Duncan of Jordanstone
College of Art & Design
University of Dundee

DISSERTATION FRONT COVER 2019/20

Title: How does the biophilic design contribute to the concept of the future schools?

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Matriculation Number: 180017827

Module (Please tick the relevant box):

- ☐ DJ41002 - Design Enterprise 2
- ☐ DJ41005 - Communication Futures 2
- ☐ DJ41001 - Research & Creative Practice 2
- ☐ DJ40002 - Critical Studies: Dissertation

Programme: Interior & Environmental Design

Word Count: 7,423

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Introduction

The definition of a school as a future educational institution is framed by multitude of contributing factors. The criteria are continually developing through observations of what solutions work for certain circumstances and times, and what aspects of created systems fail (Walden, 2009). According to Peter Struck (Struck, 1992, p.150, in Walden, 2009) schools are no longer singular institutions lecturing students at certain age, but rather hubs that offer extended activities. They merge educational and sport centres with support and therapy counselling facilities. They are adjusted to the needs of different participants of a community, such as toddlers, adolescences, families or the elderly in order to bring them together and show how they could benefit each other(Walden, 2009).

The idea behind the design of learning spaces has changed its approach from formal teachings- tutor lecturing his students- to a design based on user interaction, self-exploration and community engagement (Perrot, 2018). That means that such a building would require areas suitable for workshops, hub-labs fitted with technological tools, learning cafes or interactive libraries. Yet, it is not strictly specified which of those would be needed. Some situations may still include the need for lecture theatres as we know them (Boys, 2011; Walden, 2009). Today we cannot simply offer a pattern that should shape those institutions. That requires a deeper analysis of what is needed in a certain location, considering the potential users and the type of proposed activities. (Boys, 2011).

Today's concept of a school emphasizes the idea of an environmental as well as a socially sustainable facility by concentrating on a student's well-being and community engagement. (Gelfand and Freed, 2010; Walden, 2009) . It is increasingly important

due to the present levels of environmental degradation and the growing problems of social alienation and mental health issues, such as depression (UNDP, 2011). Placing sustainability as a central goal of an educational system is one of the key factors enabling a new generation. A generation that can collaborate on multiple social levels in order to reduce the ecological neglect and thrive in the future as a united and supportive society (Gelfand and Freed, 2010; Walden, 2009). The practice of sustainability in education and architecture can provide bigger benefits than just an improvement in the natural environment. It is because the idea of sustainability itself requires us to rethink the role of humans as a social, cultural and natural beings. Sustainable life and affiliation towards nature, indicates care, not only for the comfort of our own lives, but also for other living creatures. Thereby, sustainability becomes an ethical guide, teaching values of cooperation and mutual respect (Curry, 2011; Kellert, 2009).

Humans did not always consider their existence as an integral part of the world but thought of it as a separate phenomenon. (Heidegger, 1927, in The Stanford Ensyclopedia of Philosophy, 2011). That logic lacked consideration of mutual reliance and has been found to be damaging to the natural environment, social interactions and general well-being (Wilson, 1984). E. Wilson in Biophilia (1984) claims that the recognition of social belonging may be strongly supported by understanding humans as an indissoluble part of the natural world. He states that humans show a natural affection towards nature and that its presence could massively impact on our physical and mental health but also on our culture.

The aim of this research is to discuss how the attributes of a biophilic design could contribute to the creation of a facility that could answer to the name of a future

school. In the following chapters, the research analyses factors defining a school as a school of the future and debates how the application of biophilic design into a school building could possibly support the development of an educational institution. The final chapter presents examples of the biophilic solutions and describes a proper approach of their application.

Chapter 1.

Principals of an objective evaluation of the spatial design for learning institutions.

1a. Criteria defining a school as a school of the future.

The introduction has explained some general goals for an ideological shift in education, from an industrial-era, factory-like model, that was orientated towards business and production, to one that is community and human centred (Boys, 2011; Karpov, 2016). Yet, the investigation towards the design of learning facilities should be supported by clearly outlined principals that could grant those establishments with the title of the school of the future. Looking at the research of L. Duke and S. Trautvetter (Duke and Trautvetter, 2001) those criteria involve:

1. Improvement of mental and physical health, and through that, a reduction of absenteeism.
2. Increased levels of motivation for learning.
3. Improvement of student performance manifested in results.
4. Increase of student creativity and resourcefulness.
5. Improved conditions leading to better attention spans and concentration.
6. Adjustment of facilities for speciality subjects and projects.
7. Reduction of vandalism, aggressive behaviours, drug dealing and other forms of violence.
8. Improvement of cooperation between students, teachers, carers and community.

9. Increasing teachers' motivation for engagement beyond verbal lecturing as well as an interest in groups of students with special concerns.

The following chapters will discuss how the criteria could be met through incorporating biophilic design into the architecture of educational placements. To do so, the criteria will be grouped into the three sub-groups: health and well-being, student performance and social behaviour. The research will also examine an approach for the use of biophilic design depending on user's needs, age and intended activities in specific parts of a building.

1b. The complexity of factors contributing to spatial perception.

The area of research studying the perceptual correlation of humans and other elements of natural world is still enigmatic (Ghose and Wallace, 2014). The complexity hidden behind the way we perceive stimuli, does not allow us to clearly answer the question of what factors have had an influence on our behaviour and general well-being, or what would be the exact output of an application of certain stimuli. (Ghose and Wallace, 2014) Here we could look back at the observations of a philosopher-Martin Heidegger regarding human existence in the world. He claimed that it is important to understand that the presence of one element of reality is not restricted only to that element but to all elements that interfered with its existence. Thereby, all elements are bound to each other through a net of connections. (Heidegger, 1927, in The Stanford Ensyclopedia of Philosophy, 2011). From that we could conclude, that the way we perceive a precise moment of time, in a specific space, depends on every physical aspect of that space such as : sound, light, geometry of objects, users' interactions, subjective experiences, memories and the characteristics of each user

(Ghose and Wallace, 2014). Therefore, when we look at the influence of a schools' architectural features on student performance, we should be aware that the evaluation must be supported by relevant data. This includes the sociological background of each group of students, the educational process and the engagement of their parent and teachers. Otherwise the analysis would not be objective.(Boys, 2011; Walden, 2009).

The discipline of neuro-science provides us with some amount of information on neuro-specific factors manipulating spatial perception, but those deductions mostly refer to singular factors being changed or tested, while all others remain constant. That does not reflect the conditions we meet in everyday life (Ghose and Wallace, 2014). Therefore, the idea of how to design a space, in this case an educational facility, is an ambiguous concept. Especially if we consider new multi-purpose of a school building. Yet, by observations and the collection of data regarding changes in the body and mind functions when exposed to stimuli, we could infer the general outcome of finalising an intended design. (Caan, 2011; Kellert, 2005).

Chapter 2

Biophilic Design reflected in criteria defining a school of the future.

