

Biophilic Design in the Built Environment to Improve Well-Being: A Systematic Review of Practices

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ABSTRACT

The built environment is the man-made space including our cities, neighbourhoods, offices, and homes where people live, work, and recreate daily. Several recent research studies have devoted considerable attention to how our built environment affects our health, well-being, and quality of life. The idea of this paper stemmed from a conversation with architecture students after a lecture on healing landscapes. They have been asked to take a photo of the view out of the windows of their rooms for the following week discussion. The discussion mainly focused on why viewing nature is more favourable and advantageous than viewing buildings. The answer to this question is 'biophilia', defined as the inherent human inclination to affiliate with nature. Biophilic design -an extension of biophilia- is an innovative way of design that strives to foster a deep connection with nature in places where we live, work, and learn to induce well-being effects. The present paper seeks to systematically review and address the current practices of biophilic design in interior spaces where people spend most of their time. This paper situates the emerging concept of biophilic interior design and concludes by reflecting upon a conceptual model that enriches and sustains the human-nature connection.

KEYWORDS

interior spaces; built environment; biophilic design practices; well-being; systematic review

ملخص

البيئة المبنية هي المساحات التي صنعها الإنسان وتضم المدن والأحياء والمكاتب والمنازل حيث نتواجد يوميا للسكن والعمل والترفيه. ولقد أبرزت عدة أبحاث حديثة مدى تأثير البيئة المبنية على كل من الصحة والرفاه. جاءت فكرة هذا البحث من خلال مناقشة طلاب العمارة عقب محاضرة عن تصميم المناظر الطبيعية للشفاء، حيث طلب منهم أن يقوموا بتصوير الإطلالة الخارجية من شبايك غرفهم للتحدث عنها في الأسبوع التالي. وجاء محور الحديث عن السبب وراء إستحسان وتفضيل صور المناظر الطبيعية عن صور المباني. وإجابة هذا السؤال تكمن في "البيوفيليا" والتي تعرف علي أنها الميل الفطري للإنسان نحو الإنتساب إلى الطبيعة. والتصميم البيوفيلي أو كما يطلق عليه التصميم المحب للطبيعة هو مفهوم حديث نسبيا يعزز رفاه الإنسان من خلال الإتصال بالطبيعة في أماكن تواجدنا للسكن والعمل وغيرها. تهدف هذه الورقة البحثية إلى استعراض منهجي منظم للممارسات المرتبطة بهذا التصميم في الفراغات الداخلية حيث يقضى البشر أغلب أوقاتهم، وخلصت إلى نموذج مفاهيمي لتصميم يعزز الإتصال بالطبيعة.

INTRODUCTION

The idea of this paper stemmed from a conversation with architecture students after a lecture on healing landscapes. They have been asked to take a photo of the view out of their rooms' windows. These photos highlighted two main issues: Firstly, how viewing nature is more favourable and advantageous than viewing buildings. Secondly, how our modern built environment has been stripped of nature hence lack the ability to induce well-being effect.

The affiliation with nature as an inherited human inclination is the theory of biophilia; Wilson popularized this term in (1984). Kellert and Calabrese (2015) advocated the practice of biophilic design and defined it as a process that offers a sustainable design strategy that seeks to interconnect people and nature based on three experiences and twenty-four design attributes. Strengthening this connection with nature reduces stress and improves health and well-being. Findings from several studies on the rationale and outcomes of biophilic design specified the socio-psychological benefits as follows: improved mental health; reduced stress; attention restoration; increased well-being; decreased violence and crime; faster healing rates in hospitals; and greater altruistic behaviour(Söderlund and Newman, 2017).

Since people usually spend more time inside buildings than in exterior environments, implementing a biophilic interior design approach is of particular importance. However, this subject is still researched, and the related literature is to some extent limited. Admittedly, principles and design process are open to multiple interpretations that lead to ambiguity. "While the goal of the biophilic design is clear, understanding it and its application is less so" (Mohawk Group, 2016). The purpose of this study is to systematically review the current practices of biophilic interior design in residential buildings and workplaces seeing that people (including the very young and elderly) spend approximately 65% of daily time at home while the working adults spend about 30% of their time at the office on a workday (Morawska et al., 2017). Specifically, the research seeks to answer the following three questions: What is the existing evidence concerning indoor environments featuring biophilic design? What is the evidence of the implementations of biophilic design in workplaces and residential buildings? How can applications be integrated into a holistic conceptual model to be considered in sustainable building design?

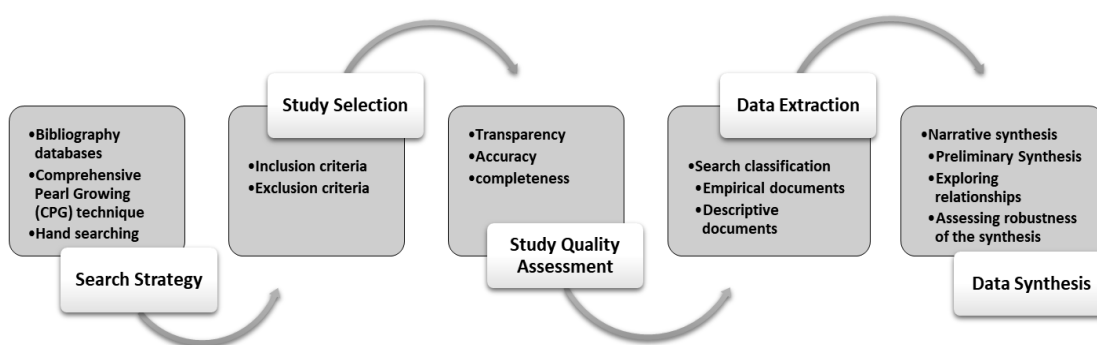
Having clarified the motivation and stated the research questions, the rest of the paper is devoted to identify the stages of the eligible systematic review protocol used in the study. The extracted evidence documents are analyzed using narrative synthesis that includes 'searching for', 'quality appraising' and 'the synthesis' of this research-based evidence. Then, results have been interpreted and discussed. Finally, concluding remarks are presented.

