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Development of Biophilic Design in Primary and Secondary School for Health Promotion

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ABSTRACT: Biophilic design is an important approach for health intervention in the use of nature force, aiming to provide an environmental strategic plan for health promotion based on existing scientific evidence. This paper provides a systematic research of biophilic design in primary and secondary school embraces both practices and scientific research. Biophilic design evolved from perceptual practical exploration to scientific research, and from a direct natural model of physical health to a systemization design of overall health. This paper summarizes the relationship between the space environment and health benefits through an interdisciplinary literature research. According to the existing basic model of biophilic design, this paper puts forward the key points of primary and secondary school buildings from three aspects, direct experience of nature, indirect experience of nature and abstract perception of nature.

KEY WORDS: health promotion; biophilic design; primary and secondary school; spatial environment; health benefits

Introduction

Artificial, indoor, and static lifestyles have led to the prevalence of "nature deficit disorder"(NDD)[1] among children and adolescents and opened the door to the associated health risks. Although the concept of nature as a health resource has been around for a long time, how does nature play a health-promoting role for the special population of children and adolescents in the specific space of primary and secondary school buildings? How can primary and secondary school buildings tap into the power of nature in their design?

Preventive medicine points out that the most efficient and and cost-effective method of intervention is to target the specific environments of different age groups [1-2], and hence the scientific regulation of health risks for children and adolescents through spatial configuration in the built environment of primary and secondary schools has enormous benefits for the health of the entire macro-population. Figure 1 shows the position of the spatial environment of primary and secondary schools in life course interventions. The current health situation of children and adolescents in China does not inspire optimism, and the occurrence and development of many health problems are related to the environment to some extent [3]. Common approaches to health promotion include environmental, dietary, medicative and managemental ones [1], but what is more popular than letting children enjoy nature? Primary and secondary schools are the environment where children and adolescents spend the longest amount of time consciously, and it is urgent to revisit the current primary and

[**The format of citation in this article**]
BAI Xiaoxia. Development of Biophilic Design in Primary and Secondary School for Health Promotio[J]. Journal of South Architecture, 2024(4): 1-11.

• **Fund Projects**: National Natural Science Foundation of China Youth Project (51808237).
Document Identification Code A **DOI** 10.33142/jsa.v1i4.14755 **Article number** 1000-0232(2024)04-001-11

secondary school environment from a health perspective. In this paper, relevant scientific research and practical applications are reviewed to provide a reference for the design and improvement of basic education facilities.

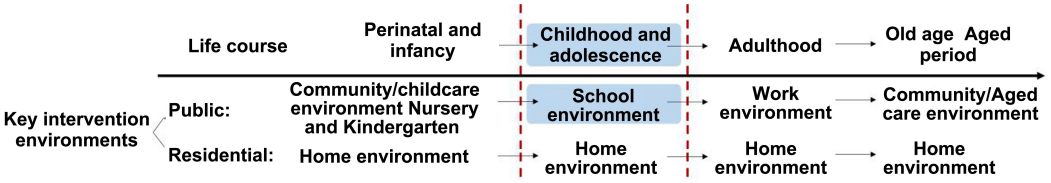

Figure 1 Schematic representation of environmental strategies for health interventions across the life course

1 Origin of biophilic design for health promotion

The term "biophilic" was coined by Professor Edward Wilson, a member of the National Academy of Sciences, in his 1984 book *Biophlia* [4], which originally meant the love of life and the nature of humans to be close to the natural elements that are beneficial to their survival, reproduction and prosperity. "Biophilic design" is not simply a return to nature in the primitive sense but focuses on how to satisfy people's inherent wish to be close to nature in artificial environments, turning to natural elements and laws as solutions to the complex problems faced by human beings. It is a reexamination of the relationship between natural and artificial forces, and the more highly artificial the environment, the more in-depth biophilic design of the environment is needed. Stephen R. Kellert, an expert in biophilic design, categorizes biophilic design into three modes: direct experience of nature (direct introduction of natural elements), indirect experience of nature (association with nature), and abstract experience of nature (creation of natural spatial sensations) [5]. Although the concept of biophilic design was introduced later, the idea of pro-nature and its exploration in design appeared much earlier. Another concept that is very similar to biophilic design is "nature-based solution," which played on the polysemy in the word "nature," as the solution itself is indeed a design based on human nature [6-7]. Compared with "nature-based solution," "biophilic design" pays more attention to stimulating the user's intrinsic characters through design, emphasizes the coupling of the role of nature and the user's agency, and is more in line with the study of specific spaces for specific groups of people. Therefore, this paper adopts the expression "biophilic design."

