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HISTORY MATTERS: THE ORIGINS OF BIOPHILIC DESIGN OF INNOVATIVE LEARNING SPACES IN TRADITIONAL ARCHITECTURE

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Keywords

university campus; Biophilia; innovation; bimaristan; metaphor; refuge; prospect

Abstract

Recent empirical studies have shown a positive correlation between nature, the built environment and creativity in the human brain. During the medieval Islamic Golden Era, higher education buildings of non-medical 'madrasa' and medical 'bimaristan' institutions applied specific techniques and strategies so that human intellectual curiosity could flourish through direct and indirect contact with nature. In contrast, the architecture of modern universities has lessened students' multisensory focus and engagement with nature. Several studies have addressed these institutions' failure to foster the innovation-generation process. This systematic review summarises and synthesises previous studies, elaborating the characteristics of those spaces that can host Innovation-Generation Processes (IGPs) based on psychological and neurological investigation. The study analyses research outcomes that support the stimulative impact of nature on people's cognitive capacities. This demonstrates that the biophilic design approach utilises natural conditions and elements within the built environment to enhance the physical, social, intellectual and psychological status of innovators. The findings of this study demonstrate a strong interrelationship between IGPs and the built environment in traditional higher education institutions based on the premise of biophilic design. Hence, we can adopt some lessons from these 'timeless' buildings to support the evolution of innovative university campuses today.

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INTRODUCTION

For more than a thousand years, higher education institutions have profoundly contributed to social, cultural and economic enrichment in society. Historically, the relationship has been mutually supportive, thus university campuses today are still expected to act as incubators of innovative ideas that enable humans to thrive and prosper (Ransom, 2015). Accordingly, strategic and physical planners of present-day university campuses seek a more dynamic built environment and organisational setting in which to nurture the unpredictable characteristics of innovative learning (Turner, 1987). This study, therefore, poses a central research question: is innovation exclusively derived from technology, or is it generated by other catalyst agents, including the built environment, which can stimulate creativity in the human brain?

To answer this question, this research investigates the architectural configurations of the innovation-driven 'timeless' institutions of science and medicine during the medieval Islamic Golden Era, called 'madrasa' (Arabic for any educational institution). It is well documented that the buildings of *madrasa* witnessed miraculous evolution and ground-breaking innovation in several fields of knowledge and applied science, such as physics, chemistry, medicine and engineering, with limited technological advantages.

American biologist Edward Wilson (1984) proposed that the innate human need to affiliate with nature requires radical reform in modern society. The evolutionary approach of *biophilia* soon influenced several research domains including architecture and the built environment. The *biophilic* design concept has continued to develop over the past decade to employ the conditions and elements of nature, and has been implemented to promote physical, social, intellectual and psychological wellbeing.

An immense body of research has recently focused on investigating the correlation between human wellbeing and productivity and its connection to nature (Shibata & Suzuki, 2002). Early studies focused on measuring the impact of having visual access to nature on employees' productivity, reducing the levels of harmful job stress and extending employment longevity. Further research continued to find correlations between the workplace and natural conditions. Most of these studies used historical examples for further insight (Kellert, 2005, 2008). This study will establish common ground between environmental psychology, neuroscience and phenomenological architecture through historical interpretation. The core aim of this study is to offer a more fine-grained, in-depth understanding of the correlation between design strategies and patterns of *biophilic* design in order to understand how to foster innovation in education spaces. Such a bond was revealed by the analysis of traditional madrasas, which spontaneously implemented these strategies in the absence of prior research. Also, this study attempts to overcome the negative tendencies of the hegemony of mere technological or visual features in designing learning spaces. This cannot be achieved without using historical case studies, which, by default, lack these features. Ultimately, this research is twofold. Firstly, the qualitative literature review investigates the premise of innovation-boosting spaces. In addition, the analysis includes the correlation between innovative space design and attributes of biophilic design. Secondly, it demonstrates a set of historical case studies of pioneering educational buildings in Islamic architecture to determine their relevance to the proposed attributes, patterns and elements of innovative biophilia-driven design.

METHOD: THE MULTISENSORY ARCHITECTURAL EXPERIENCE OF INNOVATION

This study proposes that the interrelation between *biophilic* design strategies and multisensory spaces can result in more innovation-driven learning spaces. This study looks at this correlation through an in-depth historical interpretation of the traditional academic schools or *madrasa* built between the eleventh and fourteenth centuries. This retrospective review will have a twofold impact. Firstly, it will significantly inform the design of today's academic buildings to leverage the potential of creativity, productivity, self-esteem and wellbeing for knowledge seekers. Secondly, it will lower the negative ecological impact and increase the operational efficiency of a university campus regarding energy, resource consumption and waste control. The stronger the interrelation between these factors, the more likely it is that innovation will flourish and expand (see Figure 1).

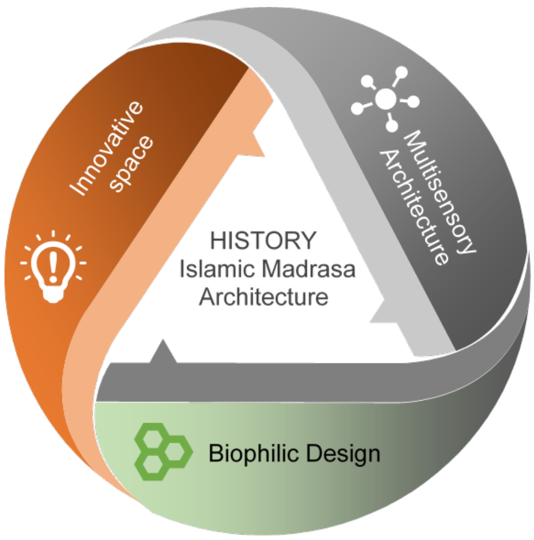

Figure 1. Research hypothesis: the correlation between *biophilic* design and innovation can be explored by using historical buildings as a template (Source: Authors).