1. METHODOLOGY

While the biophilic design has been gaining extensive attention among practitioners and academics, a review of the current practices in the indoor built environment

seems to have been rather missing. This study utilizes a systematic review with a narrative synthesis approach “that takes great care to find all relevant studies of the highest level of evidence, published and unpublished, assess each study, synthesize the findings from individual studies in an unbiased, explicit and reproducible way and present a balanced and impartial summary of the findings with due consideration of any flaws in the evidence”(Chew, 2016). The review protocol consists of five stages outlining the search strategy, study selection, study quality assessment, data extraction, and data synthesis as shown in figure 1.

Figure (1) Research protocol



Source¹: Authors, 2018

1.1 Stage One: Search Strategy

To answer the research questions, a systematic literature search was performed in February 2018. A time frame of ten years was used that 2008 was the year when Kellert, Heerwagen, and Mador(2008) described the dimensions, elements, and attributes of biophilic design in their book titled as: The theory, science, and practice of bringing buildings to life. A comprehensive pearl growing (CPG) technique was adopted as a preliminary step to identify the keywords and quality filters under which the existing relevant studies are indexed (Schlosser et al., 2006). Then, the following four electronic databases were searched using the search string ‘indoor environment’ simultaneously with the keywords ‘biophilic’ or ‘biophilia’: ScienceDirect, Springer, Scopus, and ProQuest. These databases are a leading online platform for scientific publications. The latter was checked to capture grey literature and other evidence. Also, hand-searches were conducted to identify additional journals or books, particularly those not included (indexed) in the main bibliographic databases; this process leads to other sources worthy for this review (Vassar, Atakpo, and Kash, 2016).

1.2 Stage Two: Study Selection

There were two sequential phases with regard to the research scope. Phase one includes the following three-step process: (1) identifying relevant work of articles and publications through search strategies using predefined search terms; (2) illuminating

¹ All figures and tables presented in this research paper are produced by the authors.

duplicates; and (3) screening title, abstract, and keywords to see if the document is applicable to answer the research questions. In phase two, in case of relevancy (i.e. evidence documents related to workplaces and residential buildings), reading full document to determine the research trends, methods, results and decide if it should be included and extract the employed or presented practices. This process is called data mining. The researchers selected articles and resources from the initial search based on the inclusion and exclusion criteria. Inclusion criteria were (i) original and peer-reviewed articles written in English or Arabic; (ii) data collected from studies that focused on applications and implications rather than definitions and principles; (iii) being qualitative, or quantitative or mixed method studies. Exclusion criteria were (i) studies not related to architecture and/or interior design; (ii) sources not in the timeframe studied.

1.3 Stage Three: Study Quality Assessment

In the context of the effectiveness review study, the reviewers set quality assessment criteria on which to base decisions concerning the full documents suitable for inclusion in phase two. These studies were further assessed to determine their quality addressing the review questions according to three criteria as follows (Hong and Pluye, 2018):

(a) Transparency: All documents included provide clear, detailed, and easy to understand information about the data collection and analysis methodology used to measure results. In the case of documents based on secondary sources, the methodology to select, assess and compile sources must be evidently described. (b) Accuracy: All documents included provide accurate data collection methods that generate a credible dataset, and data analysis methods that generate correct and true results. (c) Completeness: All documents included provide sufficient information (completeness) to deliver credible, coherent and convincing arguments starting from design, through data collection and analysis, ending with results achieved and conclusions.

1.4 Stage Four: Data Extraction

The extracted documents were firstly classified according to the type of indoor environment featuring biophilic design in addition to 'out of scope' and 'generic'. 'Out of scope' referred to documents not related to the field nor the research questions while 'generic' proposed general solutions not related to the indoor environment nor a specific building type. Second, evidence documents related to workplaces and residential buildings were classed as empirical or descriptive based on their focus. Empirical documents reported applications based on the findings of original studies using research methods (e.g. surveys, case studies, interviews). Descriptive documents described, explained and summarized current practices (literature reviews). The two researchers performed independently data extraction: They both discretely read evidence documents and extracted data that described methodologies, settings, biophilic design implications and applications, then they together reached consensus on the extracted data. The researchers used two software tools for data extraction and screening process: Mendeley and MS Excel.

1.5 Stage Five: Data Synthesis

Narrative synthesis has been used to systematically and comprehensively analyzing the extracted evidence documents based on 'Guidance on the Conduct of Narrative Synthesis in Systematic Reviews' (Popay et al., 2006), as shown in Table1.

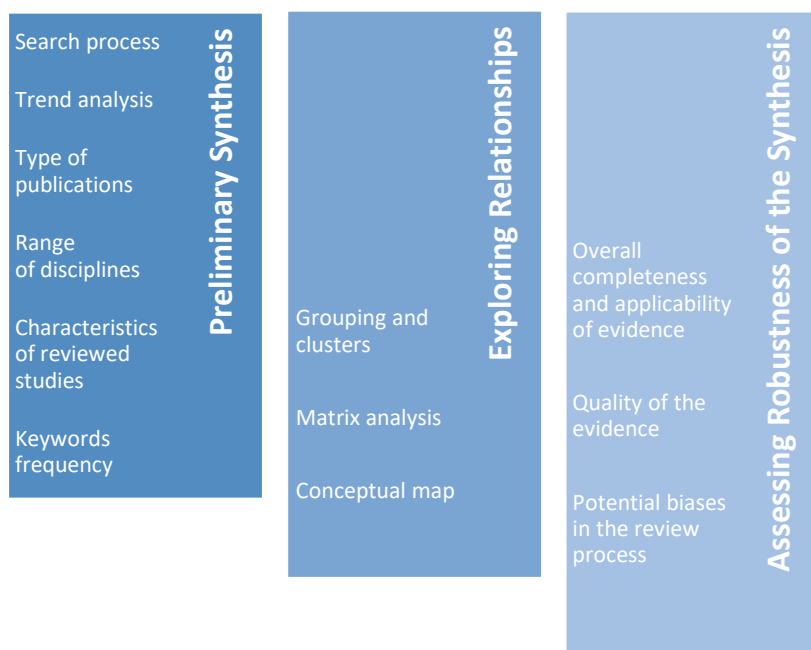
Table (1) Tools and techniques for data synthesis process