In the 1980s and 1990s, "health promoting," "active living by design," "evidence-based design" and other related concepts were successively proposed. Despite the differences in their positions and perspectives, many of the research results show interoperability with, support for, and promotion of biophilic design. The term "health promoting" was proposed by the World Health Organization (WHO) in the Ottawa Charter in 1986 [8], with the aim of enabling people to do everything possible to keep themselves in the optimal state of mind and body by making healthy choices, and its definition of health covers the physical and mental dimensions as well as that of social adaptation. The "health-disease continuum theory" states that the human body is in a state between healthy and clinical states [1], and that health promotion is to orient the body toward the healthy pole as much as possible through a variety of means, including the natural environment (Figure 2). "Active living by design," also developed in the United States [9], highlights the use of multilevel and multidisciplinary approaches to improve people's physical activity, with a particular emphasis on the impact of the environment on daily life. "Evidence-based design" emphasizes design based on rigorous scientific evidence and relies on practice to validate the relationship between the environment and people. Biophilic design for health has gradually taken shape on three levels: practice, theory and research, and has inspired many researchers and creators in a variety of fields, including healthcare, office, housing and education. For example, in an essay published in *Science* in 1984, Professor Roger Ulrich' points out that outdoor green landscapes may affect the recovery of surgical patients [10], and this landmark study advanced the concept of biophilic environment for health to the height of scientific research, and then a large number of scholars followed suite, studying the link between nature

and human behavior, psychology, disease and other aspects. Therefore, "biophilic design for health" is a comprehensive concept involving multidisciplinary contexts based on relevant theoretical and empirical studies.

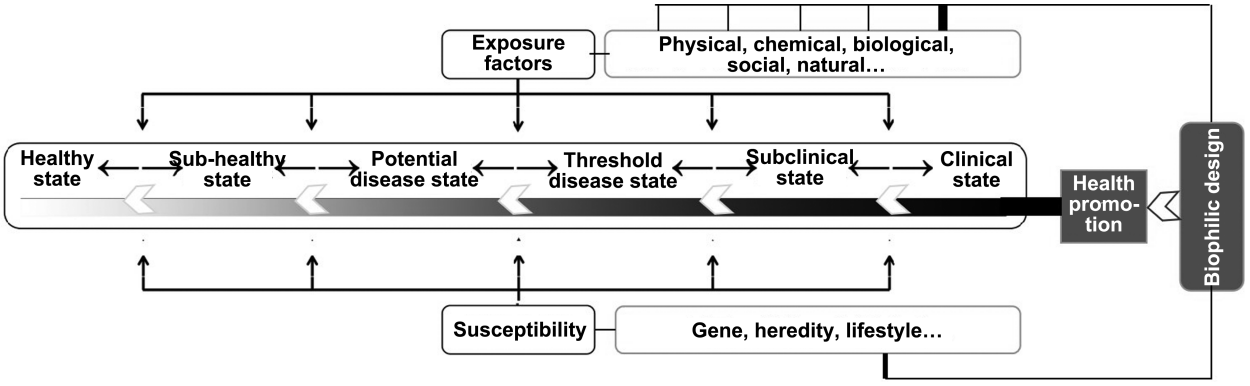

Figure 2 Illustration of the relationship between health promotion and the "health-disease continuum theory"

2 The development of biophilic design for health promotion in primary and secondary school buildings

The influence of biophilic design on children's and adolescents' health has always existed at the objective level, but due to the influence of such factors as social background, educational philosophy, public health, and scientific research means on the process of recognizing the relationship between the two, the relevant practical explorations and scientific research don't completely coincide with each other at temporal and geographical levels. Taking the social event of rethinking the education environment in response to a specific health problem at the beginning of the 20th century as the starting point, this paper reviews the development of biophilic design in primary and secondary school architecture, which can basically be summarized into five stages.