THEORETICAL BACKGROUND: THE IMPACT OF NATURAL AND BUILT ENVIRONMENTS ON COGNITIVE CAPACITY

Today, the mission of architects and urban planners has become more complex as disciplines such as psychology, physiology, sociology and anthropology provide vital information about how people perceive space, behave within that space and develop preferences. 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, Rainbolt, Bell, & Donovan, 2015; Han, 2010; Shibata & Suzuki, 2004; Tennessen & Cimprich, 1995). Other studies have found that active interaction with nature can restore attention (Lee, Williams, Sargent, Williams, & Johnson, 2015) and allow us to recover from stress and mental fatigue (D. Y. Li & Sullivan, 2016). However, few generic studies have explored the architectural characteristics and attributes of learning spaces that can foster collaboration and innovation based on scientific premises (Allen, 2007; Zundel, 2013). No single study has traced the common ground between *biophilia* and innovation in higher education. Nevertheless, architects who wish to foster innovation seek to further understand the characteristics and stages of innovation generation as a process. Until then, such a process has no precise definition and a mysterious mechanism. However, social psychologists identify innovation as a mix of creativity and knowledge, which can spark the imagination, fuelled by data.

Nature and learning spaces: psychological and experimental findings

A long list of empirical and experimental studies has revealed the importance of the connection between humanity and nature (Biederman & Vessel, 2006; Joye, 2007; Masden & Salingaros, 2014; Ulrich, 1983, 1984). For example, Ulrich (1983) suggested in his psycho-evolutionary theory that exposure to safe, natural areas is inherently restorative, because such settings were associated with survival during humanity's long evolutionary history. This inherent human affinity with natural systems and processes is defined as biophilia (Wilson, 1984). A *biophilic* relation with nature is considered to be a fundamental biological need that influences people's health, productivity, wellbeing and even existence (Kellert, 2005). The green design movement, which developed in the 1990s, established connections between improving environmental quality, work productivity, wellbeing and the built environment (Romm & Browning 1998; Ryan, Browning, Clancy, Andrews, & Kallianpurkar, 2014). These studies called for environmental building standards, such as the international building performance standard *Living Building Challenge*, which has incorporated *biophilia* into its rating system to promote buildings with a positive and generative environmental impact.

Further empirical studies proved that some natural elements act positively to support psychological, physical and emotional wellbeing for users of educational spaces to promote a more pleasant, efficient and effective innovation-generation environment. These elements include daylight (Wang, 2015), space proportions (Alexander, 1977), natural ventilation (Atchley, Strayer, & Atchley, 2012) and the presence of indoor plants (Shibata & Suzuki, 2004). From these findings, some studies explained the mechanism of innovation generation as the stimulation of the human senses by using some natural features, which may promote creative and paradoxical thinking. Some studies mentioned that paradoxical thinking is the core source of creative ideas, which leads to real innovation (Ingram, Lewis, Barton, & Gartner, 2016). Also, a recent US study at Stanford University suggested that walking in nature can positively affect the brain, which helps to curtail brooding or rumination: a likely precursor to depression (Bratman, Hamilton, Hahn, Daily, & Gross, 2015).

More recently, Li and Sullivan's (2016) experimental study on school students revealed that exposure to nature directly impacts cognitive performance and promotes attention, restoration and recovery from stressful experiences. Nevertheless, there is a general gap in knowledge around the holistic impact of the built environment on human performance. To fill this gap, the conceptual and methodological complexity of real-world users' experiences of built spaces must be addressed (Barrett, Zhang, Moffat, & Kobbacy, 2013).

The architectural settings of the Innovation-Generation Process (IGP)

Recent studies have diagnosed the Innovation-Generation Process (IGP) in business, higher education and research workplaces, and managed to break it down into multiple tasks and phases of teamwork missions (Coleman, Graham, & Mulhern, 2012). A pioneering study by Allen (2007) identified the characteristics of an innovative workplace and revealed that the creation of innovative products and processes requires certain moods and stages of innovation. Ness (2012) configured IGP from the perspective of socio-psychology. She defined it as a six-stage sequential process in a teamwork setting. Based on Ness's model of IGP, a study by Abdelaal (2018) described in detail the spatial arrangements needed to accomplish the mission of each stage, briefly listed in Table 1.

Table 1. Stages of the Innovation-Generation Process (IGP) and their associated architectural settings (Source: Authors).

