. In determining country rankings, PISA analyzes three main domains, namely reading literacy, mathematical literacy, and science literacy. Indonesia's scores were 366 for mathematics, 359 for reading, and 383 for science, placing Indonesia at the bottom of the global rankings. This is a very crucial issue because it relates to the availability of education and research facilities, as well as inclusive learning. Medan, as one of the largest cities in Indonesia and part of the Malay coastal region, still faces similar challenges. Despite its rich historical, cultural, and science potential, Medan still lacks adequate public educational spaces to support science activities, research, and knowledge production, especially in science and technology. This condition has become the spotlight that underlies the urgency of developing science and technology libraries that function not only as repositories of information and publications but also as active learning environments for intellectual interaction and innovation.

In addition to these challenges, the quality and accessibility of public educational infrastructure remain major issues, particularly in tropical cities like Medan. Various studies indicate that the physical environment and the quality of infrastructure significantly influence the public's willingness to visit libraries; however, many existing facilities are uncomfortable in terms of temperature, inflexible in terms of space, and lack an inviting

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atmosphere. This situation is exacerbated by the public's dwindling interest in physical libraries over the past few years. According to the North Sumatra Provincial Central Statistics Agency, data from the Community Literacy Development Index (IPLM) for 2023 and 2024 indicates a decline in several indicators, namely the adequacy of library collections and the daily visitor rate. These conditions reflect a decline in the enthusiasm and reading interest of the people of Medan, driven by increased access to digital resources and the inability of libraries to adapt to the ever-evolving needs of users. In Medan, many public educational spaces have not yet been optimally designed to adapt to the tropical climate for example, through natural ventilation, passive cooling, and shaded areas thereby creating an environment that is not conducive to learning. Consequently, there is a growing need to develop climate-adaptive, user-centered educational facilities capable of enhancing comfort, fostering interaction, and supporting non-formal learning activities. With various activities of science library users requiring a productive and comfortable environment, an architectural approach is needed that can influence user performance cognitively, psychologically, and physiologically, namely biophilic architecture that emphasizes the integration of nature and humans, which has been proven to have a positive effect on human performance. Therefore, it is necessary to explore biophilic architecture approaches to improve the comfort and productivity of science library users as spaces for learning, research, collaboration, and knowledge production.

2. METHODS

This study uses qualitative methods because its objective is to examine, understand, and formulate how the principles of Biophilic Architecture can be applied in the design of science libraries. This research is descriptive and exploratory in nature, focusing on a deeper understanding of the relationship between biophilic architecture principles, the characteristics of science library spaces, and how all of these can increase user productivity, knowledge creation, and community learning. This method is considered appropriate for addressing the issue of low facility usage and community literacy in the city of Medan by designing more humane and context-appropriate spaces.

The research design use a literature study and qualitative case study. This allows researchers to study the theory, concepts, and practices of using biophilic architecture in libraries and learning environments. This approach was chosen so that the research objectives, data collection methods, and analysis methods used could support each other, making the research process coherent.

2.1. Data Collection

Data collection was carried out using the following methods: (1) Literature review. Literature review was conducted focusing on books, academic journal articles, research reports, and policy documents related to biophilic architecture, science libraries, learning centers, user productivity, and community literacy. This bibliographic list was used to construct the theoretical basis and conceptual framework of the study. (2) Case studies, This research analyzed several examples of buildings that apply biophilic design principles, including libraries, science centers, and learning environments. Data was extracted from secondary sources, such as architectural drawings, floor plans, photographs, design descriptions, and related publications. Case studies were purposively selected based on their relevance to educational functions, the application of biophilic elements, and their connection to learning and research activities.