Through the millennia of thriving civilizations, the power of nature, contained in design, used to be an intuitively obvious phenomenon. People realized how influential light setting could be, or that the element of water in interiors could create a relaxing environment (Caan, 2011; Kellert, 2005). But a big part of the experiences provided by nature, is perceived only subconsciously. Until a couple of decades ago, there was no scientific proofs or technologies to support that knowledge or reveal new facts (Terrapin, 2014). That is why it was so easily pushed to one side when discoveries in physics and chemistry gave us new radical options for architectural solutions and materials. (BBC, 2002). Those changes had an experimental character and ignored the intellectual and cultural reliance of humans on the natural environment. (Khan, 2002, in Beery, 2018). During the last century we saw the negative consequences of separating humans from nature. For example, an artificial air-conditioning has seen a huge rise in headaches for those working in environments such as universities or offices (Behling, 2016). These days, with the support of scientific data we can design spaces that could allow the human organism to work better in the spaces provided. (Behling, 2016; Kellert 2005 and 2012; Terrapin, 2014).

This chapter will introduce a research backing the biophilic design in terms of a tool that could help to create a school of the future.

1. Health and well being

The first criterium defining a school of the future considered student health and well-being. Today, a large amount of data, supports the thesis that the biophilic design could positively impact on the physical and mental health of students and reduce a school absenteeism. Poor health conditions can have a detrimental effect on students and can result in poor grades and examination results. Absenteeism from school may also be devastating for the student's relationship with his fellow students. (Terrapin, 2014; Walden 2009; White Hutchinson Leisure & Learning Group, 2008; Boys 2011).

One of the key factors leading to absenteeism is the stress they face in the school environment. Whether it's because of exams, presentations or interactions with other students, it often leads to disorders such an anxiety or depression. It may also result in physical discomfort and a weakened immune system. (Walden, 2009; Frumkin 2017).

The research presented by B. J. Park, et al, shows that the level of cortisol-stress hormone was lowered by 13.4 - 15.8% for participants who had a walk through the forest. Their pulse rate and systolic blood pressure dropped by 3.9- 6.0% in comparison to those who walked through the urban environment. It was also noticed that the same people experienced an increase of parasympathetic neuro-activity by 56.1% and decrease of sympathetic activity by 19.4% (Park, B.J., 2010). Those types of neuro-activity balance each other and are responsible for internal homeostasis of the body. Parasympathetic activity regulates body functions such as digestion. Its increase means a greater feeling of comfort and balance as well as better physical functioning of the body. The other one, sympathetic activity, subjects the cognitive simulation and increases when such a stimulation is needed. That would mean that the ideal intensity

of stimuli should decrease the sympathetic activity to the minimum and let the body relax and concentrate on natural processes (Terrapin, 2018).

Presence of day light is another element vital for human health. The Length of light waves changes through the day regulates human circadian rhythm- cycle of hormonal activity. Visual receptors in the eyes and the cortex, process light waves of different lengths as different shades of colours. We can observe this in the morning, when the light has a yellow tone, then at midday it turns blue and, in the evening, it turns to red. The data is used by the human hormone system, giving a signal to produce serotonin and melatonin. Serotonin is linked to mood, when melatonin regulates the rhythm of sleep. If the human organism is unable to naturally tell the time of the day through light, it stops functioning as expected (Terrapin, 2014).

Access to fresh air and variable thermal conditions are no less important than day light. Artificial air-conditioning does not make for optimal oxygen levels. Lack of oxygen causes headaches and affects concentration and productivity (Behling, 2016). Differences in the natural lighting and temperature of a room throughout the day, and the movement of fresh air all help people to stay physically synchronized with nature. We must be aware of the natural processes in the environment, especially temporal and seasonal changes (Terrapin, 2014; Gelfand and Freed, 2010).

Designing buildings in a way that incorporates the presence of natural attributes, could supplement that experience, support students' immune system and reduce school absenteeism(Terrapin, 2014; Walden 2009; White Hutchinson Leisure & Learning Group, 2008).

2. Student performance

Improvement of health discussed in the previous subchapter is significantly related to the next criterium- The quality of student performance. Factors determining the quality of student performance could also include other factors such as level of creativity, resourcefulness, motivation and the ability to concentrate (Walden, 2009).

- **Concentration**

Research carried out in Barcelona in 2015 showed an increase of the cognitive performance among students who had access to a green outdoor environment. All 9,000 participants attended primary schools in an urbanized environment, but those who had a chance to interact with nature appeared to preform better (Greenbuild, 2015). Be around nature, or even just having a view onto elements of it, eases human sympathetic activity which results in a better ability to focus on work (Yin, 2018, et al). In an urban environment, the mind 'jumps' from one stimulus to another which puts it into the so called 'fight and flight' mode which decreases concentration (Terrapin, 2018). In the natural world, no element is identical to any other, every plant, animal or rock is unique. Because of the extreme diversity of nature, people embrace all stimuli they perceive from the natural world as one collective sensory experience, that eases their neuro systems and boosts their cognitive performance (Ullmann, 2011: Terrapin 2018) When we look at a street, our sight moves from cars to buildings, and then to advertisements. Yet none of those elements can hold our attention for long because visually they are not engaging enough. That leads to irritation and a loss of focus. If we look at a tree, we can observe the movement of thousands of different leaves. It grasps our attention for longer, as well as eases our minds, allowing to concentrate

and relax. Use of biophilic design may add or imitate the presence of nature in interiors (Terrapin, 2014).

- **Creativity**

The next factor that contributes to student performance is creativity. The Natural world provides a remarkable spectrum of sensory experiences and a knowledge that could be drawn upon from observation or interaction with its elements. Nature creates an extraordinarily rich learning library that could positively impact student's creativity and resourcefulness. To experience the range biodiversity is crucial for humans, especially at the early stages of our development. (Barrable, 2018; Beery and Jorgensen 2018; Kellert, 2005). Children, by playing with rocks or branches, learn to investigate the systems that control the world and take an inspiration from those experiences. For example, by throwing a rock into a pond, a child can visualise the laws of the physics such as gravity or the energy that moves from one element to another. By collecting birds' feathers, pine cones or pebbles, they may learn how to use them as building materials or for decoration. Biodiversity, because of its complexity, is a powerful learning tool, irreplaceable by any human-made system or objects. (Sobel, 2008, in Beery and Jorgensen 2018). Activities performed in nature are usually enriched by stimuli such as the sound of the wind, singing birds or reflections of light. The abundance of sensory experiences rising form nature helps to strengthen creativity. Limitless colours, forms and mechanisms enhance the human imagination and increase our desire for discovery. Nature has always been a muse to creators representing many different disciplines, from the arts to science (Barrable, 2018; Beery and Jorgensen 2018)

(Fig.1; 2; 3).

Inspired by Nature

Figure 1. The Kelpies, Stainless-Steel Sculptures by Andy Scott are majestic representation of nature in art (*Lynch, 2013).*

Figure 2. Velcro is a one of thousands technological inventions inspired by nature (Gunther, 2016).