Innovation Stage	Mission	Architectural settings
Phrase a question (Team forming)	To provide more freedom of thinking and better socialising among the newly assembled team.	Out-of-office gathering space, preferably an outdoor area
Identify and break frames (Team 'storming')	Focusing on finding as many valuable ideas as possible (idea centred) within a disruptive model of innovation	Two types of space: • Informal spaces within or adjacent to the workplace • Enclosed private or small group meeting spaces
Ideas generation (Team 'norming')	To filter all available ideas and shortlist one to be transferred into a product	Social indoor and outdoor spaces, group members' homes and collaborative workspaces are ideal locations for generating and modifying ideas for initial products
Incubation (Team performing I)	Imagination, observation and analogy to generate an innovative prototype	Work in an ample space and private cell-type offices for executing individual tasks.
Melding (Team performing II)	To merge the best ideas into a well-engineered product, moving forward from imagination to implementation	Two types of space: • Individually focused workspaces for production and detailing • Large showroom for testing the product and public opinion
Dissemination (Team commercialising)	To exhibit a crafted prototype and large-scale testing to be published	Convention halls, exhibitions, commercial streets, public plazas and parks

The listed typology of IGP spaces highlights that nature plays a vital role in consolidating the first four phases of the process: preparation, identification, idea generation and incubation (Plambech & Konijnendijk van den Bosch, 2015). Hence, immersion in nature, or a naturally stimulated built environment, influences the process of innovation and leads to more creative performance (Atchley et al., 2012).

Biophilic design and innovation-based learning spaces

As stated earlier, *biophilic* design can achieve a sort of retrospective reflection of nature based on the built environment to revive the genetic human affinity for nature. Neuroscience explains this biological phenomenon as 'neurological nourishment', which indicates that humans have an innate craving for a certain type of information related to the natural world. In addition, it is closely related to the brain's centres of pleasure and pain (Biederman & Vessel, 2006). The more humans are exposed, interact with and even passively view nature, the more nourishment occurs. This approach is an offspring of Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989). According to ART, connection with the natural environment can facilitate the human senses of extension and fascination, which are crucial for cognitive restoration.

However, innovation generation is not limited to the human brain's pleasure or restoration, as it is related more to intellectual skills. One of the earliest studies of outdoor learning by Mortlock (1994) confirmed that cognitive activities in nature may be regarded as an outdoor adventure, which symbolises a sense of adventure in the natural world, as exploring nature can be unpredictable and challenge people's comfort zones. Wandering in nature involves physically demanding activities (e.g. trekking), risks (e.g. getting lost) as well as opportunities for uplifting experiences (e.g. viewing a beautiful sunrise from a mountain summit). According to Ee, Seng, and Kwang (2007), people need to be open to and embrace this sense of adventure. Similarly, innovative thinkers need to be open minded to generate creative ideas. Despite the limitation of bias samples in their study, Leong, Fischer, and McClure (2014) recent empirical investigation revealed that the more connected people are with nature, the more significant their preference for innovative and holistic thinking styles.

The unlinked patterns of biophilic design and innovation

Cramer (2008) and later Kellert (2015) suggested the first conceptual framework for *biophilic* design, which included three categories of human experience within spaces: direct experience of nature, indirect experience of nature, and experience of space and place. Recently, Ryan et al. (2014) derived from these categories a list of 14 nature-based design patterns further categorised within three types: nature in the space, natural analogues, and nature of the space (Browning, Ryan, & Clancy, 2014).

Although these design patterns are more tangible and have a wide range of applications, they do not redress the gap between theory and practice in designing specific types of buildings. Ryan et al. (2014) claimed that they intended their proposed patterns of *biophilic* design to serve any building type as a 'multi-platform solution' that is flexible enough to match any project's needs based on its intentions. For this reason, from our point of view, many designers are still struggling with the embodiment of *biophilic* design features within their projects. Thus, our study focuses on integrating design patterns with the approach of IGP to be adapted in university campus architecture.

DISCUSSION: MADRASA AND BIMARISTAN COMPLEXES AS A BIOPHILIC AND MULTISENSORY EXPERIENCE

This section demonstrates the presence of the previously mentioned values, concepts and attributes of *biophilic*/multisensory design in the characteristics of the traditional 'university campus' in the Islamic era. The study is limited to secular academic institutions of applied sciences (i.e. *madrasa* and *bimaristan*) between the eleventh and fourteenth centuries in the capital cities of the Islamic world: Bagdad, Damascus, Aleppo and Cairo. Our research selected those temporal, typological and geographical limitations as those institutions witnessed endless innovation in various fields of knowledge.

International Journal of Architectural Research

Historical background: the roots of the madrasa and bimaristan prototype

From 787 A.D. Haroun Al-Rashid, the Abbasside Islamic Caliph, adapted the concept of attaching a school or madrasa to mosques and a hospital or bimaristan to a medical college from the Buddhist monastery or Sangharama (Pereira, 1994). In these schools, several advances in medical innovation functioned integrally within the hospitals of the Islamic world. It was evident that the early prototype of *madrasa* and *bimaristan* from the ninth century was influenced by other religions (e.g. via Christian Armenia and Buddhist Central Asia). By the twelfth century, the crusaders marvelled at the 'new' institutional type that had made its way to Europe (Pereira, 1994).

Early Islamic schools of medicine were influential centres of innovation that hosted Muslim, Christian, and Jewish scholars and pupils who shared the same enthusiasm to innovate, explore and generate new knowledge in science, medicine, chemistry, physics, mathematics and pharmaceuticals (Raḥmān, 1987).