2.1 Germination: a pioneering movement that began with specific physiological health needs

During the Enlightenment and the Industrial Revolution, when the scope of education expanded and the number of educated people increased, primary and secondary school buildings emerged for efficient education and effective management [11]. The health performance of primary and secondary school buildings has always been of great concern due to the high-density of crowds inhabiting them and the high social concern for children and adolescents. The integration of architecture with the fields of medicine and public health was first shown in the prevention and control of infectious diseases [12], and the same is true for primary and secondary school buildings. A prominent example of primary and secondary school design specifically targeting health issues was the "open-air school movement" [2] in 1904 in the community of Charlottenburg, Germany, which aimed to allow frail children (especially children with tuberculosis) to receive a normal education. Focusing on adequate sunlight and fresh air, the two most essential elements of the life support system, and advocating that educational activities be conducted in open spaces or outdoor environments, this movement of educational environments targeting special physiological health needs was subsequently expanded to other countries in Europe and the United States [13], and had a far-reaching impact on primary and secondary school architectural design, which can be regarded as the germ of biophilic design for health in primary and secondary school architecture.

2.2 Exploration: a direct nature experience model to serve universal health needs

Influenced by the open-air school movement, the practice of biophilic design in primary and secondary school buildings hasled to a variety of explorations of physical health, mental health, and their relationship with education, but the introduction of the natural environment is limited to the cognitive level of direct experience. In the 1920s to 1950s, it was believed that healthy children should enjoy similar pro-nature education, and health-related elements such as sunlight, air, physical exercise, safety and hygiene should be reflected in school buildings.

The most typical example is Jan Duiker's four-story Open Air School in Amsterdam, the Netherlands, designed specifically for normal children in 1928 [13-14], which enhances the integration of architecture and nature through transparent common classrooms, shared open classrooms, and overhanging structures (Figures 3-5). During this period, educator Maria Montessori proposed interactive schools, arguing that children observe and learn from the natural environment based on their nature, that the school environment not only affects physical health but also shapes children's mental health, and that proximity to nature and the outdoors is essential to the school environment. Following this, Richard Neutra emphasized that school design should be based on the reality of human physical and mental health, and more directly proposed natural school design [13], which was related to the experience he accrued working in the organic architect Frank Lloyd Wright's Taliesin and designing a health villa for Dr. Rowell, and he referred to his design as "Bio-realism" [15] represented by the Corona Avenue School and the Skeet Road Elementary School (Figure 6), with design elements such as large transparent sliding walls and semi-outdoor activity areas fully expressing the architectural characteristics of the Bio-realism school, where assemblies, meals, and classroom activities can take place outdoors. The influence of natural schools is far-reaching and can still be seen in academic discussions and design practices of green and healthy campuses today.