Tools and Techniques	Research questions
Preliminary Synthesis	<p>RQ 1: What is the existing evidence concerning indoor environments featuring biophilic design?</p> <ul style="list-style-type: none"> • Search process • Trend analysis • Type of publications • Range of disciplines <p>Textual descriptions Summarising the documents and beginning to extract information in a systematic way.</p> <p>Presenting results in graphical form Several visual and graphical tools were used to explore the extracted studies.</p>
	<p>RQ 2: What is the evidence of the implementations of biophilic design in workplaces and residential buildings?</p>
	<ul style="list-style-type: none"> • Characteristics of reviewed studies • Keywords frequency <p>Tabulation Tabulation is a commonly used approach in all types of a systematic review to represent data visually. It has been used to develop an initial description of the included studies and to begin to identify patterns across them.</p> <p>Translating data A word frequency tool was used to count keywords in extracted documents (one point for each utterance), generating "word clouds" that give greater prominence to repeated keywords</p>
	<ul style="list-style-type: none"> • Grouping and clusters <p>Groupings and clusters Organising the included studies into smaller groups to make the process more manageable.</p>
Exploring Relationships	<p>RQ 3: How can applications be integrated into a holistic conceptual model to be considered in sustainable building design?</p>
	<ul style="list-style-type: none"> • Conceptual map • Matrix analysis <p>Developing a conceptual model Idea webbing method was used for conceptualizing and representing the relationships being explored.</p> <p>Variability in applications Exploring the influence of heterogeneity is important at this stage of the synthesis process. Therefore a matrix that covers research applications and the 24 attributes of biophilic design will help to identify the existing gaps in the literature and provide a background to position future research on this topic.</p>
Assessing Robustness of the Synthesis	<ul style="list-style-type: none"> • (in the discussion section) <p>Reflecting critically on the synthesis process</p> <ul style="list-style-type: none"> - Overall completeness and applicability of evidence. - Quality of the evidence. - Potential biases in the review process.

2. RESULTS AND DISCUSSION

This section is devoted to answer the research questions based on the previously described narrative synthesis process using the three following techniques: preliminary synthesis; exploring relationships; and assessing the robustness of the synthesis (Figure 2).