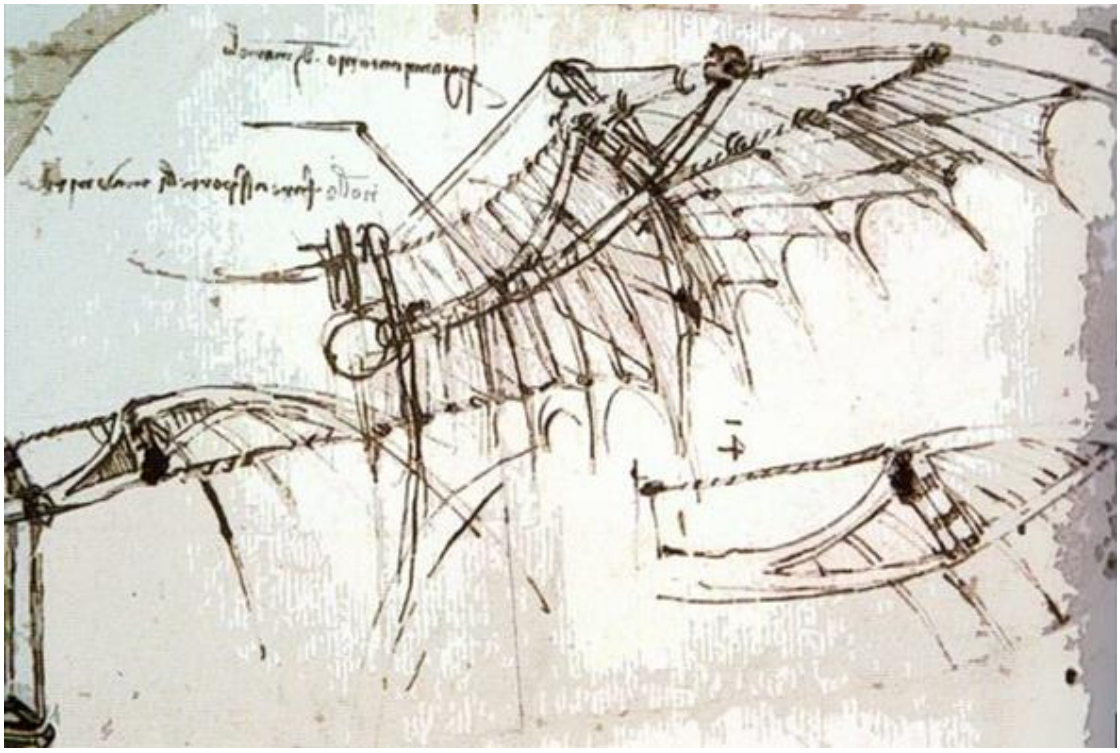

Figure 3. Wing device designed by Leonardo Da Vinci (Da Vinci, n.d.)

- **Motivation**

Natural settings present in childhood, influence the development of motivation and self-discipline. The research carried by Terrapin Bright Green, showed that the teenagers who had a view onto green environment from their rooms appeared to be, on average, 10% more self-disciplined in comparison to those who did not. A visual exposure to natural settings influences the sympathetic activity, which results in a better ability to concentrate and lowers the risk of impulsive behaviour. But the experience has a visual character only. When we look closer at the research on Self-discipline Theory, we may notice that the physical presence of nature in the early

stages of an educational process, could have a stronger impact on a student's approach to a learning process (Barrable, 2018; Terrapin, 2018).

According to Deci and Ryan (2000) we could name two main types of motivation: intrinsic and extrinsic. Intrinsic motivation is driven by satisfaction emerging from the performance of an activity. Extrinsic motivation comes from fear of a punishment or consequences that occur when we fail at a task. Children are innately curious and willing to learn. It is crucial for educational facilities to nurture this inherent ability (Kellert, 2005). Students who learn because of a passion for discovering, usually show better performance results when compared to those who learn in order to satisfy the expectations of their guardians or through fear of punishment. As the natural environment can positively impact on human mood and well-being, learning performed in the presence of nature, may be remembered as a more pleasurable experience than if performed in the non-biophilic spatial settings. Correlation of learning with pleasant memories, also comes from the level of attractiveness of an activity (Deci and Ryan, 2000; Barrable, 2018). In a traditional classroom (Fig. 4), children sit or stand in organized settings. The surface of the ground is always even, and the walls look mostly the same through the year irrespective of the changing seasons. Rules applied to traditional spatial settings tend to force a user's behaviour, like taking seats in a rows, and this makes activities more predictable (Barrable, 2018; Boys, 2011). Because of that predictability classes can be boring and routine.

Figure 4. Classroom in Cottonwood Elementary School. The image presents a screen-shot taken from a video recorded during the classes in classic spatial settings. Video available at: <https://www.youtube.com/watch?v=yY9_3Dkwj9Q>. (Miami County, 2009).

In comparison, classes carried in a natural environment rarely look alike (Fig 5). The environment changes with the time of a day or year. Complex elements within natural space settings undergo constant transformation which generate the sensation of diversity within a daily routine and helps to keep it entertaining (Barrable, 2018; Frumkin, 2017, et al).

Figure 5. Forest Kindergarten provides the way of learning which empower child's motivation toward creating and learning (Safe Baby Healthy Child, 2013).

Classes taught in nature, entail a higher level of freedom. Regarding the Self-discipline Theory, the possibility of a free choice of activity is a factor determining student's approach to learning. The fact, that a student could choose what to do or how he wants to perform planned activities, changes the perception of a learning process from the activity that is being projected onto the student to an activity of his own choice. The Self-discipline Theory implies that people who have the possibility of choice by participating in self-guided activities, take more responsibility for events, learn how to handle the consequences of their choices and participate more actively (Deci and Ryan, 2000; Barrable, 2018). Children learning in the natural environment are not restrained by rules. They can move through unmarked paths, challenging obstacles, play with objects they find on their way, name those objects and bestow them with a purpose dictated by imagination (Beery and Jorgensen, 2018; Kellert, 2005). Forrest schools and nurseries made this approach a fundament of their teaching practices. The concept of a Forest School was inspired by the Scandinavian idea of how location can impact a child's educational development (Barrable, 2018).

3. Social Behaviour

A spatial design possesses the power to alter human behaviour, both individual and social. In terms of biophilic design, an example of such behaviour was presented as an increase in motivation or well-being (Kellert, 2012; Walden, 2009). Biophilic design, may be a source of satisfaction that individuals can project onto the others. A part of the human brain is responsible for recognizing beautiful and perfect views. When stimulated, the area releases a signal for production of endorphins (Stenberg, 2013) The research carried by Kou and Sullivan in Chicago, states that people who were randomly assigned to live in a presence of a green area, are less likely to show

aggressive behaviours like vandalism. They will also develop a more positive interaction with their neighbours. Elevated level of endorphins and balance of a neuro-system keep people satisfied and rational, which increases the chance to build positive, interpersonal boundaries. Similar results could be expected in a school environment.(Kou and Sullivan in Stenberg, 2013; Terrapin 2014).