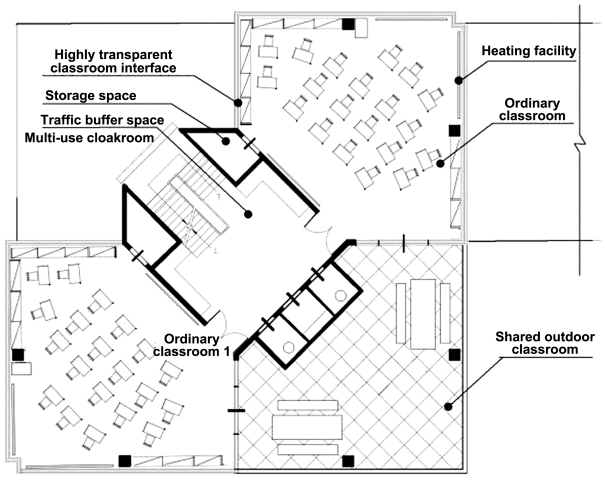

Figure 3 Classroom units of Amsterdam Open Air School

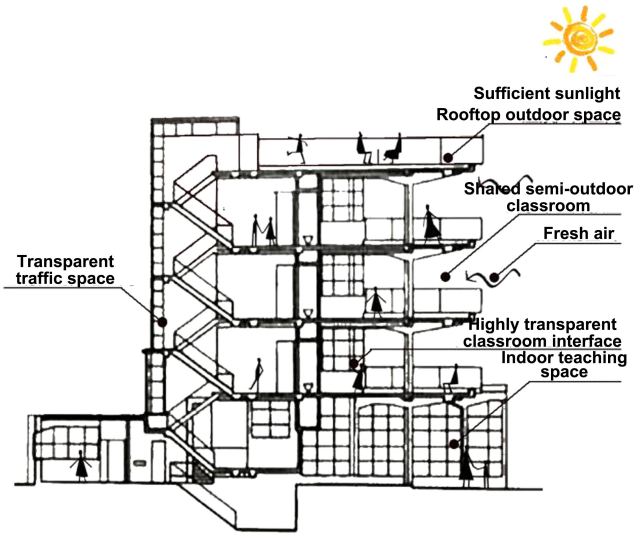

Figure 4 Sectional analysis of Amsterdam Open Air School

Figure 5 External view of Amsterdam Open Air School

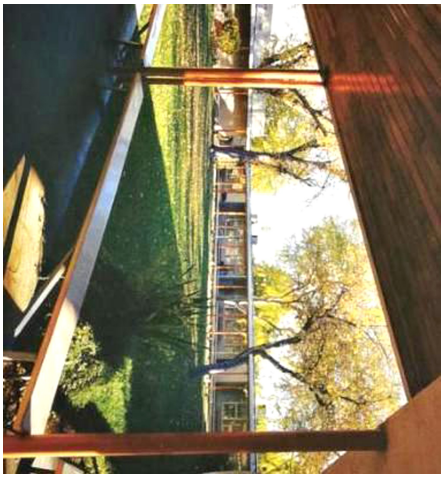

Figure 6 External view of Skeet Road Elementary School

2.3 Stagnation: a period of retrogression in pro-biotic design constrained by social contexts

After the 1950s, the economies of various countries

began to recover after the war, and basic education assumed the role of efficiently improving the quality of the workforce. Influenced by standardized process management in assembly lines, the "class-based teaching + standardized classroom" model prevailed [16], resulting in a typical corridor series multi-story building design, meeting only the basic physical health need while considerations for mental health and social adaptation considerations were extremely lacking. This nearly uniform paradigm of primary and secondary school building space model was widely used in the world, and although it has been criticized by educationalists, it still has a wide influence until today.

The development of China's primary and secondary school architecture mainly took place after the founding of New China, and the *Architectural Journal*, as the earliest architectural periodical in China, has published a total of 56 domestic primary and secondary school design cases since its inception in 1954, which formed the epitome of China's primary and secondary school architectural design exploration. From the 1950s to the 1980s, "running schools frugally" was the main guiding ideology, and the basic functions of school buildings were stretched to the limit, as represented by the newly built Hongguan Middle School and Hedley Primary School in Shanghai in 1962 [17], which were characterized by a centralized layout of the inner corridor, with a relatively closed space, let alone the construction of the public activity space, campus greening and landscape, and the biophilic design of primary and middle school buildings almost bottomed out. It was not until the 1980s that architects gradually began to explore landscape design for the campus, as seen in the design of Nanjing's Langya Road Primary School in 1986 [18].

2.4 Development: multiple nature experience models for overall health

With the development of society, people's awareness of campus health sees an increase, and at the same time, life education, nature education, quality education and a series of concepts impact on the traditional education model, all of which require changes to campus architecture. In 1977, the United States professor Gorge L. Engel put forward to the "bio-psycho-social" medical model as a substitute for the biomedical model [19], marking a new period of overall health in the consideration of health. The response to the overall health concept in the field of architectural design of primary and secondary schools in China began with the 1986 edition of the "Architectural Design Code for Primary and Secondary Schools." Since then, health standards such as lighting, ventilation, safety, greening, and indoor facilities in primary and secondary school buildings have been significantly improved. After entering the 21st century, in addition to "safety," "applicability," and economy," keywords such as "health," "green," "ecology," "venue," "atmosphere," "fun," "life," "experience" and "adaptation" emerged in various architectural journals and were used to describe newly published primary and secondary school cases. The architectural design practice of primary and secondary schools gradually broke through the stereotyped model of corridors in series, looking for more friendly and diverse spatial models, providing students with opportunities to perceive nature through the openness and transparency of space. "Learning etiquette under the big tree and teaching beside the apricot forest" once described a teaching model with direct nature as the background. However, as built environment becomes the absolute mainstream learning place, the biophilic design of primary and secondary school buildings must be systematically conducted from spatial mode to indoor environment. Based on the medical model, biophilic design has developed into a multiple natural experience design for overall health at the practical level.