Figure (2) Results and discussion procedure

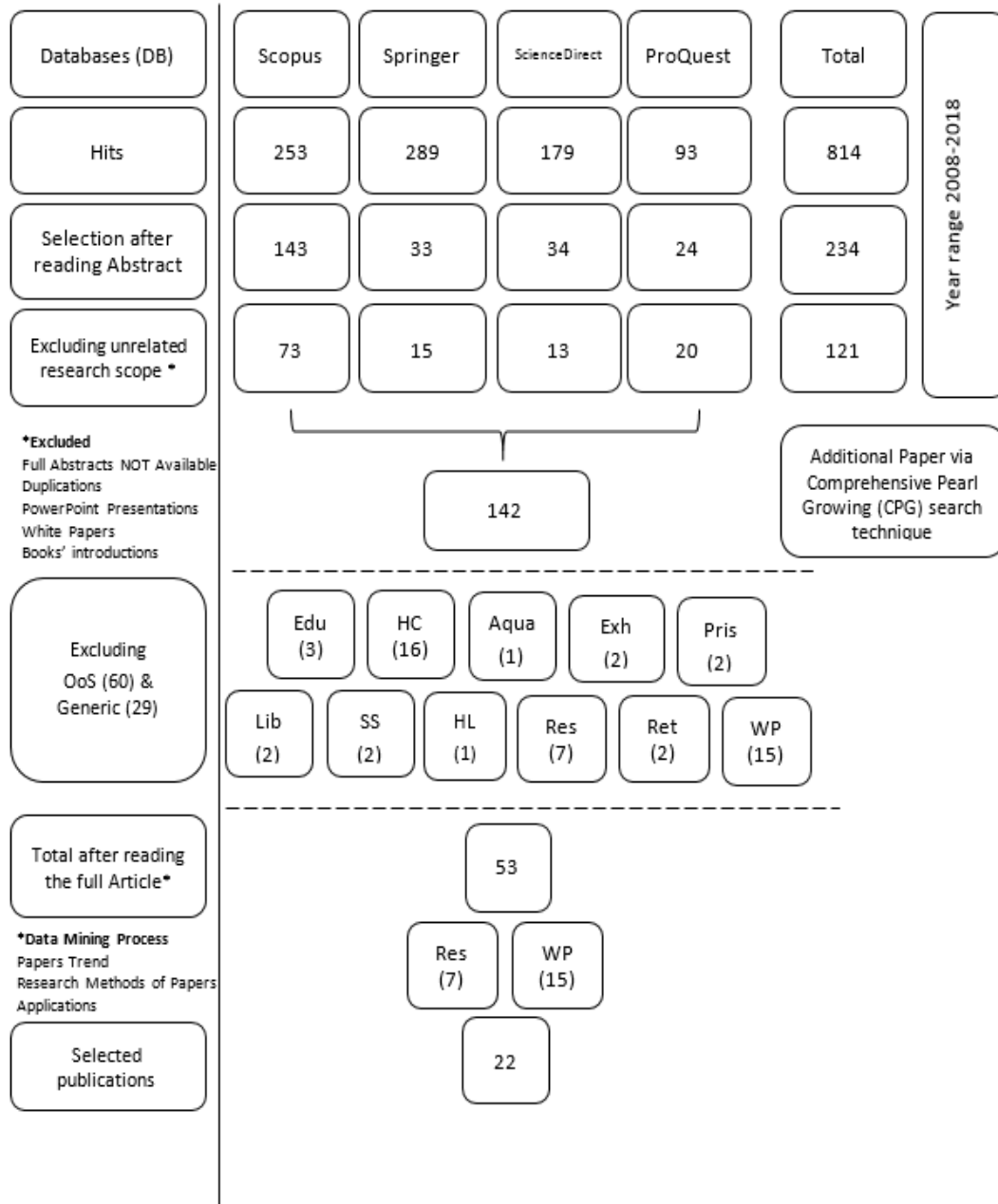


2.1 Developing a Preliminary Synthesis

It is always necessary to interrogate the preliminary synthesis to develop an initial description of the included studies

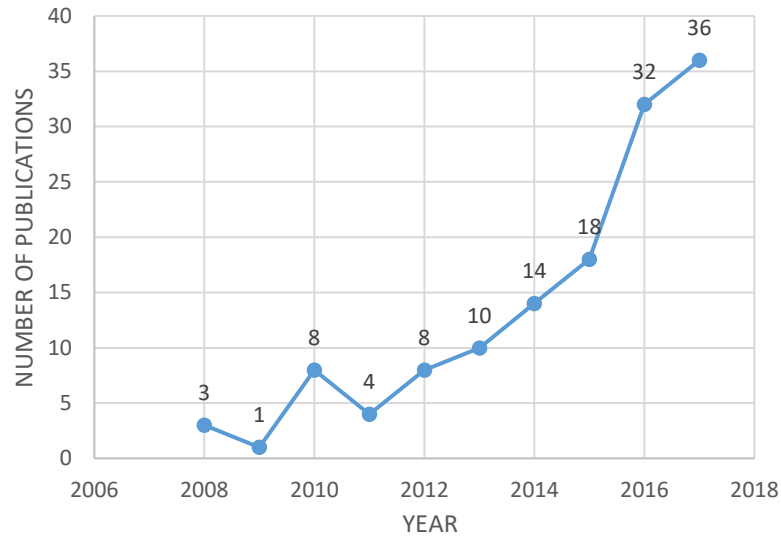
2.1.1 Search process and results: The preliminary synthesis developed an initial description of the included studies. It was used at an early stage for summarizing the search strategy, study selection, and data extraction as presented in the flow diagram in figure 3. The search in the four specified databases considering the time frame 2008–February 2018 generated a total of 814 results published in journals, conferences proceedings, books, and book sections. After reading the abstract, 234 documents remained. The exclusion process then led to the inclusion of 121. The snowball and CPG technique added another 21, bringing the total number of included studies in phase one to 142. Then, 60 documents out of scope (OoS) and 29 generic documents (Generic) were excluded and the 53 remaining studies were categorized into 11 different building types as follows: 3 Educational (Edu); 16 Health Care (HC); 1 Aquarium (Aqua); 2 Exhibitions (Exh); 2 Prison (Pris); 2 Library (Lib); 2 Subway Station (SS); 1 Hotel (HL); 7 Residential (Res); 2 Retail (Ret); and 15 Workplace (WP). Subsequently, for the purpose of phase two, reading the full text identified documents of evidence related to 15 workplaces and 7 residential buildings with a total of 22 documents.

Figure (3) Flow diagram of the data extraction process



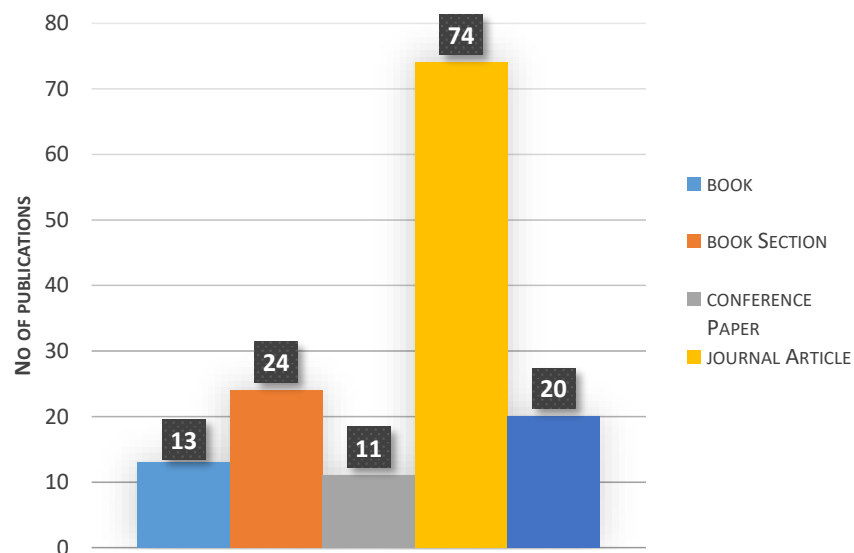
2.1.2 Trend analysis: The (142) extracted documents were organized by chronological order, classified depending on publishing year to count them for the purpose of analyzing the time trend and research distribution. Figure 4 shows the number of evidence documents in the latest ten years. As trend line highlights, three studies concerning this topic are dated 2008 (Kellert, 2008; Wu et al., 2008; Yudelson, 2008). Between this start point and 2009, only one publication was found. After 2011, the total number has been gradually increasing until 2017. Indubitably, the timeline analysis highlighted an ascending trend in the total number of studies published per year. The initial contention of a growing interest among the researchers in the field is thus substantiated.