Children properly introduced to nature, develop their biophilia, and statistically show more empathy to those around them (Kellert 2005, White and Stoecklin, 2020). An important part of this experience is direct and indirect contact with animals at the early stage of child's development. This kind of interaction with living nature, helps burgeon a child's sensitivity and empathy for other humans and wildlife (Barrable, 2018; White and Stoecklin, 2020). P. Curry in 'Ecological Ethic', conclude that people only respect what they care for. Relating to that statement it could be assumed that if people develop an affection towards nature, they will learn to care for it and respect it. In the third decade of 21st century, environmental awareness have taken a valuable place within the goals of an education system. Respect towards nature, teaches people to respect each other, cooperate at the social level and share knowledge and in order to grow stronger together (Curry, 2011). Today, the multi-functional character of a school requires it to offer a creative range of activities that could be introduced not only to students, but also to local communities in order to bring them together (Walden, 2009). Trottiscliffe School run a community farm that serves children during the classes. It is also a place where they can enjoy being with their friends and family after school (Fig. 6). The informal character of that place creates an emotional attachment by memories of time with loved ones and sparks a sense of belonging to the farm. (Trottiscliffe School, website- look at bibliography).

Figure 6. Trottiscliffe School's Farm provides a direct contact with living nature and teaches to care for it (Trottiscliffe School, n.d.).

Biophilic farms are not the only solution that could improve human interactions. Ideas like a community café, a cinema and creative, hub labs all on the school grounds, may work equally well (Boys, 2011; Walden, 2009). Biophilic design could only add to them, especially that the solutions inspired by nature are advantageous in their healing and relaxing qualities(Kellert, Heerwagen, Mador, 2013).

Characteristics of the spatial settings, like geometry, dimensions, complexity or spaciousness, may also resonate with human behaviour. This naturally inherited condition is driven by primary instinct, which used to guide our ancestors (Caan, 2011). Some places give people a sense of safety, others will encourage interactions. A proper mix of spatial factors in a school building could contribute to the mental comfort of the students, as well as boost their performance and help them to participate more in the life of the community. Those relations will be carefully discussed in the next chapter (Perrot, 2018; Walden, 2009; Boys, 2011).

Chapter 3.

Adaptation of Biophilic design in educational facilities.

1. 14 Patterns of Biophilic design

Third chapter aims to present a possible approach and guidelines for the use of biophilic design in educational facilities. The fact that a solution is biophilic does not always mean it is appropriate to the situation. School buildings require specific spatial settings applied to areas serving different purposes (Walden, 2009). It is important to evaluate which biophilic attributes may help boost mathematical skills or concentration levels and which will help to relax people and initiate their interactions in gathering areas. No less important is to fit a design proposal to the needs of different age groups, beginning with toddlers and ending with university students. This data is partialy provided by workshops or interviews with a local community (White and Stoecklin, 2020). The science of biophilia defines 14 patterns of design that should be revived and incorporated into new and existing buildings, in order to improve the standard of human life, performance and social relations. The patterns should be used as guidelines to make the right choice of a biophilic solution. They cannot be taken as separate from each other as they usually perform when overlapping one another. For example, visual relation to nature should be discussed in terms of light, complexity of forms, use of biomorphic patterns or space dynamics. (Terrapin, 2014). Because of individual characteristics, patterns could be assigned into the 3 groups (Terrapin, 2014):

Presence of nature in space	Analogues of nature	Nature of spatial perception

Visual Relation to Natural World Non-visual Relation to Natural World Non-rhythmic Stimulation Variability of Airflow and Thermal Conditions Element of Water Specifics of Light Connection to Natural Systems	Bio-morphism of Forms and Patterns Material connection with nature Complexity and Order	Perspective Asylum Mystery Risk

Practical solutions for the application of biophilic patterns will be presented in the next three subchapters respectively to the three groups classifying the patterns.

2. **Presence of nature in space**

Devoid of the possibility to interact with nature, humans experience a mental and physical fatigue (Kellert, 2005; Wilson, 1984). In order to keep the mind and body in balance, a person must stay connected to at least a part of the stimuli coming from the natural environment. As discussed in the previous chapter a connection to nature and the presence of biodiversity generates measurable benefits to students exposed to it. The ideal way to connect with nature, visually and physically, is direct contact with it. (Kellert, 2005). The use of green walls (Fig. 7), indoor gardens or the addition of an element of water into a school environment (Fig. 8)(Fig. 9) works successfully in areas used as gathering spaces such as learning hubs, libraries or cafes. Green plants and the

presence of water inject a sense of conviviality into space, boost energy and social interactions (Terappin, 2014). The Intensity and type of neuro-stimulation affect human brain functions in the way that could help to regulate it or disturb it. Dynamic, green features should not be too intense and chaotic if they are introduced to space that is dedicated to activities demanding concentration. Strong stimulation coming from their presence in space may steal the user's attention. It is important then to apply elements of living nature in places where students pass regularly or socialise in like corridors, receptions or canteens. This approach maximizes daily exposure to the healing and relaxing qualities of nature, and at the same time allowing for full focus in classroom (Terrapin, 2014, Kellert and Calabrese, 2015).

Figure 7. Living Wall at Hazel Wolf K-8, Seattle. (NAC Architecture, n.d.).

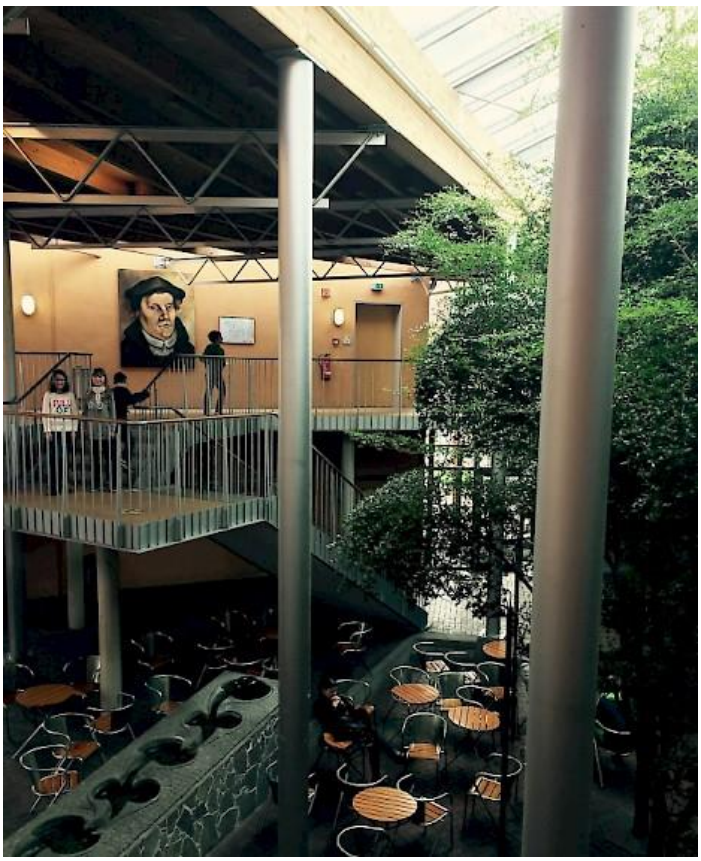

Figure 8. Evangelische Gesamtschule. German school listed as school for the future (Walden, 2009). Source of the photo: (School500reformation, n.d.).