2.2. Data Analysis

Data analysis in this study was conducted using descriptive qualitative analysis and thematic analysis to gain an in-depth understanding of the relationship between biophilic architecture principles and their potential application in science library design. Data obtained from literature studies and case studies were analyzed in several stages. The initial stage involved classifying biophilic architecture principles based on a theoretical framework. The principle of biophilia is analyzed in relation to the function of science libraries as productive spaces, learning spaces, and spaces for knowledge production, by reviewing aspects of spatial comfort, levels of focus and concentration, quality of social interaction, and intensity of space usage by users. It also uses comparative analysis of case studies of buildings or learning environments that apply a biophilic design approach, with the aim of identifying patterns of biophilic element application, design strategies used, and their impact on space quality and user activities. The results of these stages are then interpreted contextually, taking into account the conditions in the city of Medan, particularly issues related to the low utilization of public facilities and the level of community literacy. This interpretation results in the formulation of a contextual and applicable concept of biophilic architecture integration for the design of science libraries

3. RESULTS AND DISCUSSION

3.1. Science libraries as productive and learning spaces

Science libraries function as strategically managed information hubs that integrate traditional collections with collaborative and flexible spaces to support research, teaching, and community engagement [4]. Their planning and organizational processes are guided by systematic management approaches, such as the POAC (Planning, Organizing, Actuating, Controlling) framework, which aligns institutional objectives with user needs, human resources, and budgeting. Through this framework, science libraries assess user demands, develop science-focused programs, expand and curate specialized collections, and upgrade facilities including reading areas, audiovisual rooms, computer laboratories, and technology-enabled learning spaces. This strategic management ensures that library services evolve in response to academic, technological, and societal changes.

In implementation, science libraries provide continuously updated print and digital science collections, organize science-related programs, competitions, and training for students and educators, and reconfigure physical spaces into collaborative hubs that accommodate classrooms, makerspaces, cafés, and immersive technologies such as virtual reality. Increasingly, these libraries operate within collaborative and multi-level governance structures, partnering with faculty, research institutions, and regional library networks to support research data management, FAIR principles, and Open Science initiatives [3]. Ongoing evaluation through performance audits, usage statistics, and user-satisfaction assessments enables science libraries to remain effective and relevant, positioning them as key actors within the research and knowledge-production ecosystem while adapting to financial and technological pressures.

Science-library users are typically a mixed community of students, faculty, researchers and support staff who differ in disciplinary focus and skill level. Users also include teachers and the wider school community, reflecting the collaborative POAC management model [7]. They see the library as a productive, multifunctional hub rather than a static repository. Students describe the space as one that "should provide access to other services or be close to other places of usefulness or importance," highlighting its role as an integral learning node. The physical environment reinforces this view: recent renovations emphasize "safe, functional, and flexible spaces" that resemble student unions and support varied activities. Librarians note that, despite declining physical lending, demand for information persists, prompting a re-thinking of operations that "bring together more of our circulation services and integrate collections to manage our physical assets more effectively" Together, these traits and perceptions illustrate that science-library users value the facility as a dynamic, collaborative setting that supports both productive research work and creative learning experiences.

3.2. Biophilic architecture

The word 'biophilic' began to enter design discourse in the 1960s when Erich Fromm a social psychologist used biophilia to describe humanity's "love of life" (the innate tendency to seek and protect living things). During the past decade, escalating environmental crises (climate change, biodiversity loss, indoor-air problems) and a growing awareness of the health impacts of spending almost 90 % of life indoors spurred architects to revisit nature-based solutions and from there, the concept of connecting with nature was adopted as a design framework deliberately designed to integrate natural systems and elements into buildings, and quickly became a key foundation in sustainable architecture research and certification schemes. With the emergence of various studies and movements on green and sustainable development in the early 1990s, a link was established between better environmental quality and worker productivity [5]. Productivity was identified as an intermediary for health and well-being, which has a broader impact. Biophilic design far richer than mere vegetation and encompassing physical, sensory, metaphorical, morphological, material and spiritual connections to nature boosts health, well-being, productivity, biodiversity and circularity, thereby advancing numerous UN Sustainable Development Goals [2].