First, direct experience of nature is used as the basic strategy of biophilic design. By mobilizing the visual, auditory, tactile and other sensory systems, the direct stimulation of nature is brought into play, and the interactive relationship between architectural space and nature is emphasized. For example, Suzhou Science and Technology City Experimental Primary School proposed the concept of vertical academy, breaking the integrity of the building interface to form a staggered outdoor platform, and adopting

internal courtyards and three-dimensional gardens (Figures 7-8) [20]. Figure 9 shows a summary of the key points of direct experience of nature design for a large number of primary and secondary school buildings. Secondly, indirect experience of nature is used as an auxiliary strategy of biophilic design. By extracting natural elements, natural materials and natural features, beautiful associations about nature are stimulated, thereby exerting psychological comfort [5]. Children and adolescents have keen imaginations, and indirect experience of nature is based on this active expansion of natural feelings. For example, in the design of Hongling Experimental School, O-Office extracted the context of "mountain" and translated the intention of "valley," combining them with three-dimensional greening to form a feeling of being in a valley (Figures 10-11), realizing the mutual communication between artificial environment and natural intention, and making a particularly valuable contribution to the exploration of biophilic design in high-intensity development. Another example is that in the bathroom design of Munkegaard School in Denmark, where the natural patterns integrated into the wall and floor completely activate this space closely related to public health (Figure 12), reversing the tendency to ignore the bathroom as an auxiliary facility. Thirdly, using abstract experience of nature as an enhancement strategy for biophilic design, creating a built environment that allows for abstract perception of the laws of nature through spatial patterns is closely related to health issues such as learning pressure and social adaptation for children and adolescents, and is the most arcane and covert connotation of architectural biophilic design. For example, the teaching unit design of Hangzhou Future Science and Technology City Primary School, on the basis of supporting a one-to-many teaching model, forms a relatively private auxiliary space, and enhances students' social behavior around the computer information center, exploring a classroom unit that is more conducive to children and adolescents' emotional cognition, social adaptation, and autonomous learning (Figure 13).

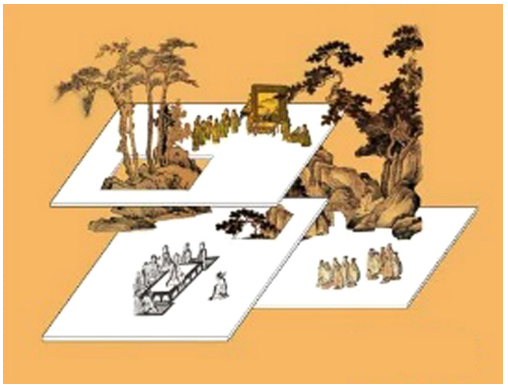

Figure 7 Concept and translation of vertical academy

Figure 8 Experimental Primary School of Suzhou Science and Technology Town

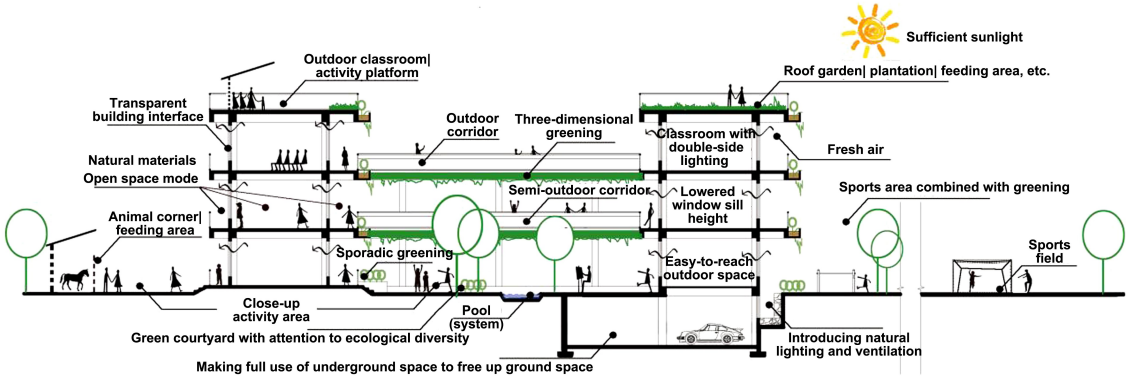

Figure 9 Key points forintegrating direct experience of nature in design of primary and secondary school buildings