Figure 9. Research funded by AIA Upjohn Research Initiative explore how biophilic learning spaces can influence student success (Ohalo123, n.d).

Classrooms that prioritize concentration, should not provide dynamic stimuli such as water ponds or vivid green patches, yet a rational exposure to green, could have a relaxing impact on students. Focus on the connection to natural systems through access to daylight, fresh air, and variability of temperature, may have a more beneficial outcome (Terrapin, 2014; White and Stoecklin, 2020). Sustainable architecture offers varied solutions to help regulate those factors by designing a proper structure of a building. From ideas on how to maximize access to daylight, through to the natural regulation of temperature and airflow. Sustainable architecture links the natural environment to the needs of the human organism (Gelfand and Freed, 2010). Examples of solutions increasing daylight access are listed as figures :10, 11, 12, 13.

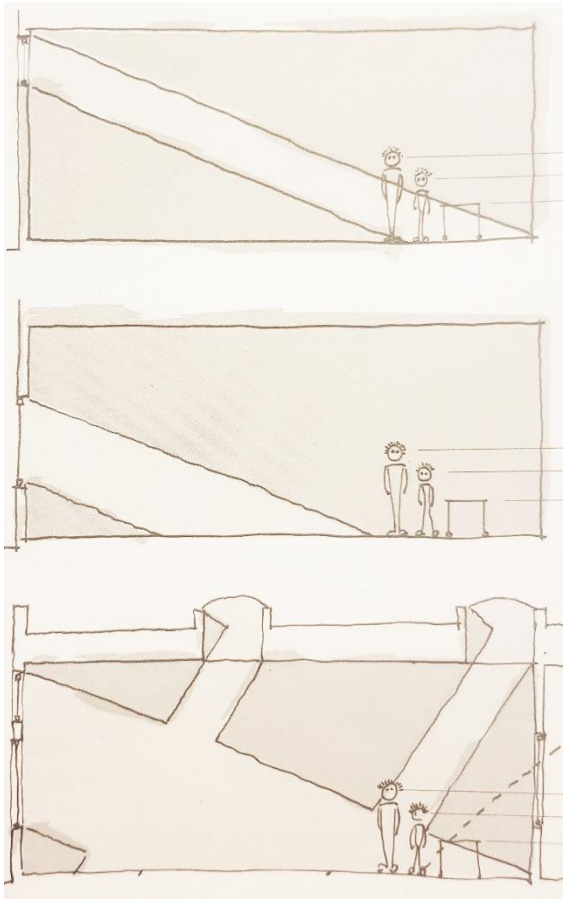

Figure 10. Diagram illustrates how to increase an access to daylight by using skylights (*Gelfand and Freed, 2010. p,97).*

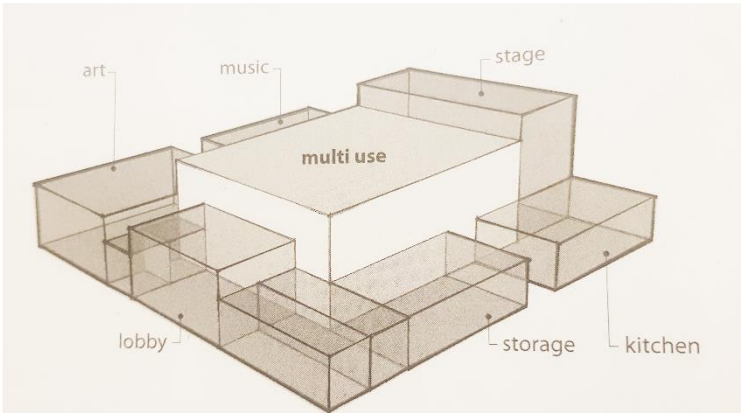

Figure 11. From three sides, the lower units expose the central unit to daylight (Gelfand and Freed, 2010 p,95).

Figure 12. Transparency of the architectural structure allow daylight inside of a building (Gelfand and Freed, 2010. p,215).

Figure 13. Placing a window as close as possible to adjoining wall, instead of centralized position, provides more light, because of the light reflected form that wall (Gelfand and Freed, 2010. p,123).

Presented examples of spaces shows the approach to the use of nature in an indoor environment. Yet, if it is possible, children should be intensively exposed to direct and physical contact with nature as it is done in forest schools or farms. From early childhood (3 years) to middle grade school (11years), contact with the natural world and processes, plays a significant part in determining a student's creativity, motivation and performance as well as social sensitivity (Kellert, 2005; White and Stoecklin, 2020; Beery, 2018). Outdoor space is beneficial to any student despite their age but is most valuable to the development process concerning younger children who cannot yet relate to abstract and distant concepts like rain forests or savannah. Contact and interaction with a familiar, domestic natural environment is an irreplaceable tool supporting child's development on multiple axis (Barrable, 2018; Kellert, 2005)(Fig. 14)

Figure 14. Thimble Forest School offers free activity classes in order to enrich children's development process (*Thimble Forest School, 2019).*

Presence of a real, living nature is always a stronger stimulus than an imitation of it. Yet, when there is no other possibility to apply nature into a space, the use of an imitation may appear to be a big advantage (Terrapin, 2014). According to the research

of J. Yin et al, the use of a virtual reality environment may be similar to the visual connections made with a real natural environment. In a study Twenty-eight people were asked to spend time in a biophilic interior. They were then divided into three groups. One group never leaves the biophilic interior. The other two groups were led into a non-biophilic environment. A random sample of those two groups were then exposed to a virtual reality environment, simulating a green environment. Reports of the emotional and physical change submitted after study, showed relatively minor differences between the exposure to the real nature and virtual reality (Yin, 2018). (Fig. 15)(Fig. 16).

Figure 15 Nature of Orbi Yokohama multisensory experience. A similar solution could be used in spaces with no access to the daylight (Beauty news Tokyo, 2013).

Figure 16. Magic-forest LED walls. Jason Bruges Studio transformed a hospital corridor into an interactive installation for kids (Jason Bruges Studio, n.d.).

3. Analogues of nature

A virtual reality environment is one of many ways to increase exposure to biomorphic forms in architecture generally (Yin, 2018). Designers and architects, since the beginning of the civilization, were taking inspiration for their creations from the natural world. Therefore, the product of their designs imitates conditions found naturally in the environment. Bio-morphism can be observed in the architectural structure of buildings, in patterns, furniture, fabrics, and textures (Kellert, 2005; Wilson, 1984).(Fig. 17).

Figure 17 Frank Lloyd Wright's design from 1936 is reflection of a savanna forest. The skilful use of spatial properties keeps this design unchanged for the past 84 years (Frank Lloyd Wright, 1936).