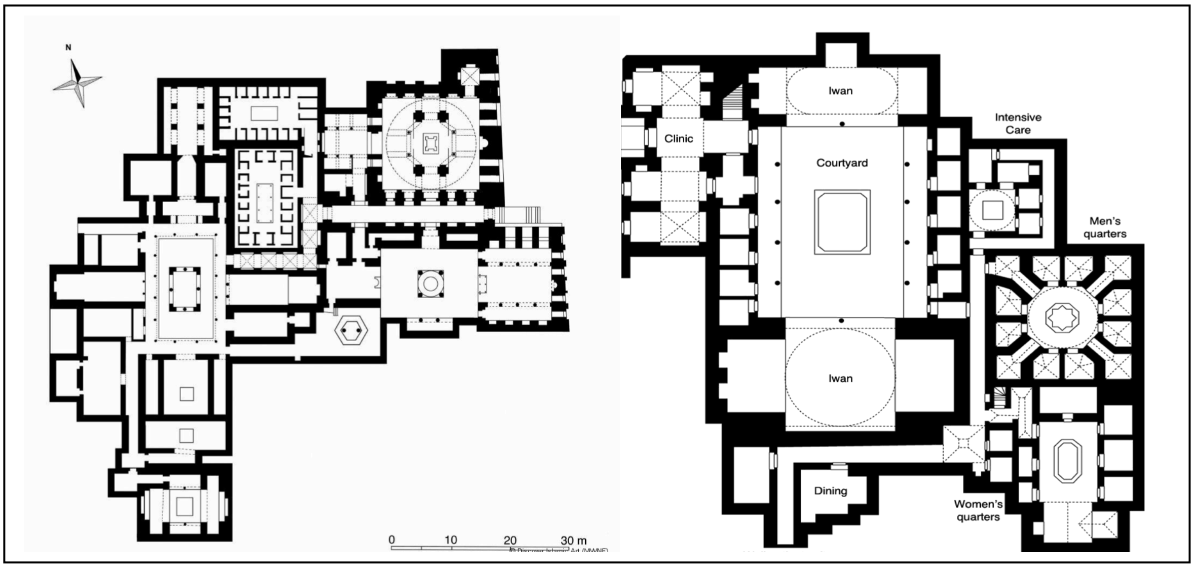

Figure 2. (Left) Madrasa, Qubbat &-Bimaristan al-Sultan Qalawun (1283 A.D.), ground floor plan.

Interestingly, Islamic academic institutions, both theological and medical, were distinguished by a set of standard features. These included: the original building form; the geometry of courtyards surrounded by four 'iwans'[1]; the impact of natural forces; and the use of water, shadow, daylight, colour and texture. The focus of this study will be the secular type of traditional madrasa (see Figure 2).

[1] An architectural unit that consists of an empty vaulted space enclosed on three sides and open to a courtyard or central space on the fourth (Peker, 1991)

Psycho-social interpretation of the madrasa complex: empirical findings

Researchers have investigated the *madrasa*, or traditional Islamic school complex, as an iconic prototype of a ‘timeless’ learning space. More recently, a study of the four ‘iwans’ of the Sultan Hassan Complex (1361 A.D.) examined the intellectual and cognitive impact of the building on its users. The study concluded that the use and experience of timeless buildings are ‘suggestive of relaxation’ after staying 30 minutes in the building (Essawy, Kamel, & Samir, 2014). Nonetheless, no empirical study has explored the secrets behind the success of these buildings as innovation hubs. However, it is well documented that these buildings are experienced as organic, alive, whole, comfortable, free, egoless, exact and mostly ‘timeless’. Hence, some architects and researchers attribute these qualities to spiritual sources while others focus on the builders’ broad and spontaneous expertise (Essawy et al., 2014). Our hypothesis supports the latter assumption.

Validating the biophilic patterns of traditional madrasa architecture

In contrast to the western conception of the building as a sculptural element in space, the traditional madrasa features well-arranged patterns on its exterior and within its interior spaces that harmoniously integrate and interplay with natural elements (Payette, 1988). These include: natural airflow, daylight, water elements, biomorphic ornamental forms and patterns; and clever manipulation of natural materials such as wood and stone (Akkach, 2005; Petruccioli & Pirani, 2013; Taheri, 2017).The abovementioned features are essential attributes of *biophilic* architecture. Hildebrand (2008) proposed five patterns in architecture that can be classified as advantageous to survival using *biophilic* design. Kellert (2015) later proposed 12 elements that could potentially influence the design of the built environment. Finally, Ryan et al. (2014) suggested the previously mentioned 14 complex patterns of *biophilic* principles, either directly, indirectly or metaphorically. The earlier proposed patterns by Hildebrand practically comprise Kellert’s 12 elements and, to a certain extent, Ryan et al.’s (2014) 14 patterns of *biophilic* design. However, the element of Kellert’s ‘change and metaphor’ and Ryan’s ‘biomorphic forms and patterns’ are considered subsections of Hildebrand’s original pattern of ‘order and complexity’, with further manipulation. Table 2 illustrates the similarities between the three approaches to the taxonomy of *biophilic* design in architecture.

Table 2. Combined patterns, elements and characteristics of *biophilic* design (Source: Authors).