Figure (4) Trend analysis: number of publications about biophilic design and indoor environment



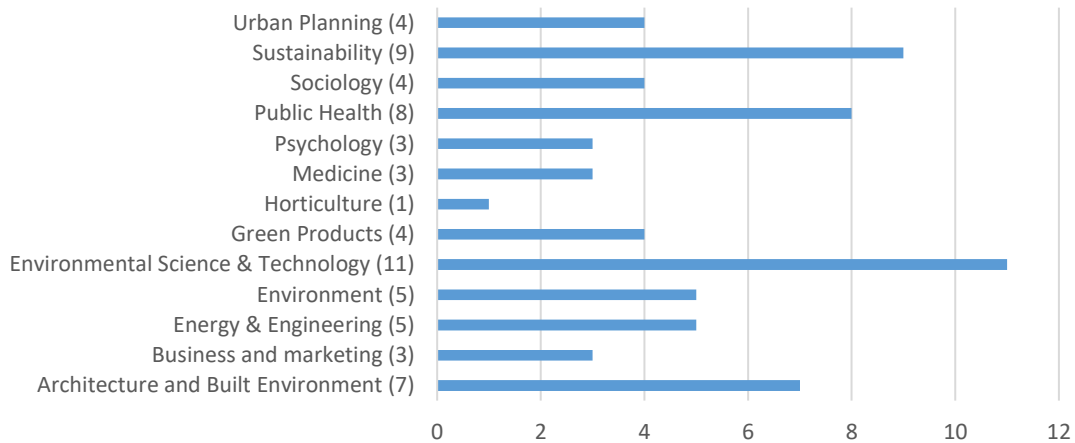
2.1.3 Type of Publications: A total of 74 from 142 identified documents were journal articles published in 69 academic journals; other documents were 11 conference papers, 13 books, 24 book sections, and 20 unpublished theses as shown in figure 5.

Figure (5) Selected resources classified by type of publications



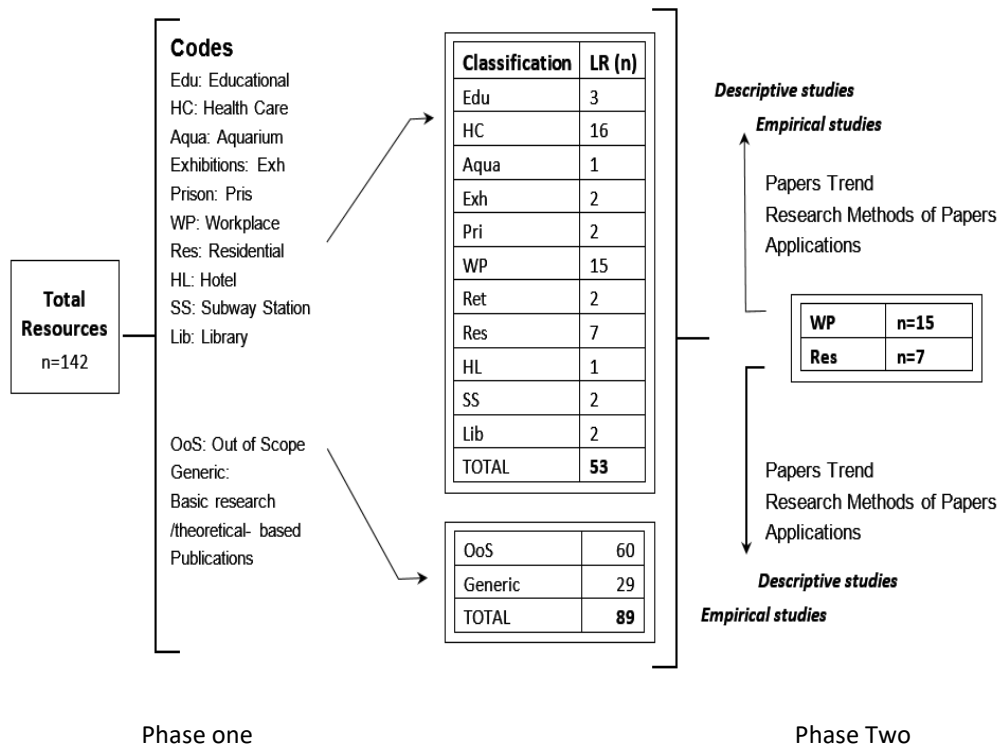
2.1.4 Range of disciplines: Journal articles were published in a wide range of international peer-reviewed academic journals. Subject area includes Architecture, Urban Studies, Sociology, Psychology, Sustainability, Built Environment, Forestry, Green Materials, Environmental Science, Medicine, Horticulture, Public Health, and Marketing and Business (Figure 6).

Figure (6) Journals classified by discipline- A total of (67)



2.1.5 Characteristics of the reviewed studies: In the second phase 22 documents of evidence were reviewed (as previously mentioned in section 1.2). They were classified into descriptive and empirical studies including 15 workplaces related studies and 7 residential buildings related studies (Figure 7). The settings of workplace empirical studies were university offices, computer workstations, construction site offices, high rise office buildings, net-zero and LBC2 certified office buildings. For residential buildings studies, settings were family homes, residential towers, supported housing facilities, floating houses, and government dwellings. Tabulation was used to develop an initial description of the characteristics of these studies based on research methods, biophilic practices, and research results (appendix A).

Figure (7) The two sequential phases relating to the research scope



2.2.6 Keyword frequency: Word cloud was used as a visualization method to display how frequently keywords appear in the reviewed studies. The more frequent the keyword is used, the larger and bolder it is displayed as illustrated in figure 8 and 9.