It is important to pay attention to the character of the patterns inspired by nature. Choice must be adjusted to the purpose of the space we design. Dynamic patterns, as mentioned before, may capture the user's attention and either distract him from tasks he intends to do, or catch his attention in order to relax him. Similar effects could be observed with the use of fractal patterns (Terrapin, 2014)(Fig. 18). Fractals are geometric patterns present in nature that are organized in a rhythmic order. They

seem to be very attractive to the observer and decrease the sympathetic activity of his brain. For this reason, fractals may appear to be a great solution for waiting rooms or school halls, where maximum relaxation is preferable to intensive concentration. (Fig. 19)(Fig. 20) However research by the terrapin group indicate that over-use of fractals, in effect, may lower physical and mental comfort, in some cases even cause panic and anxiety (Terrapin 2014 and 2018).

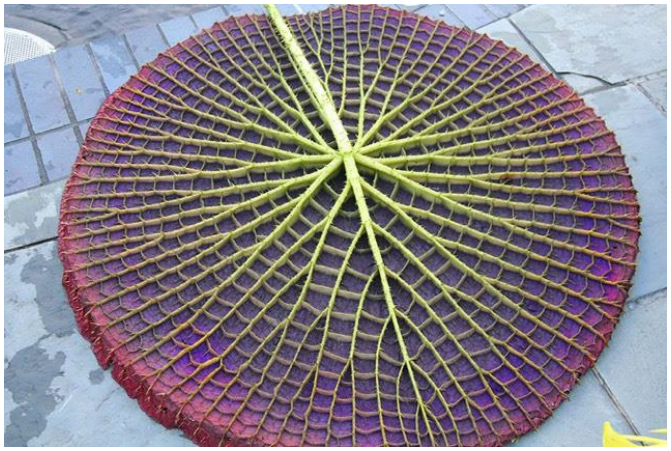

Figure 18. Fractal pattern in nature (Kottke, J., 2016).

Figure 19. Allen Lambert Galleria (Reto Fetz, n.d.).

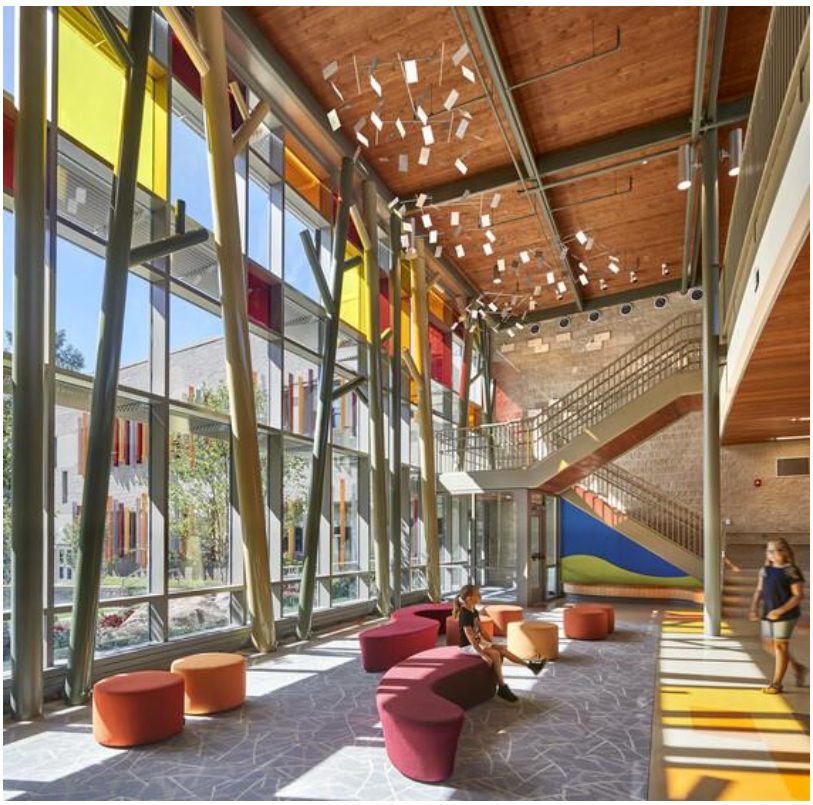

Figure 20. Sandy Hook Elementary School. Dynamic light settings, like beams of light shining through a tree brunches, may structurally reflect fractal characteristics (Atelierten, n.d.).

As fractals are highly attractive, they should not be over-used inside of classrooms or libraries where students must stay focused. Natural materials like wood or stone, feature fractal patterns within their textures. The presence of natural materials stimulates student's sensory system in a subconscious manner. (Terrapin, 2014; Park, et al,2010). According to study of Terrapin Group: "Quantities of a natural material and colour should be specified based on intended function of the space (e.g., to restore versus stimulate)" (Terrapin, 2014, p.41). Research of Yuko Tsunetsugo on interiors with different wood quantities, confirms that the amount of surface covered by wood can influence human blood pressure, pulse, and cognitive performance. Respectively, three rooms with: 0%, 45% and 90% of wood coverage, showed the following results. In room with 0% of coverage the decrease of diastolic pressure was observed, but no significant changes to neural activity. At 45% observed decreased

diastolic pressure but also an increase of pulse rate. This room was rated as most comfortable by participants of the research. In the room 90% covered by wood researchers noticed a decrease in diastolic and systolic blood pressure, but the quality of cognitive performance lowered down too (Park, et al,2010).

The research indicates that the best approach to the design of rooms where high cognitive activity is needed, is to provide stable, non-dynamic conditions with balanced use of patterns and natural materials with visible textures. Similarly, plants or elements of water and natural materials enhance human interactions and add lifelines to interiors. They emanate a sense of warmth and by reflecting local ecosystems, create a definite sense of place. (Jimenez, 2016 ;Park, et al,2010;Terrapin, 2014). (Fig. 21).

Figure 21. Classroom. Balanced use of natural materials. (*Think Wood, 2019).*

However, classrooms for young children (age 3-11) should visually allude to natural features in order to help develop creativity, empathy, and a drive towards nature. Studies reveal that 90% of dreams of children younger than 6 are about animals (White and Stoecklin, 2020). Nature uses a visual and symbolic language that builds a child's

imagination, resourcefulness and environmental sensitivity, and in later life could influence its world view (Frumkin, 2017; Kellert, 2005)(Fig. 22)(Fig. 23).

Figure 22. Symbolism of nature. (Kinsmangarden, n.d.)

Figure 23. Learning Trees of Knowledge (*DLA Architects, n.d.).*

A space is perceived differently by a child than an adult (Millar, 2006). From the thesis of Jenny Millar, it can be concluded that adults, when asked to visualize the layout by sketching it, will put lots of effort to picture the space as closely to architectural layout as possible. A child on the other hand, does not pay much attention to spatial scale. When we compare the drawings made by adults and children, presented in Millar's work (Fig. 24; 25) , we will notice, children tend to present the same space on much more abstract level than adults, upscaling elements of it and presenting it on a different axis. On their spatial diagrams, children, instead of spatial dimensions, present social interaction, people, events and emotions.