Hildebrand (2008)	Kellert (2012)	Browning et al. (2014)
Complex order	Ordered complexity Change & metaphor Affection & beauty Reverence & spirituality	Complexity & order Material connection with nature Biomorphic forms & patterns
Prospect and Refuge (paired by Appleton, 1996)	Prospect & refuge Affection & attachment Information & cognition Security & protection	Prospect Refuge Visual connection with nature Presence of water Dynamic & diffused light Connection with the natural system
Enticement	Enticement & curiosity Exploration & discovery	Mystery Non-visual connection with nature Non-rhythmic sensory stimuli Thermal & airflow variability Presence of water Dynamic & diffused light
Peril	Fear & awe Mastery & control	Risk/peril Presence of water

ArchNet IJAR
International Journal of Architectural Research

Mohamed S. Abdelaal, Veronica Soebarto
Archnet-IJAR, Volume 12 - Issue 3 - November 2018 - (106-125) – Regular Section

An earlier survey conducted by Movahed (2015) examined the impact of Ryan's patterns in the historic Aqa-Bozorg Mosque (1875 A.D.). He used this building as a template to evaluate the recognition of these patterns by its visitors. The results of his survey listed the presence of water, material connection with nature, connection with the natural system, thermal and airflow variability, biomorphic forms and patterns, visual connection with nature and refuge as the most recognised patterns (in more than 140 responses). Accordingly, the proposed patterns in our study were chosen based on the intensity of their use in traditional *madrasa* architecture: order and complexity, change and metaphor of biomorphic forms, prospect and refuge, enticement, and risk and peril.

Order and complexity

Islamic architecture implemented complexity and order in various ways. Experimental studies have concluded that patterns found in Islamic architecture can achieve a cognitive balance between tedious and overwhelming (Browning et al., 2014), which enables one to make a comparison or choice (Kaplan & Kaplan, 1989). Also, this leads to positive health responses such as reducing stress, visual nourishment, and positive psychological and cognitive responses that foster innovation (Joye & van den Berg, 2011; Moon et al., 2014; Taylor, 2006). Those premises are essential for accomplishing the tasks of the second, third and fourth stages of IGP.

The pattern or 'complex order' (Kellert, 2008) uses various strategies such as fractal geometries with a scaling factor of 3, biogeometry (Shemesh et al., 2016), hierarchical symmetry (Salingaros, 2000), connective symmetries and universal scaling with a coherent spatial hierarchy around centres (Ramzy, 2015). The British mathematician Roger Penrose's patterns, which are metaphoric geometric patterns of natural elements that do not contain arbitrarily large patches, can be found in many floors, walls and decorative roof ornaments, Muqarnas patterns, plants within the courtyard, windows and doors detail, trims and texture (see Figure 3).

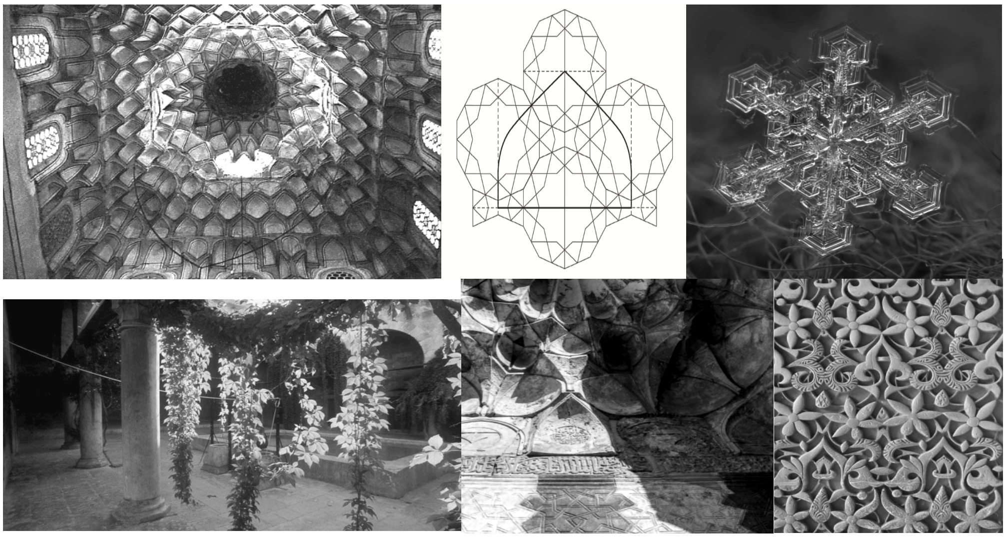

Figure 3. (Top, left to right). Muqarnas dome, Erzurum Yakutia Madrasa, Turkey; Penrose pattern in arch geometry; snowflakes fractal (by Alexey Kljatov). (Bottom, left to right) Courtyard garden and Muqarnas entry, Bimaristan Al-Argoun, Aleppo, Syria; window ornament, Bimaristan Alnuri, Syria (Source: Adapted from @ http://premoderno.tumblr.com and archnet.org).

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International Journal of Architectural Research

Change and metaphor of biomorphic forms

Stemming from order and complexity, biomorphic forms are symbolic representations of living and non-living elements in nature that are visually and perceptually pleasing, which to date has no scientific explanation. These patterns allow users of the built environment to feel connected to nature, which gives a sense of comfort, contemplation and absorption. This connection also reduces stress due to a shift in focus and enhances concentration (Joye, 2007).

For example, the golden angle (137 degrees) is the angle between successive florets in some flowers. Also, the Fibonacci series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34 ...) is used to imitate the numeric sequence that occurs in many living things, especially plants. Phillotaxian or dynamic symmetry features continuous movement and growth as in the sunflower (Hambidge, 1920). Finally, the golden section, which is the ratio of 1:1.618, is an ideal mimicry of the unfolding growth pattern of many living things (see Figure 4) (Ryan et al., 2014).