Several studies and experiments show that biophilic design has been proven to positively contribute to the recovery of patients when compared to environments that are connected to natural systems and those that are not. As a result, there are now many designs that use a biophilic approach in environments such as hospitals and formal and informal educational settings, with the aim of improving the health, well-being, and productivity of their users [5]. categorizes the relationship between nature and the application of design in the built environment into three main categories and 14 patterns, (1) *nature in the space*, providing a direct, physical, and temporary presence of nature in a space or place. This includes a multi-sensory experience and the direct movement of plants, animals, water, wind, sounds, scents, and other natural elements. (2) *Nature in Analogues*, Bringing nature indirectly into the built environment. Nature is embodied through shapes, patterns, colors, materials, and textures inspired by natural objects, such as leaves, shells, or growth patterns. These can take the form of artwork, organic-shaped furniture, or decorations, so that even though there are no direct natural elements, these elements create a natural atmosphere and impression. (3) *The Nature of Space,* this category discusses how the composition and experience of space are inspired by nature. This concept relates to the human desire to see further, a sense of curiosity about things that are slightly mysterious or challenging, and the experience of discovering hidden spaces or moments of surprise.

Table 1. Patterns of Biophilic Design

Pattern	Description
Visual Connection with Nature	Direct views of natural elements such as trees, gardens, water, or the sky.
Non-Visual Connection with Nature	Non-visual sensory connections such as the sound of water, the scent of flowers, natural textures.
Non-Rhythmic Sensory Stimuli	Random and momentary natural stimuli, such as a gentle breeze, birdsong, or flickering light.
Thermal & Airflow Variability	Natural variations in temperature and airflow that mimic outdoor conditions.
Presence of Water	The presence of water through ponds, fountains, or reflective elements.
Dynamic & Diffuse Light	Natural light variations throughout the day, such as sunlight filtering through foliage or skylights.
Connection with Natural Systems	Providing a space that is closely connected to the natural world fosters a sense of connection to the greater whole, thereby making one aware of the changing seasons and the cycles of life.
Biomorphic Forms & Patterns	Shapes or patterns resembling organisms, plants, or natural structures.
Material Connection with Nature	Natural materials such as wood, stone, bamboo, or materials with organic textures.
Complexity & Order	Natural geometric patterns such as fractals, symmetry, or soothing regularity.
Prospect	Open spaces with expansive views, providing a sense of security to observe the environment.
Refuge	Smaller, enclosed shelter spaces, providing a sense of security and comfort to rest.
Mystery	Spaces that evoke curiosity, with partially obstructed views that encourage further exploration.
Risk/Peril	Elements of space that provide a sense of mild challenge (e.g., glass bridges, high balconies) that are safe but exciting.

3.3. Integration of biophilic architecture in science library environments as learning spaces

In the context of learning spaces, especially science library environments, which have now transformed in line with the development of the open science paradigm, they have become more than just centers for storing information and publications. Their functions have expanded to include active learning environments, knowledge production spaces, and science collaboration ecosystems [4] that support the entire research cycle, from data creation and analysis to dissemination and public engagement. In this environment, the productivity of science library users is not only measured based on the intensity of activities or the number of science outputs, but also includes broader aspects, such as cognitive abilities, creativity, quality of social interaction, mental and physical health, and the sustainability of user engagement with learning and research spaces. One study shows that green scenery, indoor plants, nature-based color schemes, and images of nature can improve concentration, learning speed, and creative problem solving in the classroom. These nature-based visual interventions are consistently associated with better concentration recovery, higher test scores, and better cognitive performance in the studies reviewed [1].

The quality of the physical environment has a direct impact on human cognitive function. The presence of biophilic elements such as natural lighting, plants, and visual connections with nature contributes to increased concentration, better memory, and problem-solving abilities among library users. Learning environments that integrate natural elements have been shown to reduce mental fatigue and increase attention span, which is especially important during intensive reading, information analysis, and long-term intellectual work (Rasidah et al,. 2024).