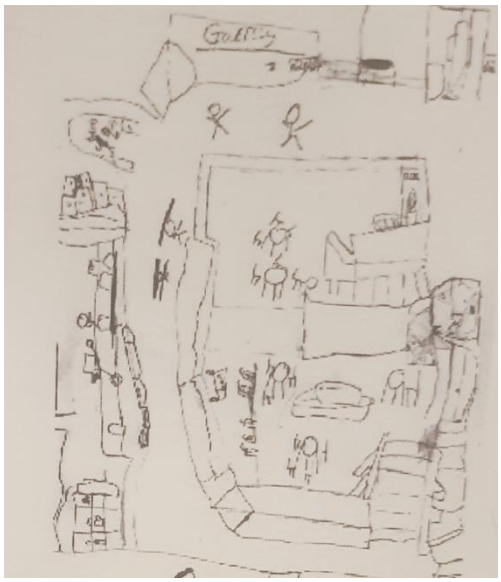

Figure 24. Child's drawing (Millar, 2006. p,78)

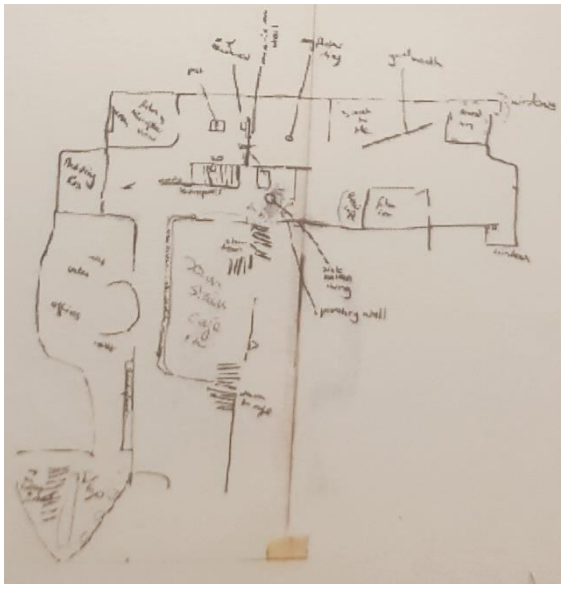

Figure 25. Adult's drawing(Millar, 2006. p,78)

It is a cluster of all significant elements that framed the space in child's eyes. Therefore, space designed for children in early childhood is supposed to present a high . level of diversity among different areas of the building, so they can easily orientate themselves inside of it. Use of varied, symbolic, biophilic forms to expose the visual

difference between the rooms and corridors is a solution supporting not only cognitive and sensory development, but also safety in a school building (Millar, 2006).

According to Millar, differences in design should be also visible between the spaces for younger and older years. An Experience of an educational process is a kind of a personal, progressive journey for a child, and a design adjusted to that progress may strengthen significance of that experience. Students passing from class to class, may see the differences emerging through the years as a form of initiation to the next stages of their maturing process (Boys, 2011; Millar, 2006).

4. Nature of spatial perception

People show an inherent preference towards some spatial settings (Caan, 2011). As mentioned in the last paragraph of the second chapter, factors like the geometry of spatial settings or complexity may influence human mood, emotions and behaviour (Caan, 2011; Perrot 2018). In a school environment, a proper spatial design, could engage social interactions and reduce aggressive behaviour (Walden, 2009). In order to feel comfortable, we must be able to occasionally look onto the distance and feel a sense of prospect. The chance to observe our surroundings gives us a sense of control and safety (Caan, 2011; Terrapin 2014)(Fig. 26).

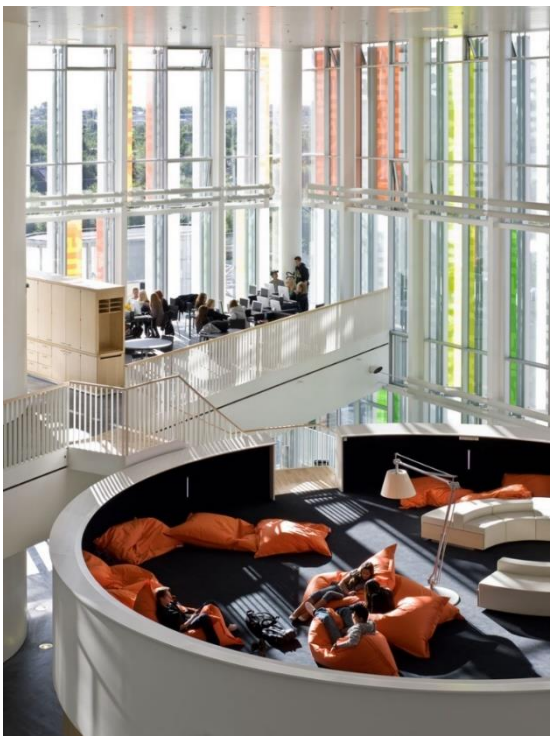

Figure 26. The Ørestad high school gymnasium in Copenhagen. (Adam Mørk, 2015).

For the same reason, a circular seating plan in a classroom may work successfully, raising trust and reducing tension (Fig. 27; 28).

Figure 27. Flexible classroom design lets its users to set it as they feel is best (Kurani, n.d).

Figure 28. Organically shaped classroom in Honolulu (Iolani School, n.d.)

The presence of prospect is important in order to create a successful space engaging human interaction. It has been also been noticed that in order to ease strained eye muscles whilst working at a computer, a person should, approximately , every 20 minutes look in distance of no less than 20 feet, for at least 20 seconds (Terrapin, 2014) In an urban environment it may appear to be challenging to find a decent view. In this situation, a designer must choose between the quality of a view or consider replacing it with biodiverse elements. If a panorama of the city is attractive, it's worthwhile keeping the view. Yet when, only a wall of concrete building can be seen, it may be a better solution to, at least partially, cover it with elements of living nature (Terrapin, 2014)(Fig. 29).

Figure 29. Gallery of The Drawers House (MIA Design Studio, n.d.).

Places of refuge, where a person feels safe and secure, in this case are equally valuable. It may be provided by organic segmentation of space or lowered ceilings, what also increases mathematical performance. High ceilings may on the other hand contribute to feeling of prospect and support spatial and abstract thinking (Wyatt, 2017). In large open spaces, mezzanine-like structures often work effectively as space divisions. Children at young age, are especially fond of any levelled structures that they could climb on or under. (Kellert 2005; Terrapin, 2014)(Fig. 30; 31; 32).

Figure 30. BIG's New York City school (Gibson, 2018).