The mathematical proportions of *madrasa* and *bimaristan* plans accurately represent an array of squares and golden mean proportioned rectangles following the spatial hierarchy from domain to court to cell (Figure 5). These arrangements had their own philosophical symbols in traditional civilisations, primarily in the Islamic society, which was richly influenced by mystical and spiritual premises inspired from the Holy Quran and earlier theological approaches (Akkach, 2005).

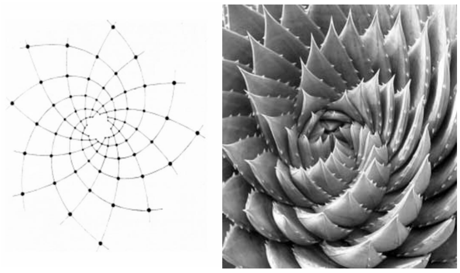

Figure 4. Nature-based mathematical geometries: phillotaxian or dynamic symmetry (Source: Joye, 2007).

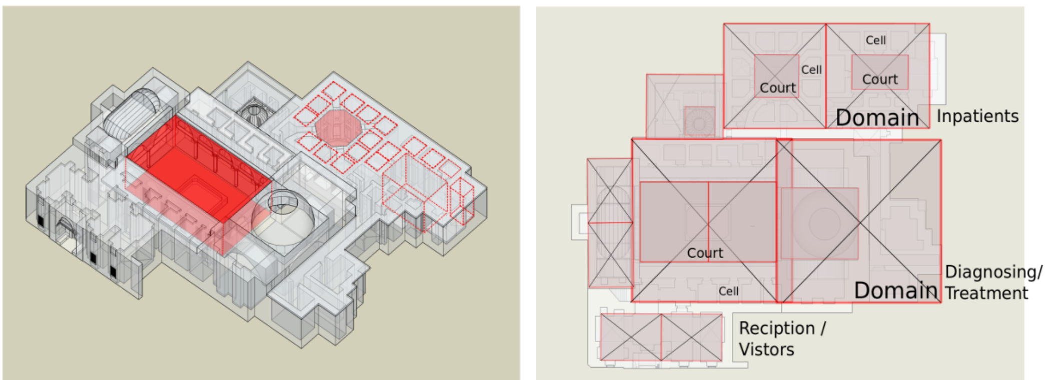

Figure 5. Implementation of nature-based patterns and proportions in Bimaristan Al-Argoun, Aleppo, Syria (Source: Authors).

Prospect and refuge (meadow and cave)

Paired patterns such as prospect and refuge refer to inseparable dichotomies and powerful design settings that facilitate obtaining information about the environment while being protected within a shelter (Appleton, 1996), depicting for example the edge of a forest (Hildebrand, 1991). Such places seem to be genetically predisposed spatial preferences for humans in evolutionary psychology. The paired patterns are visual, aesthetic and spatial preferences combined with shading elements, terraces, water and calm grazing animals to provide a sense of safety, control and freedom (Browning et al., 2014). The health benefits of both settings (i.e. prospect and refuge) include reductions in stress, boredom, irritation, fatigue and perceived vulnerability.

Prospect is characterised as the ability to see from one space to another or the view from an elevated position; this setting is most effective within a building's interior (Kellert, 2005). Refuge represents the surveillance of vast open spaces from an enclosed 'private' space accompanied by reduced lighting from a small window set in a thick wall (Ramzy, 2015). These characteristics were acknowledged by Alexander (1977) as positive spaces, which provide the feeling of being backed into a smaller space while looking out to a large space.

Such an architectural setting was widely implemented in traditional *madrasa* by providing a well-proportioned courtyard (using the golden mean[2]) which provides an average focal length (6–30 m) for a set of surrounding small study rooms or 'kholwah' with dimmed lighting (Figure 6).

Figure 6. (Top right) Refuge and prospect from a hillside cave into a valley. (Bottom, left to right) Examples of prospect and refuge patterns in an entrance hall, courtyard and small cell. Bimaristan, Al-Argoun, Aleppo, Syria (Source: Adapted from http://premoderno.tumblr.com and archnet.org).

[2] The golden mean (or Golden Section, number, or ratio, or divine proportion, etc.) refers to half the diagonal of a rectangle with length 2 and width 1. It corresponds to the 'irrational part', $\sqrt{5} / 2=1.6180$.

ArchNet IJAR
International Journal of Architectural Research

Mohamed S. Abdelaal, Veronica Soebarto
Archnet-IJAR, Volume 12 - Issue 3 - November 2018 - (106-125) – Regular Section

Enticement, curiosity/mystery

The feeling of enticement reflects a more positive and pleasant meaning of exploration than mystery. However, both moods are required to provide a sense of being teased with a kind of denial and reward that tempts the user to investigate the space with curiosity (Browning et al., 2014).

Psychological engagement with such a sense of anticipation elicits a strong pleasure response, heightened curiosity, and increased interest in gaining more information. The sense of mystery provides the desire to move deeper into the space to explore, which supports stress reduction and cognitive restoration (S. Kaplan, 1995). The term 'enticement' represents viewing and moving to a place that is brighter than the one we occupy to reveal more features (Hildebrand, 2008). The architectural setting for both enticement and mystery are pathways and transitory spaces next to the entry point of the space. Enticement-driven patterns within the built environment foster social interaction and support within the innovative team that helps the development of the first three stages of IGP.