Figure (8) Keyword frequency- Workplace studies



Figure (9) Keyword frequency- Residential studies

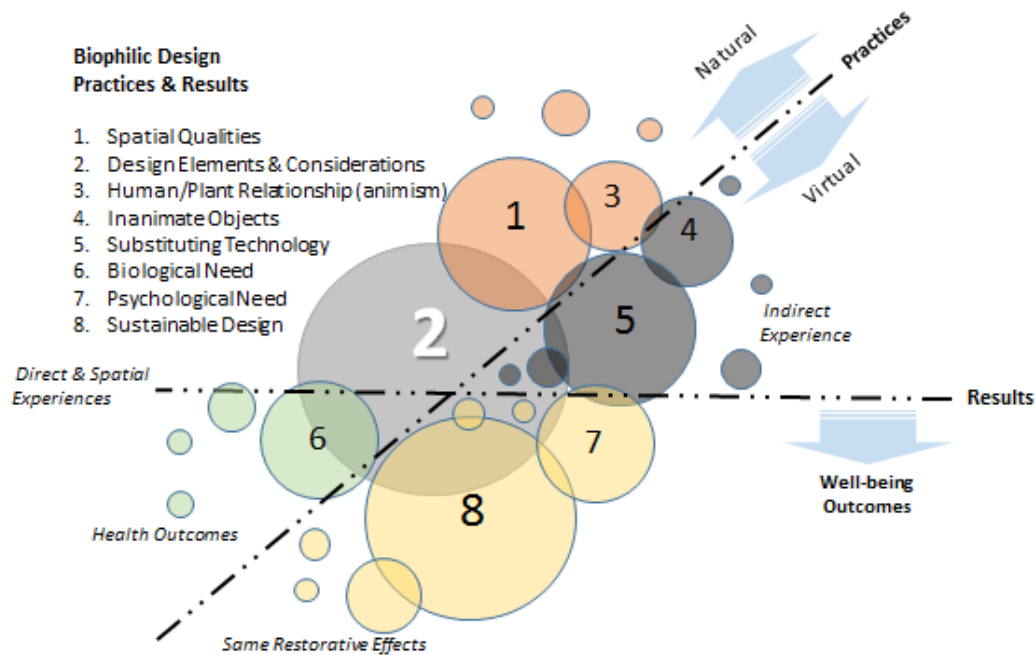


2.2 Exploring Relationships between Studies

This technique involves the analysis of workplaces and residential buildings related evidence documents utilizing groupings and clusters, matrix analysis, and conceptual map. It aims at exploring relationships, identifying patterns, and reaching conclusions.

2.2.1 Groupings and clusters: Narrative synthesis process usually involves organizing the included studies into smaller groups to make the process more manageable (Figure 10). The reviewers started to group the included studies at an early stage and then refined these initial groups as the synthesis developed to focus on exploring relationships between the biophilic practices presented in evidence documents.

Figure (10) Grouping and clusters



Biophilic design concept considers other forms of life (Beatley, 2017) and works efficiently in different contexts (Orman, 2017). It consists of direct, indirect, and symbolic experiences that aid in human-nature connections (Bewza, 2012). Characteristics include access to diverse space types with different spatial qualities (Mangone et al., 2017), varied surface textures, glass, natural view, natural materials, warm colours (Spivack and Rogelberg, 2010), plants, natural sunlight, ventilation, open spaces and windows (Gray and Birrell, 2014).

Live plants can be desktop companions and shared residents of space (animism) (Gray, 2017). Inanimate objects have similar restorative effects compared with live plants (Evensen et al., 2015). Additionally, virtual biophilic indoor environment has the same positive effect as the real one (Tomasso *et al.*, 2018); however, simulation cannot replace natural elements because the link to nature is a biological and psychological need (Gomes and Preto, 2018). Artificial skylight or daylight-substituting technologies positively influence mood states in windowless environments (Canazei *et al.*, 2017) but the exposure to sunlight and daylight is of utmost importance to prevent vitamin D deficiency (Hauge, 2015; Alhazim *et al.*, 2017).

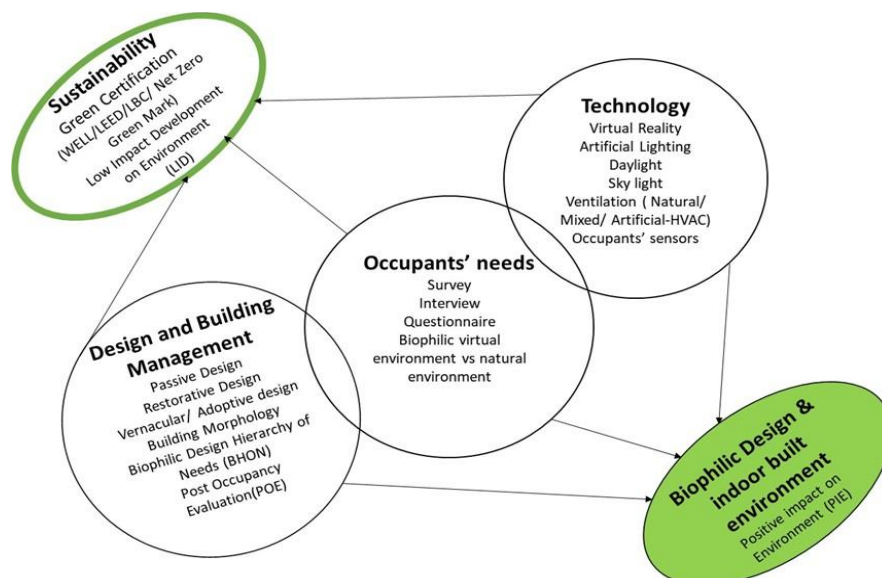
Biophilic practices are rooted in environmental quality indices (Marcheschi *et al.*, 2015), Indoor Environmental Quality (IEQ) aspects (Al Horr *et al.*, 2016), Green Mark (GM) performance indicators (Bozovic-Stamenovic *et al.*, 2016), passive climate-adaptive design strategies for green buildings (Xue, Gou and Lau, 2016), Living Building

Challenge (LBC) criteria (Leah, 2017) and biophilic design hierarchy of needs (BHON) (Holloway Cripps, 2016).