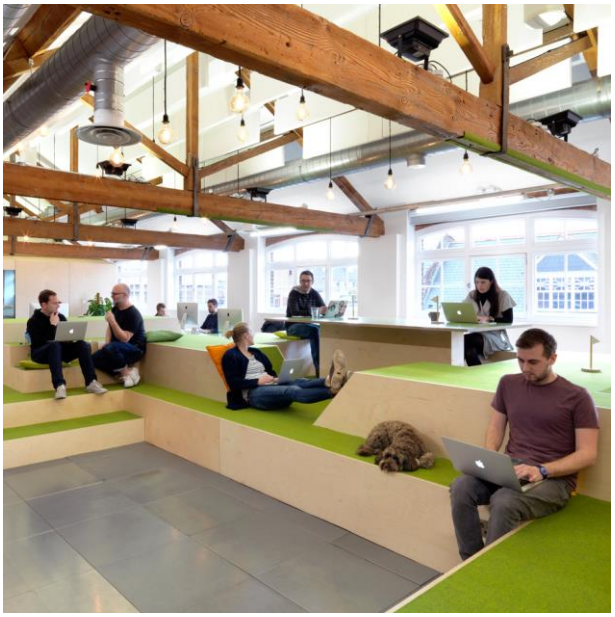

Figure 31. "Village green" a a design for Airbnb's London office (Rima, S., 2016).

Figure 32. Organic spatial settings provide both, prospect and refuge. (*The neighbourhood, n.d.)*

The last two of the biophilic patterns, concern elements of risk and mystery in the spatial design. Both stimulate neuroactivity and our senses and are of significant important to the development of motivation. Positive memories associated with making risky decisions or trying something new that formed in early childhood may help to build high self-confidence and the ability to face issues later in life (Barrable, 2018; Terrapin, 2014)(Fig. 33; 34; 35). Patterns of mystery and peril are adapted in the ideology practised by forest schools. Elements of mystery may be added to architecture using organic forms and structures that are not simply predictable.(Fig. 36; 37). Diverse and organic spatial settings stimulate the user's perception of a space and decrease their sympathetic activity, at the same time initiating human interactions (Terrapin, 2014).

Figure 33. Day at the Oak Tree Nursery (*Oak Tree Nursery, 2016).*

Figure 34. Gallery of Ama'r Children's Culture House (Escerod, T., n.d.).

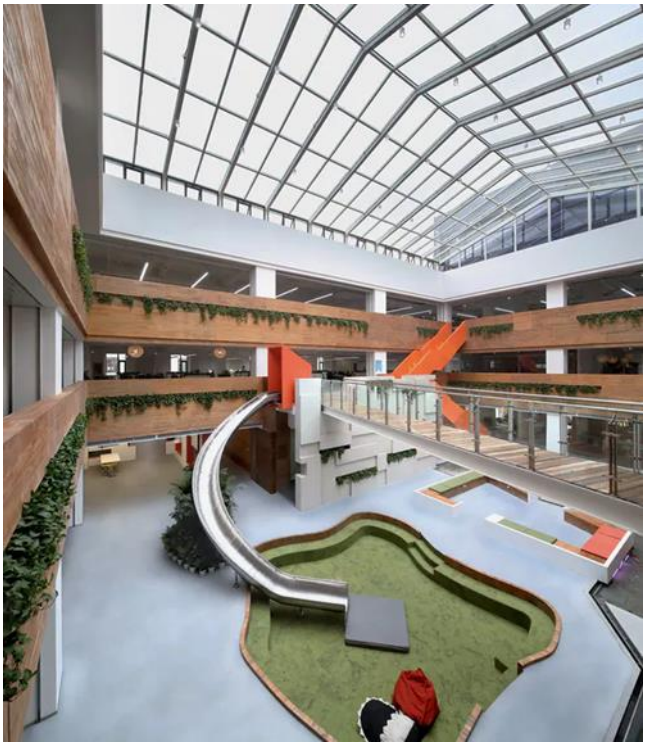

Figure 35. Creative work space in Benji (Cheetah Mobile, n.d.).

Figure 36. Hazelwood School located in Glasgow. Design supports students with disabilities (Gelfand, Freed, 2010. P,248).

Figure 37. Hazelwood School. Curved corridors stimulate sensory engagement and help to orientate on the space (Gelfand, Freed, 2010. P,248)

Conclusions

Human relation to nature is still much undiscovered. Yet, we know enough to see utilitarian value in the knowledge that we already have. Professor Howard Frumkin, in 'Nature Contact and Human Health', relates to this approach in following words:

"Perhaps we don't need such rigorous evidence when it comes to nature contact… Maybe we don't know everything there is to know about human benefits of nature contact, but we have a fair idea, and we know a lot about designing nature into built environment. And given the pace at which decisions are being made and places built, there is a pressing need to implement what we know. We can't wait for the research" (Frumkin 2008, in Terrapin, 2014).

In terms of neuro-correspondence of the human brain with the natural world, people have much to discover (Ghose and Wallace, 2014). Yet, the research available today, provide an amount of data that can be used as a decent guideline for designers. Proper use of biophilic patterns, visibly improves human physical and mental health, increases cognitive performance, creativity and intrinsic motivation. Scientists claim that the presence of nature could even alter social behaviours and relations. (Kellert, Heerwagen, Mador, 2013). Benefits coming from the use of biophilic design, directly respond to the criteria defining schools for the future, including student health, performance, social relations. Innovative schools pride themselves by providing the best conditions for learning and development, student's wellbeing, safety, and the possibility of personal growth and self-discovery (Walden, 2009). Spatial design of such institutions intends to stimulate cognitive development of students as well as interactions between them (Boys, 2011). Biophilic design, if properly adjusted to needs

of location and activity, is a tool that can support all those principles (Kellert, 2005; Terrapin, 2014).

Biophilic design cannot be the only approach considered when designing a school. Research towards the criteria defining schools for the future, shows many solutions that could be brought to life in order to successfully gain that title. For example, access to technologies that help to develop a student's interests and skills. as well as adjustments to spatial settings and the multifunctional character of classrooms (Boys, 2011; Walden, 2009). However, the healing qualities of biophilic design and its positive impact on student's performance, make it an irreplaceable addition to cafes, common areas, or even technical laboratories. Some of the biophilic solutions are necessary to provide a minimal level of comfort that must be guaranteed to students. Properly applied light setting , with strong preference of the daylight, or visually satisfying spatial settings, allow students to relax and concentrate but also keep a strong immune system and balanced hormonal production (Terrapin, 2014). Biophilic design is inspired by solutions found in nature and characterized by sustainability, which is a significant factor in defining an innovative architecture, but also an educational approach (Gelfand and Freed, 2010; Walden, 2009). The concept of sustainability and biomimicry incorporated into a built environment, shape an eco-logical awareness of society, by strengthening the emotional bond between human and nature (Barrable, 2018, Kellert 2009).

An Ethical obligation for a designer is to search for the solutions that, at least minimally, contribute to improvements in life of society, especially where the standard of living is low (Kellert, 2009). Concluding from the presented research, the use of biophilic patterns successfully help to achieve that goal. Biophilic design is popularly

used in hospitals and surgeries, accelerating patients' healing process. Business corporations invest in it because of the financial profits coming from use of it. Merging school habitats with elements of natural world, benefits students in the same way, and support on their journey through an educational process (Terrapin, 2018).

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