Techniques such as dramatic shade and shadow, winding paths, obscured subjects, auditory stimulation and translucent materials were densely applied in traditional *madrasa* architecture. Examples are the screen as a translucent element and the dark 'majaz' leading to a partially lit, winding corridor, leading to a broader courtyard immersed in light (Figure 7).

Figure 7. (Left to right) Examples of enticement and mystery in hallway, inner courtyard and small cell. Bimaristan Al-Argoun, Aleppo, Syria (Source: Adapted from @ http://premoderno.tumblr.com and archnet.org).

Risk and peril/fear and awe

Risk is an audacious experience that thrills the user and involves two paradoxical emotions – fear and pleasure – due to our genetic sensitivity to danger. Peril is characterised by observing a fully evident danger, while a controlled risk provides a thrilling sense of elation. However, it is vital to distinguish peril from anxiety, as anxiety can present in a case of lack of control, which might cause a sense of fear (Figure 8).

Controlled risk, peril or even fear and awe have a profound positive impact on raising awareness and curiosity, memory refreshment and problem-solving skills. Architecturally, the traditional *madrasa* builders used some tools to evoke low-level risk within these schools, including the use of double height in shared spaces, balconies or catwalks, cantilevers and clever use of water sounds (Figure 8). This pattern is highly recommended to stimulate the generation and manipulation of ideas during the second and third stages of IGP.

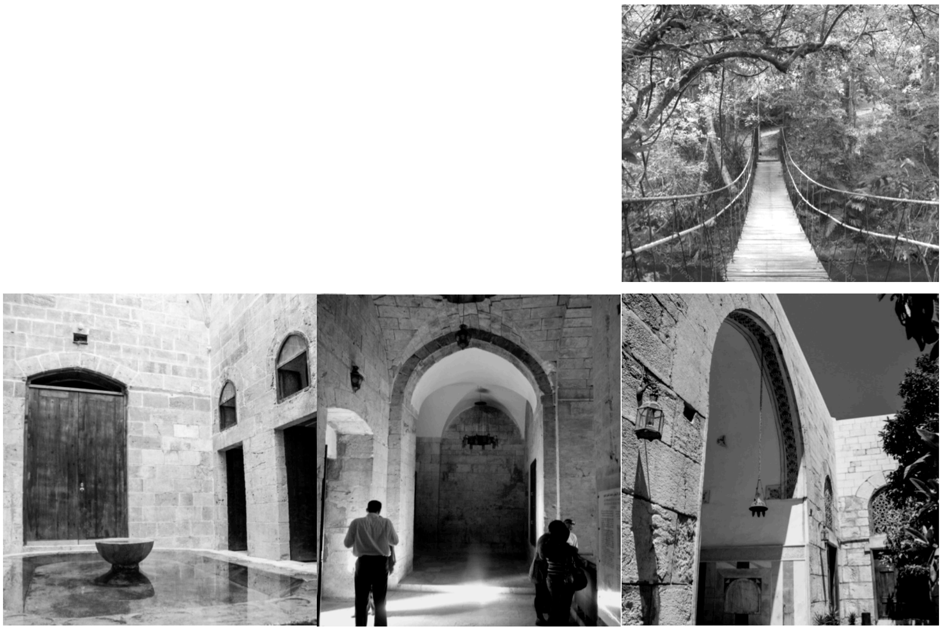

Figure 8. (top right) A long bridge in the forest resembles a setting of peril: a controlled risk (Source: www.megapexil.com), (Bottom Left to right) Examples of risk and peril patterns. Flooding water fountain and entrance hall Bimaristan Al-Argoun, Aleppo, Syria, double height alcove ‘Iwan’ Bimaristan Alnouri, Damascus, Syria (Source: Adapted from @ http://premoderno.tumblr.com and archnet.org).

A proposed mechanism of interpretation

The previous examples reflect traditional builders’ recognition of human attachment to nature in different ways. Scientifically, the six stages of the Innovation-Generation Process (IGP) require specific design strategies to fulfil the physical, psychological and emotional needs of innovators in each stage. This study proposes that the IGP stages can be linked, as each stage requires certain moods and architectural configurations (see Table 1).

Table 3 summarises the proposed concepts of *biophilic* architecture found in *madrasa* architecture. It highlights the intellectual and psychological benefits of each approach and shows how they might be reflected in design, giving examples of their implementation in traditional *madrasa* architecture. Needless to say, such a typological configuration needs to be tested empirically and clinically to examine its validity for the innovation-generation learning space.

ArchNet IJAR
International Journal of Architectural Research

Table 3. Correlation between IGP stages and proposed biophilic design strategies and their innovation-generation benefits (Source: Authors).