The results of employing biophilic practices were positive physiological, psychological, and cognitive well-being outcomes that boost productivity, creativity and comfort; ameliorate mood states; reduce stress; lessen health complaints; foster a collaborative environment; increase satisfaction, and promote the ecological and sustainable built environment.

2.2.2 Conceptual map: It was used to link multiple pieces of evidence extracted from the findings to explore relationships between and within reviewed studies. A cursory look at the results of workplaces and residential buildings studies highlights three themes related to biophilic design and indoor environment. These themes are (a) Design and building management; (b) Occupants' needs; and (c) Technology. The emerged themes have a certain degree of overlap and are related to two-poles or extremities: 'Sustainability' and 'Biophilic Interior Design as shown in figure 11.

Figure (11) Conceptual map



2.2.3 Matrix analysis: The purpose of matrix analysis was twofold: first, to further explore the variability in practices; and secondly, to identify gaps. A table was set up representing Kellert's three experiences and the twenty-four attributes of biophilic design as well as the practices related to these attributes in the reviewed studies. A simple feature is used to define building type (table 2). Examining matrix analysis results, the reviewed studies focused mainly on the 'Direct Experience of Nature' and its attributes (e.g. light, air, plant) while the 'Indirect Experience of Nature' and the 'Experience of Space and Place' were neglected to some extent. Gaps could be identified in the two types of buildings related studies as follows: for workplaces studies, work is mainly needed to fulfill the 'Indirect Experience of Nature' with regard to the attributes (A 11) and (A 16); for residential buildings, work is essentially needed to fulfill the 'Indirect Experience of Nature' considering the attributes (A 9), (A 11), (A 12), (A13), (A 16), (A 17), and (A 18).

Table (2) Matrix analysis

Biophilic Experiences		Attributes (A)	Practices employed Workplace (O) Residential (Δ)										
Direct Experience of Nature	A1	Light	O	O	O	O	O	Δ	Δ	Δ	Δ	Δ	Δ
	A2	Air	O	O	O	O	O	Δ	Δ	Δ	Δ		
	A3	Water	O	O	O	Δ	Δ						
	A4	Plants	O	O	O	O	O	O	Δ	Δ	Δ		
	A5	Animals	Δ										
	A6	Weather	O	O	Δ	Δ	Δ						
	A7	Natural landscapes and ecosystems	O	O	O	O	Δ						
	A8	Fire	Δ										
Indirect Experience of Nature	A9	Images of Nature	O										
	A10	Natural materials	O	O	O	O	Δ	Δ	Δ				
	A11	Natural colours	Δ										
	A12	Simulating natural light and air	O	O									
	A13	Naturalistic shapes and forms	O										
	A14	Evoking nature	O	O	O								
	A15	Information richness	O	Δ									
	A16	Age, change and the patina of time	O										
	A17	Natural geometries	O										
	A18	Biomimicry	O	Δ									
Experience of Space and Place	A19	Prospect and refuge	O	O	O	Δ							
	A20	Organized complexity	O	O	O	Δ	Δ	Δ					
	A21	Integration of parts to wholes	O	Δ	Δ	Δ							
	A22	Transitional spaces	O	O	Δ	Δ							
	A23	Mobility and way finding	O	Δ	Δ	Δ							
	A24	Cultural & ecological attachment to place	O	O	Δ								

2.3 Assessing Robustness of the Synthesis

To assess the robustness of the synthesis, this ‘discussion’ section addresses aspects of the narrative synthesis that can impact on the generalizability of the results of the review (Busse *et al.*, 2002).

2.3.1 Overall completeness and applicability of evidence: The included studies sufficiently address the objectives of this review and provide an answer to the three interrelated research questions, though there is an existing gap in Arabic evidence documents (only one documented was found and was excluded for being out of scope). All relevant biophilic applications and implications have been evaluated and a conceptual model was developed to make transparent the process whereby three themes relating-to-two-poles-or-extremities are identified. These two poles are sustainability and biophilic interior design and the related themes are design and

building management, occupants' needs, and technology. It has to be said that the comparison between participants of included studies has not been planned. However, it should be mentioned that participants in workplaces were: university students, workers, and employees, and in residential buildings, were: householders, older adults, and people with severe mental illness in residential buildings. Ultimately, in the course of this study, the 'twenty-four attributes' indicated in the 'three experiences' of biophilic design were looked for but were not all reported by included studies. The reason might cause research in the area to flourish.

2.3.2 Quality of the evidence: According to GRADE (grading of recommendations assessment, development, and evaluation), limitations in the primary studies constitute one important factor to be considered. The risk of bias of the included studies that might impact the results of the review is minimized due to the quality assessment criteria used to addressing transparency, accuracy, and completeness of the included studies. Also, a systematic review can be considered as a low risk of bias even though the included studies are all at high risk of bias since the review has appropriately assessed and considered the risk of bias in the primary studies when drawing the conclusions (Whiting *et al.*, 2016).

2.3.3 Potential biases in the review process: The study was limited by a ten-year time frame which ended in February 2018 when there was an increasing pool of evidence. Moreover, only workplaces and residential buildings were included in the second phase of the review, these posed constraints point the way forward for future studies. Performing simultaneous searches through the four previously mentioned large databases help overcoming the inherent limitations of each one and adding to the quality of reviewing but was time-consuming particularly to avoiding duplicate. The matrix analysis was performed independently by the two researchers. They both discretely read the findings of the included studies, extracted biophilic design applications, and implementations and coded them with regard to Kellert's 24 attributes to reach an exact agreement. While also time-consuming, but this step was of particular importance as some of these attributes are close in meaning and/or share the same features.

3. OVERALL DISCUSSION

The paper adopts a systematic review approach and a narrative synthesis process that involves critical analysis of relevant research evidence in a systematic objective rigorous way to reach clear conclusions about what is and is not known about biophilic design practices in indoor built environment (Bruce, Mollison and Lecturer, 2004; Wolpert and Reuter, 2012).