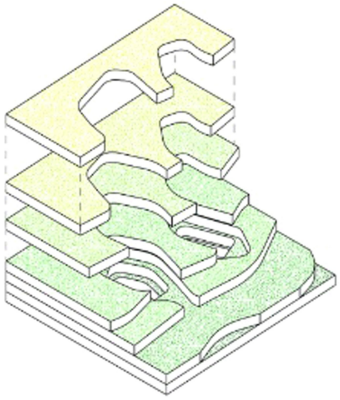

Figure 10 The context and translation of "valley"

Figure 11 Hongling Experimental Primary School

Figure 12 Public space for indirect experience of nature

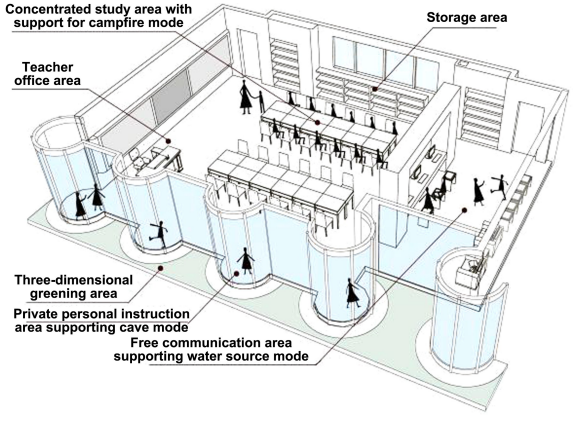

Figure 13 Teaching unitfeaturing abstract experience of nature

2.5 Deepening: relying on the continuous advancement of scientific research

The relationship between natural forces and health in design practice ultimately remains in discussions at the conceptual level. After entering the 21st century, with the development of multi- and cross-disciplinary research, the accumulation of relevant results, and the promotion of evidence-based design, the biophilic design of school buildings has entered a scientific advancement period. On the one hand, the biophilic design methods reflected in practical exploration deserve more rigorous verification. On the other hand, the relevant results in the field of scientific research need to be implemented through the promotion of design codes and concepts.

Multidisciplinary research points out that health is the result of the complex interaction between genetic susceptibility and environmental exposure. Extracting the relationship between "biophilic design-health benefits" for children and adolescents from the complex research is conducive to further deepening biophilic design. The focus of research in this field is affected by factors such as the typicality of children and adolescents' health problems and their relevance to biophilic design. First of all, the research on physiological health is the most basic, among which the related research on visual health, respiratory health, physical activity, etc. is relatively high in quantity and awareness, and to this day, these three types of problems are still typical health problems faced by children and adolescents in our country. Secondly, the disease phenomena of emotional tension, psychological anxiety, school rebellion, depression, etc. among children and adolescents are aggravating. In return, the attention paid to the mental health of children and adolescents has also increased generally. Thirdly, social adaptation, as the third connotation of health, refers to the self-regulation of human beings to their environment, including the adaptation status to school and the adaptability to the future. The campus plays a transitional role between family and society. Problems such as interpersonal relationship barriers and school bullying reflect that the current social adaptation and moral health of children and adolescents do not allow for optimism. This study clarified the specific relationship

between promoting the health of children and adolescents through biophilic design through interdisciplinary literature research, as shown in Table 1. The results of the correlation study on "biophilic design-health benefits" of primary and secondary school buildings revealed the basic characteristics of biophilic design for health promoting: (1) natural elements do not have the same health benefits; (2) there are targeted characteristics between specific natural elements and specific health problems; (3) the health benefits of biophilic design elements have systematic superposition characteristics; (4) Introducing nature into design without caution may bring corresponding health risks. On this basis, the elements of campus biophilic design are refined, and Table 2 further clarifies the systematic correlation between direct experience of nature, indirect experience of nature, abstract experience of nature and the health of children and adolescents. In summary, we believe that the biophilic design of primary and secondary school buildings based on scientific research results is in a stage of continuous deepening.