Stages of IGP	Shared strategies	Matching *biophilic* patterns & suitable strategies	Architectural settings (from history)	Innovation-generation benefits
Stage (I) Phrase a question (Team form)		Biomorphic forms & patterns, presence of water, dynamic & diffused light, connection with natural systems	**Patterned wholes, trees and column support, arches, dynamic balance, fractals, hierarchically organised scales, integrating parts to the whole, biomorphic Natural materials, botanical motifs**	• **Stress reduction** (Grafetstatter et al., 2017; Ratcliffe, Gatersleben, & Sowden, 2013) • Decreased stress hormones (Q. Li et al., 2008) • **Positive impact on concentration & memory restoration** (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Greenleaf, Bryant, & Pollock, 2013) • Education/learning opportunities (Clayton, 2007) • Facilitated social interaction (Kingsley & Townsend, 2006)
Stage (II) Identify and break frames (Team storm)		Material connection with nature, visual connection with nature, biomorphic forms & patterns, presence of water, dynamic & diffused light, connection with natural systems, risk/peril	**Outside views and vistas, domes, arches, vaults, space as shape and form Courtyard, terrace, gallery and cells overlooking open space**	• **Positive impact on attitude & overall happiness** (Barton & Pretty, 2010; Korpela, De Bloom, Sianoja, Pasanen, & Kinnunen, 2017) • Positive impact on concentration & shift in focus (Joye, 2007) • **Positive affect on cognitive performance** (Berman, Jonides, & Kaplan, 2008; Bringslimark, Hartig, & Patil, 2007; Koehler, 2011; MacNaughton et al., 2017; Ratcliffe, Gatersleben, & Sowden, 2016; Yin, Zhu, MacNaughton, Allen, & Spengler, 2018) • **Reduced anger/frustration** (Grafetstatter et al., 2017; Kuo & Sullivan, 2001) • **Increased self-esteem** (Pretty, Peacock, Sellens, & Griffin, 2005)
Stage (III) Ideas generation (Team norm)	Prospect & refuge, thermal & airflow variability	Complex order, material connection with nature, visual connection with nature, dynamic & diffused light, non-rhythmic sensory stimuli, risk/peril	**The universe and cosmic context by using fractal, dynamic symmetry and Penrose patterns, spatial harmony by using golden mean and Fibonacci series generative patterns, filtered and diffused light Multisensory contact, habitats and ecosystem & information richness, plants, animals and living organisms Sensory variability, transitional spaces, reflected light**	• **Improved mental engagement/ attentiveness** (Biederman & Vessel, 2006; Han, 2010; Jeon, Yeon, & Shin, 2018) • Enhanced creative capacity (Korpela et al., 2017) • **Increased inspiration** (Fredrickson & Anderson, 1999) • **Improved creative performance** (Lichtenfeld, Elliot, Maier, & Pekrun, 2012; Steidle & Werth, 2013) • **Foster imagination** (Glăveanu, Gillespie, & Valsiner, 2014) • **Reduced headaches** (Hansmann, Hug, & Seeland, 2007)

Mohamed S. Abdelaal, Veronica Soebarto
Archnet-IJAR, Volume 12 - Issue 3 - November 2018 - (106-125) – Regular Section

Stage (IV) Incubation (Team perform)		Complex order, material connection with nature, non-rhythmic sensory stimuli	**Bounded spaces, central focal point, warm light**	• Reduced boredom, irritation and fatigue (Clearwater & Coss, 1991) • **Improved productivity** (Bringslimark et al., 2007; Lamb & Kwok, 2017; Romm & Browning 1998) • Improved concentration, attention and perception of safety (Grahn & Stigsdotter, 2010)

CONCLUSION: ANTICIPATING THE FUTURE OF INNOVATIVE HIGHER EDUCATION FROM HISTORY'S LESSONS

This paper has summarised a literature review on the interrelation between nature, the built environment and innovation. The literature revealed that implementing the principals of biophilic design can have a positive impact on innovative learners and producers in higher education (students, staff and faculty). Hence, the reconfiguration of higher education environments, so they are more integrated with natural features (explicitly, implicitly and metaphorically), can profoundly enhance physical, psychological, cognitive and intellectual performance and foster the Innovation-Generation Process (IGP).

The review of earlier studies about biophilic design revealed that current approaches cannot offer a precise mechanism for implementation to assist designers today, as they lack consistency and inclusiveness. Possibly, the reason behind such a delay in mapping the architectural features of biophilia is due to the scarcity of examples or deliberately constructed case studies that could serve as a template. A key outcome of this research is that history matters. Historical examples of innovative learning spaces can serve as excellent precedents for future studies and design. This research brings to light the importance of reviewing the history of architecture by using different lenses.

The results of our historical interpretation inform architects and planners of tomorrow's university campuses that other aspects of design, in addition to technological aspects, deserve more manipulation to achieve an innovative working and learning environment. Although the mechanisms of the operation and stimulation of the human brain and its biochemical interactions are common variables, it is necessary for those who are seeking to build innovative learning spaces to provide the proper spatial and environmental settings for the various tasks and stages of the Innovation-Generation Process (IGP). These results support Ramzy's (2015) and Movahed's (2015) research, which suggested that further studies and analysis are needed to investigate the embodied qualities of *biophilic* design in historic buildings, which can be used as a reference to evaluate the biophilic design features in today's architecture.

Finally, the study selected five primary architectural settings for biophilic design to stimulate the human brain for better performance: complex order (including metaphoric patterns), prospect, refuge, enticement and mystery, and risk and peril. This paper further elaborates the linkages between these settings and the dynamism of the Innovation-Generation Process (IGP), especially the two early stages of IGP according to Plambech and Konijnendijk van den Bosch (2015). Some case studies of traditional educational buildings or *madrasa* from the Golden Age of Islamic civilisation have been discussed; however, further research may shed more light on the impact of geometrical patterns and metaphoric architectural forms on our neurological systems. Clinical studies should investigate how these patterns may influence our intellectual and cognitive capacities to inform the design of future innovative educational spaces.

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