Informal learning environments designed in a biophilic manner can create a sense of comfort, safety, and inclusivity, while encouraging the exploration of ideas and social interaction [6]. In addition to supporting cognitive functions, biophilic design also contributes to improving users' creativity and psychological well-being. This discovery is important for science libraries, which now function as spaces for interdisciplinary collaboration and for users from diverse backgrounds. In the context of open science, the psychological and cognitive conditions of users are important prerequisites for the success of the collaboration and knowledge production process. Science and technology libraries serve as hubs that connect researchers, institutions, research information systems, and the community in an open knowledge ecosystem [3]. In this sense, the biophilic architecture approach functions as an ecological and psychological support system that allows research activities, data analysis, and collaborative learning to develop optimally. In Open Science-based science libraries, the integration of biophilic design makes libraries a living learning environment, as well as a space for sustainable knowledge production oriented towards the common good.

The use of biophilic architecture in science libraries should be designed on a zone basis to support learning, research, science collaboration, and information storage functions. Biophilic elements such as natural lighting, visual connections to nature, and good air quality improve concentration, cognitive ability, and mental relaxation in reading and learning rooms. In research and collaboration rooms, the use of natural materials, adaptive spatial experiences, and a balance of open and closed spaces supports creativity, interaction, and high-level cognitive activities. In public rooms and collective storage areas, a biophilic approach is used selectively through natural analogies and artificial environmental features that mimic natural conditions, creating a productive, healthy, and sustainable science library environment. One case study that demonstrates how biophilic architecture can create a productive work environment by directly integrating nature into the space is the Amazon Sphere. The abundance of vegetation provides a visual connection to nature, while dynamic natural lighting helps maintain the circadian rhythm and improve focus. Variations in temperature and natural airflow also create a more adaptive comfort level compared to conventional office spaces. Spatially, the balance between open areas (prospect) and private spaces (refuge), as well as exploratory elements (mystery), allows users to choose a work atmosphere that suits them. This holistic approach results in an environment that is more comfortable, calming, and capable of boosting creativity and productivity.

In the “Nature Analogue” category, which indirectly represents nature, such as natural objects, materials, colors, shapes, and patterns as manifested in art, ornamentation, furniture, decor, and textiles within the built environment. *Biomorphic Forms & Patterns* refers to patterns that utilize forms and geometries inspired by nature; within the context of a library environment, these patterns can be applied to interior elements, facades, ceiling designs, and other decorative elements, thereby creating an organic feel even though they do not directly represent nature. These biophilic patterns can create a more comfortable and less rigid atmosphere, enhancing the emotional well-being of science library users. Furthermore, the “Nature of the Space” category explores how nature-inspired spatial configurations fulfill human needs to see further, feel a sense of wonder toward the slightly mysterious, and experience spaces that offer a sense of security despite containing elements of tension. Within this category is the *prospect* pattern, which refers to spatial conditions that allow users to have an unobstructed, wide view, enabling them to clearly understand their surroundings. This pattern can be applied to atriums and main reading rooms, combined with large voids, the use of transparent glass, and an open-plan layout with minimal partitions. The presence of a *prospect* provides a sense of visual control and security, as users can monitor their surroundings without feeling confined, making it suitable for informal learning environments. Unlike the *prospect* pattern, the *refuge* pattern creates a space that offers a sense of protection, is partially enclosed, and allows users to feel safe from external disturbances. In a library, this pattern can be applied to study spaces and create distinct spatial elements such as reading nooks, individual reading areas, study booths, or small discussion rooms.

4. CONCLUSION

This study shows that a biophilic architecture approach plays a crucial role in supporting the function of a science library as a learning space, a collaborative space, and a knowledge production center. The integration of natural elements into the design of the science library has been proven to enhance the physical and psychological environment for users, which in turn improves concentration, comfort, creativity, and productivity in learning and research. The application of biophilic principles in zones tailored for reading, research, collaboration, and public spaces will create a more adaptive, inclusive, and sustainable library environment. In the context of Medan City, which still faces challenges with low literacy and underutilized public facilities, this approach can be a relevant architectural strategy to revitalize the role of the science library as an active learning space and knowledge ecosystem that supports human resource development. This study has several limitations, as it is based on a literature review and does not draw on direct field observations or a survey of library users in Medan; consequently, its conclusions do not fully reflect the reality on the ground or the actual experiences of users.

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