Table 1 Evidence in research on "biophilic design-health benefits" of primary and secondary school buildings

Health problems	Representative research conclusions related to biophilic design	Closely related disciplines
Visual health [21-23]	• An environment with insufficient natural light can easily cause visual fatigue; • Natural strong light has the effect of preventing myopia, which is manifested in biological effects such as promoting the secretion of retinal dopamine; • The most direct way to obtain natural strong light is to extend the outdoor exposure time; • Research on the prevention of myopia through outdoor exposure has overturned the traditional concept of preventing myopia through exercise; • A more open spatial model promotes children's outdoor exposure; • The recovery time of children's visual fatigue is about less than 10 minutes, and green plants can help relieve visual fatigue.	Ophthalmology Preventive medicine
Respiratory health [24-26]	• It covers a variety of diseases such as acute and chronic diseases, and is affected by multiple environmental factors such as physical, chemical, and microbial ones; • The respiratory health of children and adolescents is closely related to campus microclimate and classroom air quality; • Green plants are beneficial for campus microclimate regulation and air purification; • Health problems such as rhinitis and allergies are related to air quality, pollen, flying catkins, mold index, etc..	Microbiology Hygiene Clinical medicine
Physical health [10, 23, 27-30]	• Insufficient physical activity threatens the health of children and adolescents. The environment can affect physical activity through multiple pathways, including behavioral, psychological, and physiological ones. Active design can promote physical activity. • Optimizing the location, layout, visibility, accessibility and vegetation density of campus activity venues can help increase the amount of activity. For example, the green area mixed with artificial facilities is the most frequently used and attractive activity area; measures such as providing activity space during breaks, configuring a weatherproof playground with good natural lighting, increasing the proportion of semi-indoor and semi-outdoor spaces, and providing a variety of outdoor activity spaces can all increase the amount of activity.	Behavioral science Preventive medicine Sports science
Mental health [31-33]	• The environment can be both a source of psychological stress and a way to relieve it; • The environment can affect mental state through behavior, perception, memory, imagination, thinking, language, emotion, etc.; • Urban primary and secondary schools lack natural resources in general and have a serious lack of restorative environments; • Green environment, landscape items, and psychological adjustment space can relieve psychological pressure to a certain extent; • The natural environment has better stress relief and fatigue recovery effects than the artificial environment; • The restorative benefits of the environment are most effective through direct visual stimulation of natural elements. Ranked second is the psychological association promoted by indirect elements. The abstract spatial pattern is more of an activity support and stress prevention, and its short-term restorative effect is not significant.	Psychology Education

(Continued)

Health problems	Representative research conclusions related to biophilic design	Closely related disciplines
Social adaptation and moral health [16, 33, 34、35]	• Campus buildings should provide a campus environment that is consistent with the nature and age characteristics of children and adolescents and is conducive to promoting emotional regulation, social cognition, and active life; • A biophilic environment can better support children's health, communication, and the diversity of games and the friendly campus space model promotes children's communication; • Children with ADHD are more likely to concentrate after contact with nature; • A campus environment rich in greenery has a positive impact on the development of children's autonomy and collaboration; • A biophilic campus design improves learning efficiency; • Playing in a variety of natural environments can reduce school bullying.	Sociology Education Psychology

Table 2 Correlation matrix between biophilic design elements and health issues

Biophilic design elements		Visual health	Respiratory health	Physical activity	Psychological health	Social adaptation
Direct nature	Natural light	★	—	○	★	★
	Air	—	★	○	—	—
	Water	—	○	○	▲	○
	Vegetation	★	★	★	★	★
	View	○	—	—	▲	▲
	Natural materials	—	○	—	▲	▲
Indirect nature	Concrete features	—	—	—	▲	○
	Abstract features	—	—	—	▲	○
	Simulation of dynamic changes in nature	○	○	○	○	○
Abstract nature	Spatial mode	★	★	★	▲	▲
	Spatial feel	—	—	▲	▲	▲
	Distance	○	—	○	—	○

Notes: ★ Empirical research evidence; ▲ Theoretical research and applied research; ○ Logical reasoning based on similar research in other environments; — No specific research has been found yet.