- In the light of this review, biophilic practices were mainly found in evidence documents related to the following building types: healthcare (16), workplaces (15), and residential (7). There is also an ascending trend in the total number of studies published per year in a wide range of disciplines.
- Most of us spend our lifetime in the indoor built environment, thus evidence documents related to workplace and residential building types were configured to identify research methods, biophilic design practices, and research results.

- Research methods used were surveys, experiments, interviews, and case studies/longitudinal studies. Biophilic practices were grouped into clusters based on descriptive similarities within each cluster. The results of these practices were mostly positive physiological, psychological, and cognitive well-being outcomes.
- The three following themes emerged from the design practices presented in the reviewed studies: design and building management; occupants' needs; and technology. These themes have a certain degree of overlap and are related to both 'sustainability and 'biophilic interior design'.
- The matrix analysis helped to identify the existing gaps and clearly specified that future research should focus on 'Indirect Experience of Nature'.
- Finally, the analysis of robustness was applied to temper the synthesis of evidence as well as indicating how generalizable the synthesis might be.

4. CONCLUSION

Biophilic interior design is a rapidly evolving approach and a sustainable design strategy that can mediate between nature and indoor environment hence promote nature-health relationships. The systematic review of 142 studies over the last ten years seeks to articulate a growing body of research and emerging design application in the built environment. The twenty-four attributes of biophilic design and their related three experiences are partly adopted in empirical studies and explored in descriptive others. There has been little research on how all these different attributes might work together, or how to measure and quantify their human, environmental, and economic outcomes.

In this review, all extracted biophilic applications and implications have been evaluated and a conceptual model is developed to make transparent the process whereby three themes allied with two poles emerged. These two poles are sustainability and biophilic interior design and the related themes are design and building management, occupants' needs, and technology. Management should take the lead especially in office buildings given that unsustainable workplaces cost corporations by wearing down their social and human capital. Occupants, comfort, and level of satisfaction in different building types might be gained which call for the repeatability and measurability of design applications. Technology might change markets toward sustainable high-quality buildings that deliver far more than what we can imagine several years back.

Eventually, the future objective is to examine how biophilic interior design may interact with the current sustainability standards and rating systems which still an amorphous idea to many practitioners and researchers.

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Appendix A. Characteristics of the reviewed studies

AUTHOR(S)	METHODS	PRACTICES	RESULTS
(Gomes and Preto, 2018)	Literature review	Biophilic virtual environment vs natural environment	Virtual environment can't be a substitute of a real and natural one as it jeopardize our physiological and psychological systems
(Tomasso et al., 2018)	Randomized crossover study	Biophilic virtual environment vs natural environment	Virtual environment has the similar effect of the actual environment in reducing stress and improving cognition
(Alhazim et al., 2017)	Case study	Indoor sunlight / daylight access	Importance of sunlight at home to prevent vitamin D deficiency
(Canazei et al., 2017)	Randomized controlled study design	Daylight-substituting technologies vs fluorescent illumination	Daylight-substituting technologies positively influence mood states in windowless environments
(Gray, 2017)	Longitudinal study	Human-Plant Relationships 'Desk –Buddy'	Animism (plants as stewards and shared residents of space) might influence wellbeing and sustainability contribution
(Hutchinson, 2017)	Case study	Bringing more intelligence and quality to buildings	Drivers of health, productivity and comfort
(Leah, 2017)	Case study	Meeting the stringent Living Building Challenge criteria	Healthy, ecological and sustainable built environment
(Mangone et al., 2017)	Survey	Access to diverse space types with different spatial qualities	Increased productivity and creativity, as well as positive emotional and physical health outcomes
(Orman, 2017)	Comparative case study	Applicability of biophilic design attributes	Biophilic design concept works efficiently in different contexts
(Poscablo, 2017)	Case study	Adaptive bioclimatic features	Enhancing the quality of life for older adults and supporting their well-being
(Al Horr et al., 2016)	Literature review	Indoor environmental quality (IEQ) aspects	Optimizing occupant productivity
(Beatley, 2016)	Case study	Green features and sustainable features such as bamboo	Design that considers other forms of life
(Bozovic-Stamenovic et al., 2016)	Post Occupancy Evaluation (POE)	Green Mark (GM) performance indicators	Awareness of Green lifestyle is closely connected to self-reported wellness
(Holloway Cripps, 2016)	Systematic review	Biophilic design hierarchy of needs (BHON)	Positive physiological, psychological, and cognitive functioning outcomes.
(Xue, Gou and Lau, 2016)	Survey	Green certification, ventilation mode, and building morphology	Better health perceptions and passive climate-adaptive design strategies for green buildings
(Evensen et al., 2015)	Mixed randomized experiment	Live plants vs inanimate objects	Live plants did not have superior restorative effects compared with inanimate objects, neither with nor without access to a window view
(Hauge, 2015)	Survey	Indoor daylight access	Using window for daylight that is fundamental for people's well-being.
(Marcheschi et al., 2015)	Post Occupancy Evaluation (POE)	Environmental quality indices	Perceived physical and social-environment qualities predicted quality of life
(Gray and Birrell, 2014)	Longitudinal study	'Working Bee' A bespoke site design incorporating aspects of biophilic design	Strong positive effect that boost productivity, ameliorate stress, enhance well-being, foster a collaborative environment and promote satisfaction
(Evensen, Raanaas and Patil, 2013)	Intervention case study	Indoor plants and daylight simulation	Reduction of reported health complaints
(Bewza, Amber, 2012)	Interior design practicum	Direct, indirect, and symbolic experiences	Designs that are spatially efficient and aid in human-nature connections
(Spivack, Askay and Rogelberg, 2010)	Literature review	Biophilic environmental characteristics	Greater perceived creativity