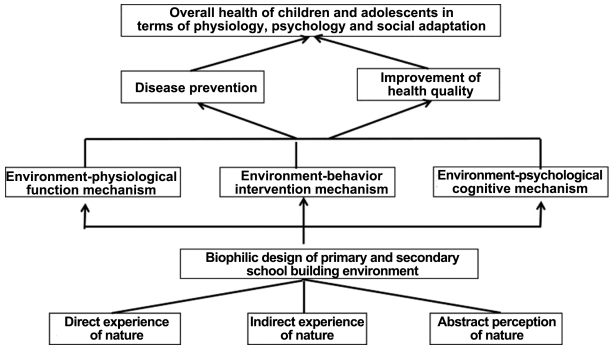

Figure 14 Schematic diagram of the mechanism of biophilic design in health promotion

3 Conclusion

The core of biophilic design is to stimulate the inner nature of children and adolescents, give play to the positive effects of nature at the physiological and psychological levels as well as social adaptation, and provide a supportive environment for promoting health as much as possible, which are also the basic responsibilities of the design and research related to primary and secondary school buildings. Through a systematic review of the practical exploration and scientific research of biophilic design in primary and secondary schools over the past century, the following conclusions can be drawn, First, there is a direct correlation between the health problems of children and adolescents and the environment, and the impact on the health of children and adolescents is mainly manifested in prevention and health promotion, with additional manifestations in healing. Second, all kinds of natural elements do not have the same health benefits, and cross-verification of related multidisciplinary results is more likely to offer systematic guidance. Third, the "biophilic design-health benefits" relationship can be preliminarily summarized as

the environment-physiological function mechanism, the environment-psychological cognitive mechanism, and the environment-behavior intervention mechanism. The three are combined to jointly play a role in disease prevention and health quality improvement (Figure 14). Fourth, the research scope of environmental biophilia has expanded from direct natural elements to the biophilia of the overall spatial environment. The design of primary and secondary school buildings should form a systematic design concept based on the direct experience of nature as the basic strategy, the indirect experience of nature as the auxiliary strategy, and the abstract experience of nature as the enhancement strategy.

Our country is in a period of development of new construction, expansion, and reconstruction of basic education facilities. The health situation and education reform jointly call for the biophilia of campuses. The biophilic design of primary and secondary school buildings takes the inherent nature of children and adolescents as the starting point and re-examines the relationship between educational environment and natural experience from the perspective of health promotion. In the past ten years, studies on the impact of the natural environment on human health have developed towards quantitative research, including environmental factors, natural doses, physiological feedback, behavioral records, psychological reactions, etc., which can be studied more deeply through human factors feedback technology, mobile monitoring technology, virtual reality technology, big data, etc. The simultaneous analysis of multimodal data is expected to further reveal the deep impact of biophilic design on the health of children and adolescents [36]. Whether it is a school located amidst mountains and rivers or a school in a high-density urban area, there are opportunities for improvement from spatial patterns to natural elements. The more artificial the environment, the more it can reflect the health benefits of biophilic design. The design and operation of primary and secondary school buildings should take biophilic design as a strategically valuable approach throughout.

Figure and table sources

Figures 1, 2, 9, 13, and 14 are drawn by the author; Tables 1 and 2 are drawn by the author; Figures 3-4 are redrawn; Figures 5-6 are quoted from Hiller. Modern School Design: A Century Long View of Educational Architecture Design [M]. Electronic Industry Press, 2014

Figures 7-8 are quoted from Zhang Bin, Li Shuo. Vertical Academy - Design Notes of Suzhou Science and Technology City Experimental Primary School [J]. Journal of Architecture 2017 (6): 67-69.

Figures 10-11 https: // www. gooood. cn/hongling-experimental-primary-school-china-by-o-office-architects.htm

Figure 12 Duan Qian (ed.), World Architecture Series: School Architecture 1 [M], Liaoning Science and Technology Press, 2015.

Notes

1) Nature-deficit disorder: Originally proposed by Richard Louv in *The Last Child in the Woods*, it refers to a common social phenomenon in which children spend less and less time in nature, and the highly artificial environment erodes the lives of the new generation, thus bringing about many behavioral and psychological problems.

2) Open-air school movement: InRepublic of China, the activity of teaching poor children outdoors due to the shortage of educational resources was also named "open-air school movement," but this is essentially different from the open-air school movement in Europe and the United States mentioned in the article, the intention of which was to gain fresh air and sunshine.

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